PAKCS 1.13.1

The Portland Aachen Kiel Curry System

User Manual

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Michael Hanus[1] [editor]

Additional Contributors:

Sergio Antoy[2]

Bernd Braßel[3]

Martin Engelke[4]

Klaus Höppner[5]

Johannes Koj[6]

Philipp Niederau[7]

Björn Peemöller[8]

Ramin Sadre[9]

Frank Steiner[10]

(1) University of Kiel, Germany, `mh@informatik.uni-kiel.de`

(2) Portland State University, USA, `antoy@cs.pdx.edu`

(3) University of Kiel, Germany, `bbr@informatik.uni-kiel.de`

(4) University of Kiel, Germany, `men@informatik.uni-kiel.de`

(5) University of Kiel, Germany, `klh@informatik.uni-kiel.de`

(6) RWTH Aachen, Germany, `johannes.koj@sdm.de`

(7) RWTH Aachen, Germany, `philipp@navigium.de`

(8) University of Kiel, Germany, `bjp@informatik.uni-kiel.de`

(9) RWTH Aachen, Germany, `ramin@lvs.informatik.rwth-aachen.de`

(10) LMU Munich, Germany, `fst@bio.informatik.uni-muenchen.de`

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Preface

This document describes PAKCS (formerly called "PACS"), an implementation of the multi-paradigm language Curry, jointly developed at the University of Kiel, the Technical University of Aachen and Portland State University. Curry is a universal programming language aiming at the amalgamation of the most important declarative programming paradigms, namely functional programming and logic programming. Curry combines in a seamless way features from functional programming (nested expressions, lazy evaluation, higher-order functions), logic programming (logical variables, partial data structures, built-in search), and concurrent programming (concurrent evaluation of constraints with synchronization on logical variables). Moreover, the PAKCS implementation of Curry also supports constraint programming over various constraint domains, the high-level implementation of distributed applications, graphical user interfaces, and web services (as described in more detail in [12, 13, 14]). Since PAKCS compiles Curry programs into Prolog programs, the availability of some of these features might depend on the underlying Prolog system.

We assume familiarity with the ideas and features of Curry as described in the Curry language definition [20]. Therefore, this document only explains the use of the different components of PAKCS and the differences and restrictions of PAKCS (see Section 1.2) compared with the language Curry (Version 0.8.3).

Acknowledgements

1 Overview of PAKCS

1.1 General Use

This version of PAKCS has been tested on Sun Solaris, Linux, and Mac OS X systems. In principle, it should be also executable on other platforms on which a Prolog system like SICStus-Prolog or SWI-Prolog exists (see the file `INSTALL.html` in the PAKCS directory for a description of the necessary software to install PAKCS).

All executable files required to use the different components of PAKCS are stored in the directory *pakcshome*`/bin` (where *pakcshome* is the installation directory of the complete PAKCS installation). You should add this directory to your path (e.g., by the `bash` command "`export PATH=`*pakcshome*`/bin:$PATH`").

The source code of the Curry program must be stored in a file with the suffix ".`curry`", e.g., `prog.curry`. Literate programs must be stored in files with the extension ".`lcurry`".

Since the translation of Curry programs with PAKCS creates some auxiliary files (see Section D for details), you need write permission in the directory where you have stored your Curry programs. The auxiliary files for all Curry programs in the current directory can be deleted by the command

```
cleancurry
```

(this is a shell script stored in the `bin` directory of the PAKCS installation, see above). The command

```
cleancurry -r
```

also deletes the auxiliary files in all subdirectories.

1.2 Restrictions

There are a few minor restrictions on Curry programs when they are processed with PAKCS:

- *Singleton pattern variables*, i.e., variables that occur only once in a rule, should be denoted as an anonymous variable "`_`", otherwise the parser will print a warning since this is a typical source of programming errors.

- PAKCS translates all *local declarations* into global functions with additional arguments ("lambda lifting", see Appendix D of the Curry language report). Thus, in the compiled target code, the definition of functions with local declarations look different from their original definition (in order to see the result of this transformation, you can use the CurryBrowser, see Section 6).

- Tabulator stops instead of blank spaces in source files are interpreted as stops at columns 9, 17, 25, 33, and so on. In general, tabulator stops should be avoided in source programs.

- Since PAKCS compiles Curry programs into Prolog programs, non-deterministic computations are treated as in Prolog by a backtracking strategy, which is known to be incomplete. Thus, the order of rules could influence the ability to find solutions for a given goal.

- Threads created by a concurrent conjunction are not executed in a fair manner (usually, threads corresponding to leftmost constraints are executed with higher priority).

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- Encapsulated search: In order to allow the integration of non-deterministic computations in programs performing I/O at the top-level, PAKCS supports the search operators `findall` and `findfirst`. These and some other operators are available in the library `Findall` (i.e., they are not part of the standard prelude). In contrast to the general definition of encapsulated search [19], the current implementation suspends the evaluation of `findall` and `findfirst` until the argument does not contain unbound global variables. Moreover, the evaluation of `findall` is strict, i.e., it computes all solutions before returning the complete list of solutions.

  Since it is known that the result of these search operators might depend on the evaluation strategy due to the combination of sharing and lazy evaluation (see [9] for a detailed discussion), it is recommended to use *set functions* [7] as a strategy-independent encapsulation of non-deterministic computations. Set functions compute the set of all results of a defined function but do not encapsulate non-determinism occurring in the actual arguments. See the library `SetFunctions` (Section A.2.49) for more details.

- There is currently no general connection to external constraint solvers. However, the PAKCS compiler provides constraint solvers for arithmetic and finite domain constraints (see Appendix A).

1.3 Modules in PAKCS

PAKCS searches for imported modules in various directories. By default, imported modules are searched in the directory of the main program and the system module directories "*pakcshome*/lib" and "*pakcshome*/lib/meta". This search path can be extended by setting the environment variable `CURRYPATH` (which can be also set in a PAKCS session by the option ":set path", see below) to a list of directory names separated by colons (":"). In addition, a local standard search path can be defined in the ".pakcsrc" file (see Section 2.6). Thus, modules to be loaded are searched in the following directories (in this order, i.e., the first occurrence of a module file in this search path is imported):

1. Current working directory (".") or directory prefix of the main module (e.g., directory "/home/joe/curryprogs" if one loads the Curry program "/home/joe/curryprogs/main").

2. The directories enumerated in the environment variable `CURRYPATH`.

3. The directories enumerated in the ".pakcsrc" variable "`libraries`".

4. The directories "*pakcshome*/lib" and "*pakcshome*/lib/meta".

The same strategy also applies to modules with a hierarchical module name with the only difference that the hierarchy prefix of a module name corresponds to a directory prefix of the module. For instance, if the main module is stored in directory `MAINDIR` and imports the module `Test.Func`, then the module stored in `MAINDIR/Test/Func.curry` is imported (without setting any additional import path) according to the module search strategy described above.

Note that the standard prelude (*pakcshome*/lib/Prelude.curry) will be always implicitly imported to all modules if a module does not contain an explicit import declaration for the module `Prelude`.

2 PAKCS: An Interactive Curry Development System

PAKCS is an interactive system to develop applications written in Curry. It is implemented in Prolog and compiles Curry programs into Prolog programs. It contains various tools, a source-level debugger, solvers for arithmetic constraints over real numbers and finite domain constraints, etc. The compilation process and the execution of compiled programs is fairly efficient if a good Prolog implementation like SICStus-Prolog is used.

2.1 Invoking PAKCS

To start PAKCS, execute the command "`pakcs`" (this is a shell script stored in *pakcshome*/bin where *pakcshome* is the installation directory of PAKCS). When the system is ready (i.e., when the prompt "`Prelude>`" occurs), the prelude (*pakcshome*/lib/Prelude.curry) is already loaded, i.e., all definitions in the prelude are accessible. Now you can type various commands (see next section) or an expression to be evaluated.

One can also invoke PAKCS with parameters. These parameters are usual a sequence of commands (see next section) that are executed before the user interaction starts. For instance, the invocation

```
pakcs :load Mod :add List
```

starts PAKCS, loads the main module `Mod`, and adds the additional module `List`. The invocation

```
pakcs :load Mod :eval config
```

starts PAKCS, loads the main module `Mod`, and evaluates the operation `config` before the user interaction starts. As a final example, the invocation

```
pakcs :load Mod :save :quit
```

starts PAKCS, loads the main module `Mod`, creates an executable, and terminates PAKCS. This invocation could be useful in "make" files for systems implemented in Curry.

There are also some specific options that can be used when invoking PAKCS:

-q or --quiet: With this option, PAKCS works silently, i.e., the initial banner and the input prompt are not shown. The output of other information is determined by the options "`verbose`" and "vn" (see Section 2.3).

--noreadline: Do not use input line editing (see Section 2.5).

-Dname=val: Overwrite values defined in the configuration file "`.pakcsrc`" (see Section 2.6), where `name` is a property defined in the configuration file and `val` its new value.

2.2 Commands of PAKCS

The **most important commands** of PAKCS are (it is sufficient to type a unique prefix of a command if it is unique, e.g., one can type "`:r`" instead of "`:reload`"):

`:help` Show a list of all available commands.

`:load` *prog* Compile and load the program stored in *prog*.`curry` together with all its imported modules. If this file does not exist, the system looks for a FlatCurry file *prog*.`fcy` and compiles from this intermediate representation. If the file *prog*.`fcy` does not exists, too, the system looks for a file *prog*_`flat.xml` containing a FlatCurry program in XML representation (compare command ":`xml`"), translates this into a FlatCurry file *prog*.`fcy` and compiles from this intermediate representation.

`:reload` Recompile all currently loaded modules.

`:add` $m_1 \ldots m_n$ Add modules $m_1, \ldots, m_n$ to the set of currently loaded modules so that their exported entities are available in the top-level environment.

expr Evaluate the expression *expr* to normal form and show the computed results. Since PAKCS compiles Curry programs into Prolog programs, non-deterministic computations are implemented by backtracking. Therefore, computed results are shown one after the other. In the *interactive mode* (which can be set in the configuration file ".`pakcsrc`" or by setting the option `interactive`, see below), you will be asked after each computed result whether you want to see the next alternative result or all alternative results. The default answer value for this question can be defined in the configuration file ".`pakcsrc`" file (see Section 2.6).

Free variables in initial expressions must be declared as in Curry programs (if the free variable mode is not turned on, see option "`+free`" below). Thus, in order to see the results of their bindings, they must be introduced by a "`where...free`" declaration. For instance, one can write

```
not b where b free
```

in order to obtain the following bindings and results:

```
{b = True} False
{b = False} True
```

Without these declarations, an error is reported in order to avoid the unintended introduction of free variables in initial expressions by typos.

`:eval` *expr* Same as *expr*. This command might be useful when putting commands as arguments when invoking `pakcs`.

`:define` *x=expr* Define the identifier *x* as an abbreviation for the expression *expr* which can be used in subsequent expressions. The identifier *x* is visible until the next `load` or `reload` command.

`:quit` Exit the system.

There are also a number of **further commands** that are often useful:

`:type` *expr* Show the type of the expression *expr*.

`:browse` Start the CurryBrowser to analyze the currently loaded module together with all its imported modules (see Section 6 for more details).

`:edit` Load the source code of the current main module into a text editor. If the variable `editcommand` is set in the configuration file ".pakcsrc" (see Section 2.6), its value is used as an editor command, otherwise the environment variable "EDITOR" or a default editor (e.g., "vi") is used.

`:edit m` Load the source text of module m (which must be accessible via the current load path if no path specification is given) into a text editor which is defined as in the command ":edit".

`:interface` Show the interface of the currently loaded module, i.e., show the names of all imported modules, the fixity declarations of all exported operators, the exported datatypes declarations and the types of all exported functions.

`:interface prog` Similar to ":interface" but shows the interface of the module "prog.curry". If this module does not exist, this command looks in the system library directory of PAKCS for a module with this name, e.g., the command ":interface FlatCurry" shows the interface of the system module `FlatCurry` for meta-programming (see Appendix A.1.4).

`:usedimports` Show all calls to imported functions in the currently loaded module. This might be useful to see which import declarations are really necessary.

`:modules` Show the list of all currently loaded modules.

`:programs` Show the list of all Curry programs that are available in the load path.

`:set option` Set or turn on/off a specific option of the PAKCS environment (see 2.3 for a description of all options). Options are turned on by the prefix "+" and off by the prefix "-". Options that can only be set (e.g., `printdepth`) must not contain a prefix.

`:set` Show a help text on the possible options together with the current values of all options.

`:show` Show the source text of the currently loaded Curry program. If the variable `showcommand` is set in the configuration file ".pakcsrc" (see Section 2.6), its value is used as a command to show the source text, otherwise the environment variable `PAGER` or the standard command "cat" is used. If the source text is not available (since the program has been directly compiled from a FlatCurry or XML file), the loaded program is decompiled and the decompiled Curry program text is shown.

`:show m` Show the source text of module m which must be accessible via the current load path.

`:source f` Show the source code of function f (which must be visible in the currently loaded module) in a separate window.

`:source m.f` Show the source code of function f defined in module m in a separate window.

`:cd dir` Change the current working directory to dir.

`:dir` Show the names of all Curry programs in the current working directory.

`:!cmd` Shell escape: execute cmd in a Unix shell.

`:save` Save the currently loaded program as an executable evaluating the main expression "`main`". The executable is stored in the file `Mod` if `Mod` is the name of the currently loaded main module.

`:save` *expr* Similar as "`:save`" but the expression *expr* (typically: a call to the main function) will be evaluated by the executable.

`:fork` *expr* The expression *expr*, which must be of type "`IO ()`", is evaluated in an independent process which runs in parallel to the current PAKCS process. All output and error messages from this new process are suppressed. This command is useful to test distributed Curry programs (see Appendix A.1.3) where one can start a new server process by this command. The new process will be terminated when the evaluation of the expression *expr* is finished.

`:coosy` Start the Curry Object Observation System COOSy, a tool to observe the execution of Curry programs. This commands starts a graphical user interface to show the observation results and adds to the load path the directory containing the modules that must be imported in order to annotate a program with observation points. Details about the use of COOSy can be found in the COOSy interface (under the "Info" button), and details about the general idea of observation debugging and the implementation of COOSy can be found in [8].

`:xml` Translate the currently loaded program module into an XML representation according to the format described in `http://www.informatik.uni-kiel.de/~curry/flat/`. Actually, this yields an implementation-independent representation of the corresponding FlatCurry program (see Appendix A.1.4 for a description of FlatCurry). If *prog* is the name of the currently loaded program, the XML representation will be written into the file "*prog*`_flat.xml`".

`:peval` Translate the currently loaded program module into an equivalent program where some subexpressions are partially evaluated so that these subexpressions are (hopefully) more efficiently executed. An expression *e* to be partially evaluated must be marked in the source program by (`PEVAL e`) (where `PEVAL` is defined as the identity function in the prelude so that it has no semantical meaning).

The partial evaluator translates a source program *prog*`.curry` into the partially evaluated program in intermediate representation stored in *prog*`_pe.fcy`. The latter program is implicitly loaded by the `peval` command so that the partially evaluated program is directly available. The corresponding source program can be shown by the `show` command (see above).

The current partial evaluator is an experimental prototype (so it might not work on all programs) based on the ideas described in [1, 2, 3, 4].

2.3 Options of PAKCS

The following options (which can be set by the command "`:set`") are currently supported:

`+/-debug` Debug mode. In the debug mode, one can trace the evaluation of an expression, setting spy points (break points) etc. (see the commands for the debug mode described below).

`+/-free` Free variable mode. If the free variable mode is off (default), then free variables occurring in initial expressions entered in the PAKCS environment must always be declared by

"`where...free`". This avoids the introduction of free variables in initial expressions by typos (which might lead to the exploration of infinite search spaces). If the free variable mode is on, each undefined symbol occurring in an initial expression is considered as a free variable. In this case, the syntax of accepted initial expressions is more restricted. In particular, lambda abstractions, `lets` and list comprehensions are not allowed if the free variable mode is on.

`+/-printfail` Print failures. If this option is set, failures occurring during evaluation (i.e., non-reducible demanded subexpressions) are printed. This is useful to see failed reductions due to partially defined functions or failed unifications. Inside encapsulated search (e.g., inside evaluations of `findall` and `findfirst`), failures are not printed (since they are a typical programming technique there). Note that this option causes some overhead in execution time and memory so that it could not be used in larger applications.

`+/-allfails` If this option is set, *all* failures (i.e., also failures on backtracking and failures of enclosing functions that fail due to the failure of an argument evaluation) are printed if the option `printfail` is set. Otherwise, only the first failure (i.e., the first non-reducible subexpression) is printed.

`+/-consfail` Print constructor failures. If this option is set, failures due to application of functions with non-exhaustive pattern matching or failures during unification (application of "`=:=`") are shown. Inside encapsulated search (e.g., inside evaluations of `findall` and `findfirst`), failures are not printed (since they are a typical programming technique there). In contrast to the option `printfail`, this option creates only a small overhead in execution time and memory use.

`+consfail all` Similarly to "`+consfail`", but the complete trace of all active (and just failed) function calls from the main function to the failed function are shown.

`+consfail file:`f Similarly to "`+consfail all`", but the complete fail trace is stored in the file f. This option is useful in non-interactive program executions like web scripts.

`+consfail int` Similarly to "`+consfail all`", but after each failure occurrence, an interactive mode for exploring the fail trace is started (see help information in this interactive mode). When the interactive mode is finished, the program execution proceeds with a failure.

`+/-compact` Reduce the size of target programs by using the parser option "`--compact`" (see Section 11 for details about this option).

`+/-interactive` Turn on/off the interactive mode. In the interactive mode, the next non-deterministic value is computed only when the user requests it. Thus, one has also the possibility to terminate the enumeration of all values after having seen some values. The default value for this option can be set in the configuration file "`.pakcsrc`" (initially, the interactive mode is turned off).

`+/-first` Turn on/off the first-only mode. In the first-only mode, only the first value of the main expression is printed (instead of all values).

`+/-profile` Profile mode. If the profile mode is on, then information about the number of calls, failures, exits etc. are collected for each function during the debug mode (see above) and shown after the complete execution (additionaly, the result is stored in the file *prog*.`profile` where *prog* is the current main program). The profile mode has no effect outside the debug mode.

`+/-suspend` Suspend mode (initially, it is off). If the suspend mode is on, all suspended expressions (if there are any) are shown (in their internal representation) at the end of a computation.

`+/-time` Time mode. If the time mode is on, the cpu time and the elapsed time of the computation is always printed together with the result of an evaluation.

`+/-verbose` Verbose mode (initially, it is off). If the verbose mode is on, the initial expression of a computation is printed before it is evaluated. If the verbose mode is on and the verbosity level (see below) is non-zero, the type of the initial expression is also printed and the output of the evaluation is more detailed.

`+/-warn` Parser warnings. If the parser warnings are turned on (default), the parser will print warnings about variables that occur only once in a program rule (see Section 1.2) or locally declared names that shadow the definition of globally declared names. If the parser warnings are switched off, these warnings are not printed during the reading of a Curry program.

`path` *path* Set the additional search path for loading modules to *path*. Note that this search path is only used for loading modules inside this invocation of PAKCS, i.e., the environment variable "`CURRYPATH`" (see also Section 1.3) is set to *path* in this invocation of PAKCS.

The path is a list of directories separated by ":". The prefix "~" is replaced by the home directory as in the following example:

```
:set path aux:~/tests
```

Relative directory names are replaced by absolute ones so that the path is independent of later changes of the current working directory.

`printdepth` *n* Set the depth for printing terms to the value `n` (initially: 0). In this case subterms with a depth greater than `n` are abbreviated by dots when they are printed as a result of a computation or during debugging. A value of `0` means infinite depth so that the complete terms are printed.

`v`*n* Set the verbosity level to *n*. The following values are allowed for *n*:

$n = 0$: Do not show any messages (except for errors).

$n = 1$: Show only messages of the front-end, like loading of modules.

$n = 2$: Show also messages of the back end, like loading intermediate files or generating Prolog target files.

$n = 3$: Show also messages related to loading Prolog files and libraries into the run-time systems and other intermediate messages and results.

$\boxed{\text{safe}}$ Turn on the safe execution mode. In the safe execution mode, the initial goal is not allowed to be of type `IO` and the program should not import the module `Unsafe`. Furthermore, the allowed commands are `eval`, `load`, `quit`, and `reload`. This mode is useful to use PAKCS in uncontrolled environments, like a computation service in a web page, where PAKCS could be invoked by

```
pakcs :set safe
```

$\boxed{\text{parser } opts}$ Define additional options passed to the PAKCS front end, i.e., the parser program *pakcshome*`/bin/cymake`. For instance, setting the option

```
:set parser -F --pgmF=transcurry
```

has the effect that each Curry module to be compiled is transformed by the preprocessor command `transcurry` into a new Curry program which is actually compiled.

$\boxed{\text{args } arguments}$ Define run-time arguments for the evaluation of the main expression. For instance, setting the option

```
:set args first second
```

has the effect that the I/O operation `getArgs` (see library `System` (Section A.2.51) returns the value `["first","second"]`.

PAKCS can also execute programs in the **debug mode**. The debug mode is switched on by setting the `debug` option with the command ":`set +debug`". In order to switch back to normal evaluation of the program, one has to execute the command ":`set -debug`".

In the debug mode, PAKCS offers the following additional options:

$\boxed{\text{+/-single}}$ Turn on/off single mode for debugging. If the single mode is on, the evaluation of an expression is stopped after each step and the user is asked how to proceed (see the options there).

$\boxed{\text{+/-trace}}$ Turn on/off trace mode for debugging. If the trace mode is on, all intermediate expressions occurring during the evaluation of an expressions are shown.

$\boxed{\text{spy } f}$ Set a spy point (break point) on the function f. In the single mode, you can "leap" from spy point to spy point (see the options shown in the single mode).

$\boxed{\text{+/-spy}}$ Turn on/off spy mode for debugging. If the spy mode is on, the single mode is automatically activated when a spy point is reached.

2.4 Using PAKCS in Batch Mode

Although PAKCS is primarily designed as an interactive system, it can also be used to process data in batch mode. For example, consider a Curry program, say `myprocessor`, that reads argument strings from the command line and processes them. Suppose the entry point is a function called `just_doit` that takes no arguments. Such a processor can be invoked from the shell as follows:

```
> pakcs :set args string1 string2 :load myprocessor.curry :eval just_doit :quit
```

The ":quit" directive in necessary to avoid PAKCS going into interactive mode after the excution of the expression being evaluated. The actual run-time arguments (string1, string2) are defined by setting the option args (see above).

Here is an example to use PAKCS in this way:

```
> pakcs :set args Hello World :add System :eval "getArgs >>= putStrLn . unwords" :quit
Hello World
>
```

2.5 Command Line Editing

In order to have support for line editing or history functionality in the command line of PAKCS (as often supported by the readline library), you should have the Unix command rlwrap installed on your local machine. If rlwrap is installed, it is used by PAKCS if called on a terminal. If it should not be used (e.g., because it is executed in an editor with readline functionality), one can call PAKCS with the parameter "--noreadline".

2.6 Customization

In order to customize the behavior of PAKCS to your own preferences, there is a configuration file which is read by PAKCS when it is invoked. When you start PAKCS for the first time, a standard version of this configuration file is copied with the name ".pakcsrc" into your home directory. The file contains definitions of various settings, e.g., about showing warnings, progress messages etc. After you have started PAKCS for the first time, look into this file and adapt it to your own preferences.

2.7 Emacs Interface

Emacs is a powerful programmable editor suitable for program development. It is freely available for many platforms (see http://www.emacs.org). The distribution of PAKCS contains also a special *Curry mode* that supports the development of Curry programs in the Emacs environment. This mode includes support for syntax highlighting, finding declarations in the current buffer, and loading Curry programs into PAKCS in an Emacs shell.

The Curry mode has been adapted from a similar mode for Haskell programs. Its installation is described in the file README in directory "*pakcshome*/tools/emacs" which also contains the sources of the Curry mode and a short description about the use of this mode.

3 Extensions

PAKCS supports some extensions in Curry programs that are not (yet) part of the definition of Curry. These extensions are described below.

3.1 Recursive Variable Bindings

Local variable declarations (introduced by `let` or `where`) can be (mutually) recursive in PAKCS. For instance, the declaration

```
ones5 = let ones = 1 : ones
          in take 5 ones
```

introduces the local variable `ones` which is bound to a *cyclic structure* representing an infinite list of 1's. Similarly, the definition

```
onetwo n = take n one2
 where
    one2 = 1 : two1
    two1 = 2 : one2
```

introduces a local variables `one2` that represents an infinite list of alternating 1's and 2's so that the expression (`onetwo 6`) evaluates to `[1,2,1,2,1,2]`.

3.2 Functional Patterns

Functional patterns [6] are a useful extension to code operations in a more readable way. Furthermore, defining operations with functional patterns avoids problems caused by strict equality ("`=:=`") and leads to programs that are potentially more efficient.

Consider the definition of an operation to compute the last element of a list `xs` based on the prelude operation "`++`" for list concatenation:

```
last xs | _++[y] =:= xs  = y   where y free
```

Since the equality constraint "`=:=`" evaluates both sides to a constructor term, all elements of the list `xs` are fully evaluated in order to satisfy the constraint.

Functional patterns can help to improve this computational behavior. A *functional pattern* is a function call at a pattern position. With functional patterns, we can define the operation `last` as follows:

```
last (_++[y]) = y
```

This definition is not only more compact but also avoids the complete evaluation of the list elements: since a functional pattern is considered as an abbreviation for the set of constructor terms obtained by all evaluations of the functional pattern to normal form (see [6] for an exact definition), the previous definition is conceptually equivalent to the set of rules

```
last [y] = y
last [_,y] = y
last [_,_,y] = y
...
```

which shows that the evaluation of the list elements is not demanded by the functional pattern.

In general, a pattern of the form (f $t_1 \ldots t_n$) ($n > 0$) is interpreted as a functional pattern if f is not a visible constructor but a defined function that is visible in the scope of the pattern.

It is also possible to combine functional patterns with as-patterns. Similarly to the meaning of as-patterns in standard constructor patterns, as-patterns in functional patterns are interpreted as a sequence of pattern matching where the variable of the as-pattern is matched before the given pattern is matched. This process can be described by introducing an auxiliary operation for this two-level pattern matching process. For instance, the definition

```
f (_ ++ x@[(42,_)] ++ _) = x
```

is considered as syntactic sugar for the expanded definition

```
f (_ ++ x ++ _) = f' x
  where
   f' [(42,_)] = x
```

However, as-patterns are usually implemented in a more efficient way without introducing auxiliary operations.

Optimization of programs containing functional patterns. Since functions patterns can evaluate to non-linear constructor terms, they are dynamically checked for multiple occurrences of variables which are, if present, replaced by equality constraints so that the constructor term is always linear (see [6] for details). Since these dynamic checks are costly and not necessary for functional patterns that are guaranteed to evaluate to linear terms, there is an optimizer for functional patterns that checks for occurrences of functional patterns that evaluate always to linear constructor terms and replace such occurrences with a more efficient implementation. This optimizer can be enabled by the following possibilities:

- Set the environment variable `FCYPP` to "`--fpopt`" before starting PAKCS, e.g., by the shell command

  ```
  export FCYPP="--fpopt"
  ```

  Then the functional pattern optimization is applied if programs are compiled and loaded in PAKCS.

- Put an option into the source code: If the source code of a program contains a line with a comment of the form (the comment must start at the beginning of the line)

  ```
  {-# PAKCS_OPTION_FCYPP --fpopt #-}
  ```

  then the functional pattern optimization is applied if this program is compiled and loaded in PAKCS.

The optimizer also report errors in case of wrong uses of functional patterns (i.e., in case of a function f defined with functional patterns that recursively depend on f).

3.3 Order of Pattern Matching

Curry allows multiple occurrences of pattern variables in standard patterns. These are an abbreviation of equational constraints between pattern variables. Functional patterns might also contain multiple occurrences of pattern variables. For instance, the operation

```
f (_++[x]++_++[x]++_) = x
```

returns all elements with at least two occurrences in a list.

If functional patterns as well as multiple occurrences of pattern variables occur in a pattern defining an operation, there are various orders to match an expression against such an operation. In the current implementation, the order is as follows:

1. Standard pattern matching: First, it is checked whether the constructor patterns match. Thus, functional patterns and multiple occurrences of pattern variables are ignored.

2. Functional pattern matching: In the next phase, functional patterns are matched but occurrences of standard pattern variables in the functional patterns are ignored.

3. Non-linear patterns: If standard and functional pattern matching is successful, the equational constraints which correspond to multiple occurrences pattern variables are solved.

4. Guards: Finally, the guards supplied by the programmer are checked.

The order of pattern matching should not influence the computed result. However, it might have some influence on the termination behavior of programs, i.e., a program might not terminate instead of finitely failing. In such cases, it could be necessary to consider the influence of the order of pattern matching. Note that other orders of pattern matching can be obtained using auxiliary operations.

3.4 Datatypes with Field Labels

A datatype declaration may optionally define data constructors with field labels.[1] These field labels can be used to construct, select from, and update fields in a manner that is independent of the overall structure of the datatype.

3.4.1 Declaration of Constructors with Labeled Fields

A data constructor of arity n creates an object with n components. These components are normally accessed positionally as arguments to the constructor in expressions or patterns. For large datatypes it is useful to assign *field labels* to the components of a data object. This allows a specific field to be referenced independently of its location within the constructor. A constructor definition in a data declaration may assign labels to the fields of the constructor, using the *record syntax* C {...}. Constructors using field labels may be freely mixed with constructors without them. A constructor with associated field labels may still be used as an ordinary constructor. The various use of labels (see below) are simply a shorthand for operations using an underlying positional constructor. The arguments to the positional constructor occur in the same order as the labeled fields.

---

[1]Field labels are quite similar to Haskell [22] so that we adopt most of the description of Haskell here.

For example, the definition using field labels

```
data Person = Person { firstName, lastName :: String, age :: Int }
            | Agent  { firstName, lastName :: String, trueIdentity :: Person }
```

is translated to

```
data Person = Person String String Int
            | Agent  String String Person
```

A data declaration may use the same field label in multiple constructors as long as the typing of the field is the same in all cases after type synonym expansion. A label cannot be shared by more than one type in scope. Field names share the top-level name space with ordinary definition of functions and must not conflict with other top-level names in scope.

Consider the following example:

```
data S = S1 { x :: Int } | S2 { x :: Int  } -- OK
data T = T1 { y :: Int } | T2 { y :: Bool } -- BAD
```

Here S is legal but T is not, because y is given inconsistent typings in the latter.

3.4.2   Field Selection

Field labels are used as *selector functions*, i.e., each field label serves as a function that extracts the field from an object. Selectors are top-level bindings and so they may be shadowed by local variables but cannot conflict with other top-level bindings of the same name. This shadowing only affects selector functions; in record construction (Section 3.4.3) and update (Section 3.4.4), field labels cannot be confused with ordinary variables.

For example the definition of `Person` above introduces the selector functions

```
firstName :: Person  →  String
firstName (Person x _ _) = x
firstName (Agent  x _ _) = x

lastName :: Person  →  String
lastName (Person _ x _) = x
```

```
lastName (Agent  _ x _) = x

age :: Person  → Int
age (Person _ _ x) = x

trueIdentity :: Person  → Person
trueIdentity (Agent  _ _ x) = x
```

3.4.3 Construction Using Field Labels

A constructor with labeled fields may be used to construct a value in which the components are specified by name rather than by position. In this case, the components are enclosed by braces. Construction using field labels is subject to the following constraints:

- Only field labels declared with the specified constructor may be mentioned.

- A field label may not be mentioned more than once.

- Fields not mentioned are initialized to different free variables.

The expression C{}, where C is a data constructor, is legal *whether or not C was declared with record syntax*; it denotes C Prelude.unknown$_1$ ... Prelude.unknown$_n$ where n is the arity of C. Note that this will introduce the constructor C with n *different* free variables as arguments.

Translation: In the binding $f = v$, the field f labels v.
$$C \; \{ \; bs \; \} = C \; (pick_1^C \; bs \; \texttt{Prelude.unknown}) \; ... \; (pick_k^C \; bs \; \texttt{Prelude.unknown})$$
where k is the arity of C.
The auxiliary function $pick_i^C \; bs \; d$ is defined as follows:
If the ith component of a constructor C has the field label f and $f = v$ appears in the binding list bs, then $pick_i^C \; bs \; d$ is v. Otherwise, $pick_i^C \; bs \; d$ is the default value d.

For example, a `Person` can be constructed by

```
smith = Agent { lastName = "Smith", firstName = "Agent" }
```

which is equivalent to the following agent, whose true identity might be any person:

```
smith = Agent "Agent" "Smith" _
```

3.4.4 Updates Using Field Labels

Values belonging to a datatype with field labels may be non-destructively updated. This creates a new value in which the specified field values replace those in the existing value. Updates are restricted in the following ways:

- All labels must be taken from the same datatype.

- No label may be mentioned more than once.

- The computation fails when the value being updated does not contain all of the specified labels.

Translation: Using the prior definition of $pick$,

e { bs } = `fcase` e `of`

$\qquad C_1\ v_1 \ldots v_{k_1}$ `->` $C_1\ (pick_1^{C_1}\ bs\ v_1)\ \ldots\ (pick_{k_1}^{C_1}\ bs\ v_{k_1})$

$\qquad\qquad \ldots$

$\qquad C_j\ v_1 \ldots v_{k_j}$ `->` $C_j\ (pick_1^{C_j}\ bs\ v_1)\ \ldots\ (pick_{k_j}^{C_j}\ bs\ v_{k_j})$

where $\{C_1, \ldots, C_j\}$ is the set of constructors containing *all* labels in bs, k_i is the arity of C_i.

For example, after watching a few more movies, we might want to update our information about `smith`. We can do so by writing

```
smith { trueIdentity = complement neo }
```

which is equivalent to

```
fcase smith of
  Agent fn ln _  → Agent fn ln (complement neo)
```

3.4.5 Pattern Matching Using Field Labels

A constructor with labeled fields may be used to specify a pattern in which the components are identified by name rather than by position. Matching against a constructor using labeled fields is the same as matching ordinary constructor patterns except that the fields are matched in the order they are named in the field list. All listed fields must be declared by the constructor; fields may not be named more than once. Fields not named by the pattern are ignored (matched against `_`).

Translation: Using the prior definition of $pick$,

C { `bs` } = ($C\ (pick_1^C\ bs\ \_)\ \ldots\ (pick_k^C\ bs\ \_)$)

where k is the arity of C.

For example, we could define a Smith-tester by writing:

```
isSmith Agent { lastName = "Smith" } = success
```

which is equivalent to

```
isSmith (Agent _ "Smith" _) = success
```

3.4.6 Field Labels and Modules

As described in the Curry report, there are two forms of exporting a data type T: The simple name T exports only the types name without constructors, whereas $T(..)$ also exports all constructors. Analogously, the form T does not export any field labels, whereas $T(..)$ exports all constructors and all field labels.

4 Recognized Syntax of Curry

The PAKCS Curry compiler accepts a slightly extended version of the grammar specified in the Curry Report [20]. Furthermore, the syntax recognized by PAKCS differs from that specified in the Curry Report regarding numeric or character literals. We therefore present the complete description of the syntax below, whereas syntactic extensions are highlighted.

4.1 Notational Conventions

The syntax is given in extended Backus-Naur-Form (eBNF), using the following notation:

$$
\begin{array}{rll}
NonTerm & ::= \alpha & \text{production} \\
& NonTerm & \text{nonterminal symbol} \\
& \texttt{Term} & \text{terminal symbol} \\
& [\alpha] & \text{optional} \\
& \{\alpha\} & \text{zero or more repetitions} \\
& (\alpha) & \text{grouping} \\
& \alpha \mid \beta & \text{alternative} \\
& \alpha_{\langle\beta\rangle} & \text{difference – elements generated by } \alpha \\
& & \text{without those generated by } \beta
\end{array}
$$

The Curry files are expected to be encoded in UTF8. However, source programs are biased towards ASCII for compatibility reasons.

4.2 Lexicon

4.2.1 Case Mode

Although the Curry Report specifies four different case modes (Prolog, Gödel, Haskell, free), the PAKCS only supports the *free* mode which puts no constraints on the case of identifiers.

4.2.2 Identifiers and Keywords

$$
\begin{array}{rcl}
Letter & ::= & \text{any ASCII letter} \\
Dashes & ::= & \texttt{--} \ \{\texttt{-}\} \\[4pt]
Ident & ::= & Letter \ \{Letter \mid Digit \mid \_ \mid \text{'}\} \\
Symbol & ::= & \texttt{\textasciitilde} \mid \texttt{!} \mid \texttt{@} \mid \texttt{\#} \mid \texttt{\$} \mid \texttt{\%} \mid \texttt{\textasciicircum} \mid \texttt{\&} \mid \texttt{*} \mid \texttt{+} \mid \texttt{-} \mid \texttt{=} \mid \texttt{<} \mid \texttt{>} \mid \texttt{?} \mid \texttt{.} \mid \texttt{/} \mid \texttt{|} \mid \texttt{\textbackslash} \mid \texttt{:} \\[4pt]
ModuleID & ::= & \{Ident \ \texttt{.}\} \ Ident \\
TypeConstrID & ::= & Ident \\
DataConstrID & ::= & Ident \\
TypeVarID & ::= & Ident \mid \_ \\
InfixOpID & ::= & (Symbol \ \{Symbol\})_{\langle Dashes \rangle} \\
FunctionID & ::= & Ident \\
VariableID & ::= & Ident \\
LabelID & ::= & Ident
\end{array}
$$

$$
\begin{array}{rcl}
QTypeConstrID & ::= & [ModuleID\ .]\ TypeConstrID \\
QDataConstrID & ::= & [ModuleID\ .]\ DataConstrID \\
QInfixOpID & ::= & [ModuleID\ .]\ InfixOpID \\
QFunctionID & ::= & [ModuleID\ .]\ FunctionID \\
QVariableID & ::= & [ModuleID\ .]\ VariableID \\
QLabelID & ::= & [ModuleID\ .]\ LabelID
\end{array}
$$

The following identifiers are recognized as keywords and cannot be used as an identifier:

case	data	do	else	external	fcase	foreign
free	if	import	in	infix	infixl	infixr
let	module	newtype	of	then	type	where

Note that the symbols `as`, `hiding` and `qualified` are not keywords. They have only a special meaning in module headers and can be used as ordinary identifiers.

The following symbols also have a special meaning and cannot be used as an infix operator identifier:

```
..     :      ::     =      \\      |      <-     ->     @      ~
```

4.2.3 Comments

Comments begin either with "`--`" and terminate at the end of the line or with "`{-`" and terminate with a matching "`-}`", i.e., the delimiters "`{-`" and "`-}`" act as parentheses and can be nested.

4.2.4 Numeric and Character Literals

Contrasting to the Curry Report, PAKCS adopts Haskell's notation of literals, for both numeric literals as well as `Char` and `String` literals. The precise syntax for both kinds is given below.

$$
\begin{array}{rcl}
Int & ::= & Decimal \\
& | & \texttt{0o}\ Octal\ |\ \texttt{0O}\ Octal \\
& | & \texttt{0x}\ Hexadecimal\ |\ \texttt{0X}\ Hexadecimal \\[4pt]
Float & ::= & Decimal\ .\ Decimal\ [Exponent] \\
& | & Decimal\ Exponent \\
Exponent & ::= & (\texttt{e}\ |\ \texttt{E})\ [\texttt{+}\ |\ \texttt{-}]\ Decimal \\[4pt]
Decimal & ::= & Digit\ [Decimal] \\
Binary & ::= & Binit\ [Binary] \\
Octal & ::= & Octit\ [Octal] \\
Hexadecimal & ::= & Hexit\ [Hexadecimal] \\[4pt]
Digit & ::= & \texttt{0}\ |\ \texttt{1}\ |\ \texttt{2}\ |\ \texttt{3}\ |\ \texttt{4}\ |\ \texttt{5}\ |\ \texttt{6}\ |\ \texttt{7}\ |\ \texttt{8}\ |\ \texttt{9} \\
Binit & ::= & \texttt{0}\ |\ \texttt{1} \\
Octit & ::= & \texttt{0}\ |\ \texttt{1}\ |\ \texttt{2}\ |\ \texttt{3}\ |\ \texttt{4}\ |\ \texttt{5}\ |\ \texttt{6}\ |\ \texttt{7} \\
Hexit & ::= & \texttt{0}\ |\ \texttt{1}\ |\ \texttt{2}\ |\ \texttt{3}\ |\ \texttt{4}\ |\ \texttt{5}\ |\ \texttt{6}\ |\ \texttt{7}\ |\ \texttt{8}\ |\ \texttt{9}\ |\ \texttt{A}\ |\ \texttt{B}\ |\ \texttt{C}\ |\ \texttt{D}\ |\ \texttt{E}\ |\ \texttt{F}\ |\ \texttt{a}\ |\ \texttt{b}\ |\ \texttt{c}\ |\ \texttt{d}\ |\ \texttt{e}\ |\ \texttt{f} \\[4pt]
Char & ::= & \texttt{'}(Graphic_{\langle\backslash\rangle}\ |\ Space\ |\ Escape_{\langle\backslash\&\rangle})\texttt{'} \\
String & ::= & \texttt{"}\{Graphic_{\langle"|\backslash\rangle}\ |\ Space\ |\ Escape\ |\ Gap\}\texttt{"} \\
Escape & ::= & \backslash\ (CharEsc\ |\ Ascii\ |\ Decimal\ |\ \texttt{o}\ Octal\ |\ \texttt{x}\ Hexadecimal)
\end{array}
$$

$$
\begin{array}{rcl}
\mathit{CharEsc} & ::= & \texttt{a} \mid \texttt{b} \mid \texttt{f} \mid \texttt{n} \mid \texttt{r} \mid \texttt{t} \mid \texttt{v} \mid \texttt{\textbackslash} \mid \texttt{"} \mid \texttt{'} \mid \texttt{\&} \\
\mathit{Ascii} & ::= & \verb|^| \; \mathit{Cntrl} \mid \texttt{NUL} \mid \texttt{SOH} \mid \texttt{STX} \mid \texttt{ETX} \mid \texttt{EOT} \mid \texttt{ENQ} \mid \texttt{ACK} \\
& \mid & \texttt{BEL} \mid \texttt{BS} \mid \texttt{HT} \mid \texttt{LF} \mid \texttt{VT} \mid \texttt{FF} \mid \texttt{CR} \mid \texttt{SO} \mid \texttt{SI} \mid \texttt{DLE} \\
& \mid & \texttt{DC1} \mid \texttt{DC2} \mid \texttt{DC3} \mid \texttt{DC4} \mid \texttt{NAK} \mid \texttt{SYN} \mid \texttt{ETB} \mid \texttt{CAN} \\
& \mid & \texttt{EM} \mid \texttt{SUB} \mid \texttt{ESC} \mid \texttt{FS} \mid \texttt{GS} \mid \texttt{RS} \mid \texttt{US} \mid \texttt{SP} \mid \texttt{DEL} \\
\mathit{Cntrl} & ::= & \mathit{AsciiLarge} \mid \texttt{@} \mid \texttt{[} \mid \texttt{\textbackslash} \mid \texttt{]} \mid \verb|^| \mid \texttt{\_} \\
\mathit{AsciiLarge} & ::= & \texttt{A} \mid \ldots \mid \texttt{Z} \\
\mathit{Gap} & ::= & \texttt{\textbackslash} \; \mathit{WhiteChar} \; \{ \mathit{WhiteChar} \} \; \texttt{\textbackslash}
\end{array}
$$

4.3 Layout

Similarly to Haskell, a Curry programmer can use layout information to define the structure of blocks. For this purpose, we define the indentation of a symbol as the column number indicating the start of this symbol. The indentation of a line is the indentation of its first symbol.[2]

The layout (or "off-side") rule applies to lists of syntactic entities after the keywords `let`, `where`, `do`, or `of`. In the subsequent context-free syntax, these lists are enclosed with curly brackets ({ }) and the single entities are separated by semicolons (;). Instead of using the curly brackets and semicolons of the context-free syntax, a Curry programmer must specify these lists by indentation: the indentation of a list of syntactic entities after `let`, `where`, `do`, or `of` is the indentation of the next symbol following the `let`, `where`, `do`, `of`. Any item of this list start with the same indentation as the list. Lines with only whitespaces or an indentation greater than the indentation of the list continue the item in its previous line. Lines with an indentation less than the indentation of the list terminate the entire list. Moreover, a list started by `let` is terminated by the keyword `in`. Thus, the sentence

```
f x = h x where { g y = y + 1 ; h z = (g z) * 2 }
```

which is valid w.r.t. the context-free syntax, is written with the layout rules as

```
f x = h x
 where g y = y + 1
       h z = (g z) * 2
```

or also as

```
f x = h x  where
   g y = y + 1
   h z = (g z)
         * 2
```

To avoid an indentation of top-level declarations, the keyword `module` and the end-of-file token are assumed to start in column 0.

4.4 Context Free Grammar

$$
\begin{array}{rcl}
\mathit{Module} & ::= & \texttt{module} \; \mathit{ModuleID} \; [\mathit{Exports}] \; \texttt{where} \; \mathit{Block} \\
& \mid & \mathit{Block}
\end{array}
$$

---

[2]In order to determine the exact column number, we assume a fixed-width font with tab stops at each 8th column.

$$
\begin{array}{rcl}
\textit{ModuleID} & ::= & \text{see lexicon} \\[4pt]
\textit{Exports} & ::= & (\ \textit{Export}_1\ ,\ \ldots\ ,\ \textit{Export}_n\ ) \hfill (n \geq 0) \\
\textit{Export} & ::= & \textit{QFunctionName} \\
 & | & \textit{QTypeConstrID}\ [(\ \textit{ConsLabelName}_1\ ,\ \ldots\ ,\ \textit{ConsLabelName}_n\ )] \hfill (n \geq 0) \\
 & | & \textit{QTypeConstrID}\ (\text{..}) \\
 & | & \text{module } \textit{ModuleID} \\
\textit{ConsLabelName} & ::= & \textit{LabelID}\ |\ \textit{DataConstr} \\[4pt]
\textit{Block} & ::= & \{\ [\textit{ImportDecl}_1\ ;\ \ldots\ ;\ \textit{ImportDecl}_k\ ;] \hfill (\textit{no fixity declarations here}) \\
 & & \quad \textit{BlockDeclaration}_1\ ;\ \ldots\ ;\ \textit{BlockDeclaration}_n\ \} \hfill (k, n \geq 0) \\[4pt]
\textit{ImportDecl} & ::= & \text{import } [\text{qualified}]\ \textit{ModuleID}\ [\text{as } \textit{ModuleID}]\ [\textit{ImportRestr}] \\
\textit{ImportRestr} & ::= & (\ \textit{Import}_1\ ,\ \ldots\ ,\ \textit{Import}_n\ ) \hfill (n \geq 0) \\
 & | & \text{hiding } (\ \textit{Import}_1\ ,\ \ldots\ ,\ \textit{Import}_n\ ) \hfill (n \geq 0) \\
\textit{Import} & ::= & \textit{FunctionName} \\
 & | & \textit{TypeConstrID}\ [(\ \textit{ConsLabelName}_1\ ,\ \ldots\ ,\ \textit{ConsLabelName}_n\ )] \hfill (n \geq 0) \\
 & | & \textit{TypeConstrID}\ (\text{..}) \\[4pt]
\textit{BlockDeclaration} & ::= & \textit{TypeSynonymDecl} \\
 & | & \textit{DataDeclaration} \\
 & | & \textit{FixityDeclaration} \\
 & | & \textit{FunctionDeclaration} \\[4pt]
\textit{TypeSynonymDecl} & ::= & \text{type } \textit{SimpleType} = \textit{TypeExpr} \\
\textit{SimpleType} & ::= & \textit{TypeConstrID}\ \textit{TypeVarID}_1\ \ldots\ \textit{TypeVarID}_n \hfill (n \geq 0) \\
\textit{TypeConstrID} & ::= & \text{see lexicon} \\[4pt]
\textit{DataDeclaration} & ::= & \text{data } \textit{SimpleType} \hfill (\textit{external data type}) \\
 & | & \text{data } \textit{SimpleType} = \textit{ConstrDecl}_1\ |\ \ldots\ |\ \textit{ConstrDecl}_n \hfill (n > 0) \\
\textit{ConstrDecl} & ::= & \textit{DataConstr}\ \textit{SimpleTypeExpr}_1\ \ldots\ \textit{SimpleTypeExpr}_n \hfill (n \geq 0) \\
 & | & \textit{SimpleTypeExpr}\ \textit{ConsOp}\ \textit{TypeConsExpr} \hfill (\textit{infix data constructor}) \\
 & | & \textit{DataConstr}\ \{\ \textit{FieldDeclaration}_1\ ,\ \ldots\ ,\ \textit{FieldDeclaration}_n\ \} \hfill (n \geq 0) \\
\textit{FieldDeclaration} & ::= & \textit{LabelID}_1\ ,\ \ldots\ ,\ \textit{LabelID}_n\ ::\ \textit{TypeExpr} \hfill (n > 0) \\
\textit{LabelID} & ::= & \text{see lexicon} \\[4pt]
\textit{TypeExpr} & ::= & \textit{TypeConsExpr}\ [\text{-> } \textit{TypeExpr}] \\
\textit{TypeConsExpr} & ::= & \textit{QTypeConstrID}\ \textit{SimpleTypeExpr}_1\ \ldots\ \textit{SimpleTypeExpr}_n \hfill (n > 0) \\
 & | & \textit{SimpleTypeExpr} \\
\textit{SimpleTypeExpr} & ::= & \textit{TypeVarID} \\
 & | & \textit{QTypeConstrID} \\
 & | & (\text{)} \hfill (\textit{unit type}) \\
 & | & (\ \textit{TypeExpr}_1\ ,\ \ldots\ ,\ \textit{TypeExpr}_n\ ) \hfill (\textit{tuple type},\ n > 1) \\
 & | & [\ \textit{TypeExpr}\ ] \hfill (\textit{list type}) \\
 & | & (\ \textit{TypeExpr}\ ) \hfill (\textit{parenthesized type}) \\
\textit{TypeVarID} & ::= & \text{see lexicon} \\[4pt]
\textit{FixityDeclaration} & ::= & \textit{FixityKeyword}\ \textit{Digit}\ \textit{InfixOpID}_1\ ,\ \ldots\ ,\ \textit{InfixOpID}_n \hfill (n > 0) \\
\textit{FixityKeyword} & ::= & \text{infixl}\ |\ \text{infixr}\ |\ \text{infix} \\
\textit{InfixOpID} & ::= & \text{see lexicon} \\[4pt]
\textit{FunctionDeclaration} & ::= & \textit{Signature}\ |\ \textit{External}\ |\ \textit{Equat} \\
\textit{External} & ::= & \textit{FunctionNames}\ \text{external} \hfill (\textit{externally defined functions}) \\
\textit{Signature} & ::= & \textit{FunctionNames}\ ::\ \textit{TypeExpr} \\
\end{array}
$$

$$
\begin{array}{rcll}
\textit{FunctionNames} & ::= & \textit{FunctionName}_1 \text{ , } \ldots \text{ , } \textit{FunctionName}_n & (n > 0) \\
\textit{Equat} & ::= & \textit{FunLHS} \text{ = } \textit{TypedExpr} \, [\text{where } \textit{LocalDefs}] & \\
& | & \textit{FunLHS } \textit{CondExprs} \, [\text{where } \textit{LocalDefs}] & \\
\textit{FunLHS} & ::= & \textit{FunctionName } \textit{SimplePat}_1 \ \ldots \ \textit{SimplePat}_n & (n \geq 0) \\
& | & \textit{SimplePat } \textit{InfixOpID } \textit{SimplePat} & \\
\textit{CondExprs} & ::= & |\ \textit{InfixExpr} \text{ = } \textit{TypedExpr} \, [\textit{CondExprs}] & \\
& & & \\
\textit{Pattern} & ::= & \textit{ConsPattern } [\textit{QConsOp } \textit{Pattern}] & (\textit{infix constructor pattern}) \\
\textit{ConsPattern} & ::= & \textit{GDataConstr } \textit{SimplePat}_1 \ \ldots \ \textit{SimplePat}_n & (\textit{constructor pattern}) \\
& | & \textit{SimplePat} & \\
\textit{SimplePat} & ::= & \textit{Variable} & \\
& | & \text{\_} & (\textit{wildcard}) \\
& | & \textit{QDataConstr} & \\
& | & \textit{Literal} & \\
& | & \text{-- } \textit{Int} & (\textit{negative pattern}) \\
& | & \text{--. } \textit{Float} & (\textit{negative float pattern}) \\
& | & \text{()} & (\textit{empty tuple pattern}) \\
& | & (\ \textit{Pattern}_1 \text{ , } \ldots \text{ , } \textit{Pattern}_n \ ) & (n > 1) \\
& | & (\ \textit{Pattern} \ ) & (\textit{parenthesized pattern}) \\
& | & [\ \textit{Pattern}_1 \text{ , } \ldots \text{ , } \textit{Pattern}_n \ ] & (n \geq 0) \\
& | & \textit{Variable } \text{@ } \textit{SimplePat} & (\textit{as-pattern}) \\
& | & \text{\textasciitilde } \textit{SimplePat} & (\textit{irrefutable pattern}) \\
& | & (\ \textit{SimplePat } \textit{QFunOp } \textit{SimplePat} \ ) & (\textit{infix functional pattern}) \\
& | & (\ \textit{QFunctionName } \textit{SimplePat}_1 \ \ldots \ \textit{SimplePat}_n \ ) & (\textit{functional pattern, } n > 0) \\
& | & \textit{QDataConstr } \{\ \textit{FieldPat}_1 \text{ , } \ldots \text{ , } \textit{FieldPat}_n \ \} & (\textit{labeled pattern, } n \geq 0) \\
\textit{FieldPat} & ::= & \textit{QLabelID } \text{= } \textit{Pattern} & \\
\textit{QLabelID} & ::= & \text{see lexicon} & \\
& & & \\
\textit{LocalDefs} & ::= & \{\ \textit{ValueDeclaration}_1 \text{ ; } \ldots \text{ ; } \textit{ValueDeclaration}_n \ \} & (n > 0) \\
\textit{ValueDeclaration} & ::= & \textit{FunctionDeclaration} & \\
& | & \textit{PatternDeclaration} & \\
& | & \textit{VariableID}_1 \text{ , } \ldots \text{ , } \textit{VariableID}_n \ \text{free} & (n > 0) \\
& | & \textit{FixityDeclaration} & \\
\textit{PatternDeclaration} & ::= & \textit{Pattern} \text{ = } \textit{TypedExpr} \, [\text{where } \textit{LocalDefs}] & \\
& & & \\
\textit{TypedExpr} & ::= & \textit{InfixExpr } \text{:: } \textit{TypeExpr} & (\textit{expression type signature}) \\
& | & \textit{InfixExpr} & \\
\textit{InfixExpr} & ::= & \textit{Expr } \textit{QOp } \textit{InfixExpr} & (\textit{infix operator application}) \\
& | & \text{-- } \textit{InfixExpr} & (\textit{unary int minus}) \\
& | & \text{--. } \textit{InfixExpr} & (\textit{unary float minus}) \\
& | & \textit{Expr} & \\
\textit{Expr} & ::= & \text{\textbackslash } \textit{SimplePat}_1 \ \ldots \ \textit{SimplePat}_n \text{ -> } \textit{TypedExpr} & (\textit{lambda expression, } n > 0) \\
& | & \text{let } \textit{LocalDefs } \text{in } \textit{TypedExpr} & (\textit{let expression}) \\
& | & \text{if } \textit{TypedExpr } \text{then } \textit{TypedExpr } \text{else } \textit{TypedExpr} & (\textit{conditional}) \\
& | & \text{case } \textit{TypedExpr } \text{of } \{\textit{Alt}_1 \text{ ; } \ldots \text{ ; } \textit{Alt}_n \} & (\textit{case expression, } n \geq 0) \\
& | & \text{fcase } \textit{TypedExpr } \text{of } \{\textit{Alt}_1 \text{ ; } \ldots \text{ ; } \textit{Alt}_n \} & (\textit{fcase expression, } n \geq 0) \\
& | & \text{do } \{\ \textit{Stmt}_1 \text{ ; } \ldots \text{ ; } \textit{Stmt}_n \text{ ; } \textit{TypedExpr} \ \} & (\textit{do expression, } n \geq 0) \\
& | & \textit{FunctExpr} & \\
\textit{FunctExpr} & ::= & [\textit{FunctExpr}] \ \textit{BasicExpr} & (\textit{function application}) \\
\textit{BasicExpr} & ::= & \textit{QVariableID} & (\textit{variable}) \\
& | & \text{\_} & (\textit{anonymous free variable})
\end{array}
$$

	QFunctionName	(*qualified function*)
	GDataConstr	(*general constructor*)
	Literal	
	(*TypedExpr*)	(*parenthesized expression*)
	(*TypedExpr*$_1$, ... , *TypedExpr*$_n$)	(*tuple, $n > 1$*)
	[*TypedExpr*$_1$, ... , *TypedExpr*$_n$]	(*finite list, $n > 0$*)
	[*TypedExpr* [, *TypedExpr*] .. [*TypedExpr*]]	(*arithmetic sequence*)
	[*TypedExpr* | *Qual*$_1$, ... , *Qual*$_n$]	(*list comprehension, $n \geq 1$*)
	(*InfixExpr QOp*)	(*left section*)
	(*QOp*$_{\langle -,-.\rangle}$ *InfixExpr*)	(*right section*)
	QDataConstr { *FBind*$_1$, ... , *FBind*$_n$ }	(*labeled construction, $n \geq 0$*)
	BasicExpr$_{\langle QDataConstr\rangle}$ { *FBind*$_1$, ... , *FBind*$_n$ }	(*labeled update, $n > 0$*)

$$Alt ::= Pattern \texttt{ -> } TypedExpr \text{ [}\texttt{where } LocalDefs]$$
$$| \quad Pattern \; GdAlts \text{ [}\texttt{where } LocalDefs]$$
$$GdAlts ::= \texttt{ | } TypedExpr \texttt{ -> } TypedExpr \text{ [}GdAlts]$$

$$FBind ::= QLabelID \texttt{ = } TypedExpr$$

$$Qual ::= TypedExpr$$
$$| \quad \texttt{let } LocalDefs$$
$$| \quad Pattern \texttt{ <- } TypedExpr$$

$$Stmt ::= TypedExpr$$
$$| \quad \texttt{let } LocalDefs$$
$$| \quad Pattern \texttt{ <- } TypedExpr$$

$$Literal ::= Int \mid Char \mid String \mid Float$$

$$GDataConstr ::= \texttt{()}$$
$$| \quad \texttt{[]}$$
$$| \quad \texttt{(,\{,\})}$$
$$| \quad QDataConstr$$

FunctionName	::=	*FunctionID* | (*InfixOpID*)	(*function*)
QFunctionName	::=	*QFunctionID* | (*QInfixOpID*)	(*qualified function*)
Variable	::=	*VariableID* | (*InfixOpID*)	(*variable*)
DataConstr	::=	*DataConstrID* | (*InfixOpID*)	(*constructor*)
QDataConstr	::=	*QDataConstrID* | (*QConsOp*)	(*qualified constructor*)
QFunOp	::=	*QInfixOpID* | ' *QFunctionID* '	(*qualified function operator*)
ConsOp	::=	*InfixOpID* | ' *DataConstrID* '	(*constructor operator*)
QOp	::=	*QFunOp* | *QConsOp*	(*qualified operator*)
QConsOp	::=	*GConSym* | ' *QDataConstrID* '	(*qualified constructor operator*)
GConSym	::=	: | *QInfixOpID*	(*general constructor symbol*)

5 CurryDoc: A Documentation Generator for Curry Programs

CurryDoc is a tool in the PAKCS distribution that generates the documentation for a Curry program (i.e., the main module and all its imported modules) in HTML format. The generated HTML pages contain information about all data types and functions exported by a module as well as links between the different entities. Furthermore, some information about the definitional status of functions (like rigid, flexible, external, complete, or overlapping definitions) are provided and combined with documentation comments provided by the programmer.

A *documentation comment* starts at the beginning of a line with "`---` " (also in literate programs!). All documentation comments immediately before a definition of a datatype or (top-level) function are kept together.[3] The documentation comments for the complete module occur before the first "module" or "import" line in the module. The comments can also contain several special tags. These tags must be the first thing on its line (in the documentation comment) and continues until the next tag is encountered or until the end of the comment. The following tags are recognized:

`@author` *comment*

> Specifies the author of a module (only reasonable in module comments).

`@version` *comment*

> Specifies the version of a module (only reasonable in module comments).

`@cons` *id comment*

> A comment for the constructor *id* of a datatype (only reasonable in datatype comments).

`@param` *id comment*

> A comment for function parameter *id* (only reasonable in function comments). Due to pattern matching, this need not be the name of a parameter given in the declaration of the function but all parameters for this functions must be commented in left-to-right order (if they are commented at all).

`@return` *comment*

> A comment for the return value of a function (only reasonable in function comments).

The comment of a documented entity can be any string in Markdown's syntax (the currently supported set of elements is described in detail in the appendix). For instance, it can contain Markdown annotations for emphasizing elements (e.g., `_verb_`), strong elements (e.g., `**important**`), code elements (e.g., `'3+4'`), code blocks (lines prefixed by four blanks), unordered lists (lines prefixed by " `*` "), ordered lists (lines prefixed by blanks followed by a digit and a dot), quotations (lines prefixed by "`>` "), and web links of the form "`<http://...>`" or "`[link text](http://...)`". If the Markdown syntax should not be used, one could run CurryDoc with the parameter "`--nomarkdown`".

The comments can also contain markups in HTML format so that special characters like "<" must be quoted (e.g., "`<`"). However, header tags like `<h1>` should not be used since the structuring is generated by CurryDoc. In addition to Markdown or HTML markups, one can also mark

---

[3]The documentation tool recognizes this association from the first identifier in a program line. If one wants to add a documentation comment to the definition of a function which is an infix operator, the first line of the operator definition should be a type definition, otherwise the documentation comment is not recognized.

references to names of operations or data types in Curry programs which are translated into links inside the generated HTML documentation. Such references have to be enclosed in single quotes. For instance, the text `'conc'` refers to the Curry operation `conc` inside the current module whereas the text `'Prelude.reverse'` refers to the operation `reverse` of the module `Prelude`. If one wants to write single quotes without this specific meaning, one can escape them with a backslash:

```
--- This is a comment without a \'reference\'.
```

To simplify the writing of documentation comments, such escaping is only necessary for single words, i.e., if the text inside quotes has not the syntax of an identifier, the escaping can be omitted, as in

```
--- This isn't a reference.
```

The following example text shows a Curry program with some documentation comments:

```
--- This is an
--- example module.
--- @author Michael Hanus
--- @version 0.1

module Example where

--- The function 'conc' concatenates two lists.
--- @param xs - the first list
--- @param ys - the second list
--- @return a list containing all elements of 'xs' and 'ys'
conc []     ys = ys
conc (x:xs) ys = x : conc xs ys
-- this comment will not be included in the documentation

--- The function 'last' computes the last element of a given list.
--- It is based on the operation 'conc' to concatenate two lists.
--- @param xs - the given input list
--- @return last element of the input list
last xs | conc ys [x] =:= xs  = x   where x,ys free

--- This data type defines _polymorphic_ trees.
--- @cons Leaf - a leaf of the tree
--- @cons Node - an inner node of the tree
data Tree a = Leaf a | Node [Tree a]
```

To generate the documentation, execute the command

```
currydoc Example
```

(`currydoc` is a command usually stored in *pakcshome*/`bin` where *pakcshome* is the installation directory of PAKCS; see Section 1.1). This command creates the directory `DOC_Example` (if it does not exist) and puts all HTML documentation files for the main program module `Example` and all its imported modules in this directory together with a main index file `index.html`. If one prefers another directory for the documentation files, one can also execute the command

```
currydoc docdir Example
```

where `docdir` is the directory for the documentation files.

In order to generate the common documentation for large collections of Curry modules (e.g., the libraries contained in the PAKCS distribution), one can call `currydoc` with the following options:

`currydoc --noindexhtml docdir Mod` : This command generates the documentation for module `Mod` in the directory `docdir` without the index pages (i.e., main index page and index pages for all functions and constructors defined in `Mod` and its imported modules).

`currydoc --onlyindexhtml docdir Mod1 Mod2 ...Mod`n : This command generates only the index pages (i.e., a main index page and index pages for all functions and constructors defined in the modules `Mod1`, `M2`,...,`Mod`n and their imported modules) in the directory `docdir`.

6 CurryBrowser: A Tool for Analyzing and Browsing Curry Programs

CurryBrowser is a tool to browse through the modules and functions of a Curry application, show them in various formats, and analyze their properties.[4] Moreover, it is constructed in a way so that new analyzers can be easily connected to CurryBrowser. A detailed description of the ideas behind this tool can be found in [15, 16].

CurryBrowser is part of the PAKCS distribution and can be started in two ways:

- In the command shell via the command: *pakcshome*/bin/currybrowser mod

- In the PAKCS environment after loading the module mod and typing the command ":browse".

Here, "mod" is the name of the main module of a Curry application. After the start, CurryBrowser loads the interfaces of the main module and all imported modules before a GUI is created for interactive browsing.

To get an impression of the use of CurryBrowser, Figure 1 shows a snapshot of its use on a particular application (here: the implementation of CurryBrowser). The upper list box in the left column shows the modules and their imports in order to browse through the modules of an application. Similarly to directory browsers, the list of imported modules of a module can be opened or closed by clicking. After selecting a module in the list of modules, its source code, interface, or various other formats of the module can be shown in the main (right) text area. For instance, one can show pretty-printed versions of the intermediate flat programs (see below) in order to see how local function definitions are translated by lambda lifting [21] or pattern matching is translated into case expressions [11, 23]. Since Curry is a language with parametric polymorphism and type inference, programmers often omit the type signatures when defining functions. Therefore, one can also view (and store) the selected module as source code where missing type signatures are added.

Below the list box for selecting modules, there is a menu ("Analyze selected module") to analyze all functions of the currently selected module at once. This is useful to spot some functions of a module that could be problematic in some application contexts, like functions that are impure (i.e., the result depends on the evaluation time) or partially defined (i.e., not evaluable on all ground terms). If such an analysis is selected, the names of all functions are shown in the lower list box of the left column (the "function list") with prefixes indicating the properties of the individual functions.

The function list box can be also filled with functions via the menu "Select functions". For instance, all functions or only the exported functions defined in the currently selected module can be shown there, or all functions from different modules that are directly or indirectly called from a currently selected function. This list box is central to focus on a function in the source code of some module or to analyze some function, i.e., showing their properties. In order to focus on a function, it is sufficient to check the "focus on code" button. To analyze an individually selected function, one can select an analysis from the list of available program analyses (through the menu "Select analysis"). In this case, the analysis results are either shown in the text box below the main text area or visualized by separate tools, e.g., by a graph drawing tool for visualizing call graphs. Some

---

[4]Although CurryBrowser is implemented in Curry, some functionalities of it require an installed graph visualization tool (dot http://www.graphviz.org/), otherwise they have no effect.
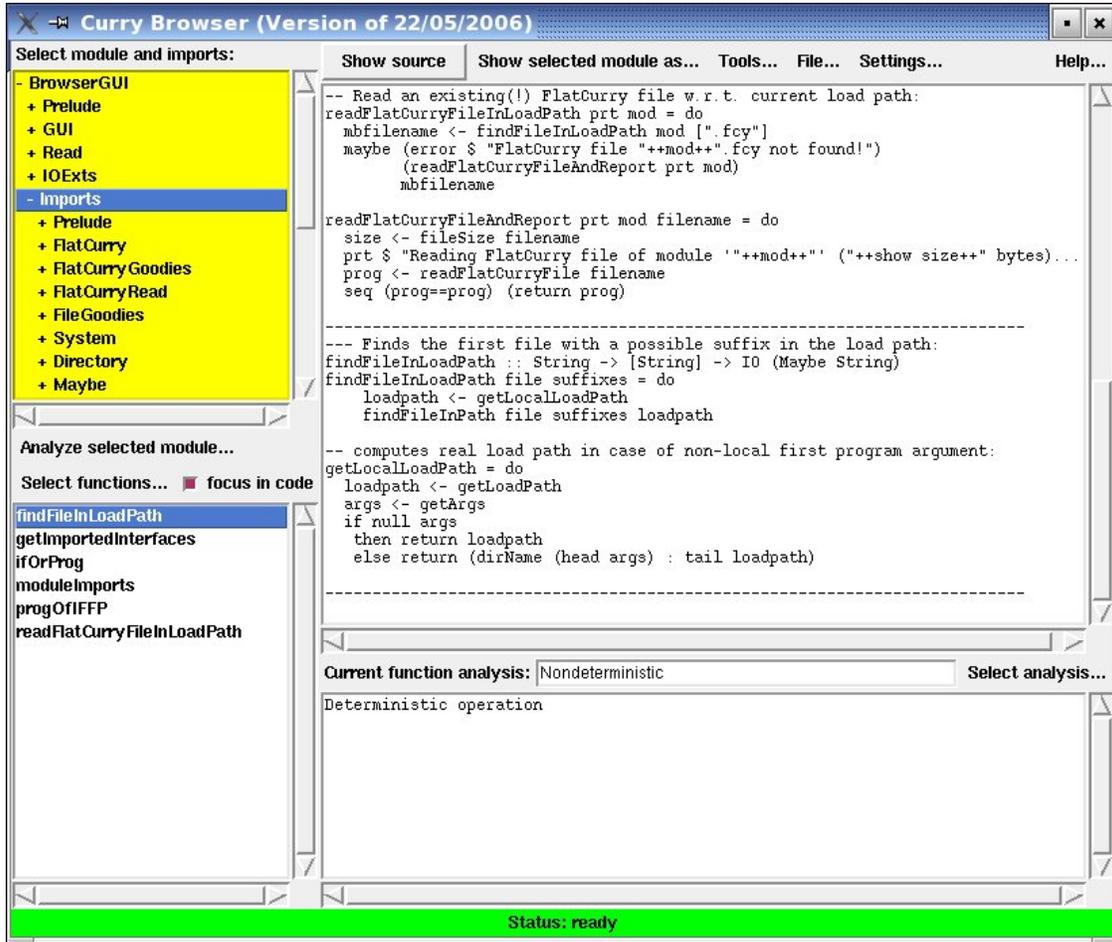
Figure 1: Snapshot of the main window of CurryBrowser

analyses are local, i.e., they need only to consider the local definition of this function (e.g., "Calls directly," "Overlapping rules," "Pattern completeness"), where other analyses are global, i.e., they consider the definitions of all functions directly or indirectly called by this function (e.g., "Depends on," "Solution complete," "Set-valued"). Finally, there are a few additional tools integrated into CurryBrowser, for instance, to visualize the import relation between all modules as a dependency graph. These tools are available through the "Tools" menu.

More details about the use of CurryBrowser and all built-in analyses are available through the "Help" menu of CurryBrowser.

7 CurryTest: A Tool for Testing Curry Programs

CurryTest is a simple tool in the PAKCS distribution to write and run repeatable tests. CurryTest simplifies the task of writing test cases for a module and executing them. The tool is easy to use. Assume one has implemented a module `MyMod` and wants to write some test cases to test its functionality, making regression tests in future versions, etc. For this purpose, there is a system library `Assertion` (Section A.2.2) which contains the necessary definitions for writing tests. In particular, it exports an abstract polymorphic type "`Assertion a`" together with the following operations:

```
assertTrue      :: String  →  Bool  →  Assertion ()
assertEqual     :: String  →  a  →  a  →  Assertion a
assertValues    :: String  →  a  →  [a]  →  Assertion a
assertSolutions :: String  →  (a → Success)  →  [a]  →  Assertion a
assertIO        :: String  →  IO a  →  a  →  Assertion a
assertEqualIO   :: String  →  IO a  →  IO a  →  Assertion a
```

The expression "`assertTrue` s b" is an assertion (named s) that the expression b has the value `True`. Similarly, the expression "`assertEqual` s e_1 e_2" asserts that the expressions e_1 and e_2 must be equal (i.e., e_1==e_2 must hold), the expression "`assertValues` s e vs" asserts that vs is the multiset of all values of e, and the expression "`assertSolutions` s c vs" asserts that the constraint abstraction c has the multiset of solutions vs. Furthermore, the expression "`assertIO` s a v" asserts that the I/O action a yields the value v whenever it is executed, and the expression "`assertEqualIO` s a_1 a_2" asserts that the I/O actions a_1 and a_2 yield equal values. The name s provided as a first argument in each assertion is used in the protocol produced by the test tool.

One can define a test program by importing the module to be tested together with the module `Assertion` and defining top-level functions of type `Assertion` in this module (which must also be exported). As an example, consider the following program that can be used to test some list processing functions:

```
import List
import Assertion

test1 = assertEqual      "++"      ([1,2]++[3,4]) [1,2,3,4]

test2 = assertTrue       "all"     (all (<5) [1,2,3,4])

test3 = assertSolutions "prefix" (\x  →  x++_ =:= [1,2])
                                 [[],[1],[1,2]]
```

For instance, `test1` asserts that the result of evaluating the expression (`[1,2]++[3,4]`) is equal to `[1,2,3,4]`.

We can execute a test suite by the command

```
currytest TestList
```

(`currytest` is a program stored in *pakcshome*`/bin` where *pakcshome* is the installation directory of PAKCS; see Section 1.1). In our example, "`TestList.curry`" is the program containing the definition of all assertions. This has the effect that all exported top-level functions of type `Assertion` are
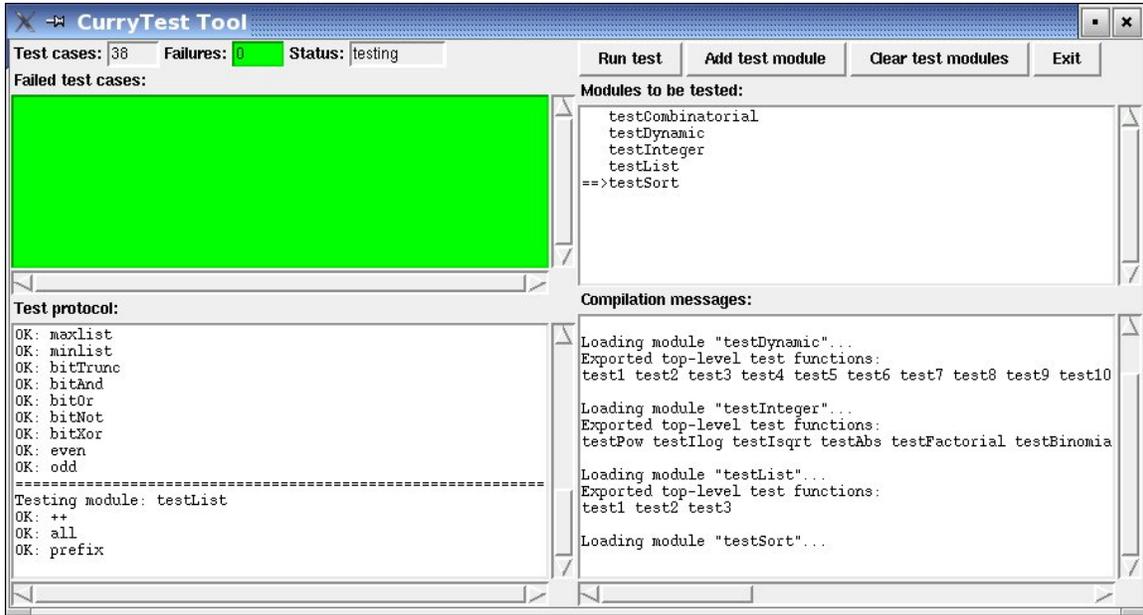
Figure 2: Snapshot of CurryTest's graphical interface

tested (i.e., the corresponding assertions are checked) and the results ("OK" or failure) are reported together with the name of each assertion. For our example above, we obtain the following successful protocol:

```
============================================================
Testing module "TestList"...
OK: ++
OK: all
OK: prefix
All tests successfully passed.
============================================================
```

There is also a graphical interface that summarizes the results more nicely.[5] In order to start this interface, one has to add the parameter "--window" (or "-w"), e.g., executing a test suite by

```
currytest --window TestList
```

or

```
currytest -w TestList
```

A snapshot of the interface is shown in Figure 2.

---

[5]Due to a bug in older versions of SICStus-Prolog, it works only with SICStus-Prolog version 3.8.5 (or newer).

8 ERD2Curry: A Tool to Generate Programs from ER Specifications

ERD2Curry is a tool to generate Curry code to access and manipulate data persistently stored from entity relationship diagrams. The idea of this tool is described in detail in [10]. Thus, we describe only the basic steps to use this tool in the following.

If one creates an entity relationship diagram (ERD) with the Umbrello UML Modeller, one has to store its XML description in XMI format (as offered by Umbrello) in a file, e.g., "`myerd.xmi`". This description can be compiled into a Curry program by the command

```
erd2curry -x myerd.xmi
```

(`erd2curry` is a program stored in *pakcshome*/`bin` where *pakcshome* is the installation directory of PAKCS; see Section 1.1). If `MyData` is the name of the ERD, the Curry program file "`MyData.curry`" is generated containing all the necessary database access code as described in [10]. In addition to the generated Curry program file, two auxiliary program files `ERDGeneric.curry` and `KeyDatabase.curry` are created in the same directory.

If one does not want to use the Umbrello UML Modeller, which might be the preferred method since the interface to the Umbrello UML Modeller is no longer actively supported, one can also create a textual description of the ERD as a Curry term of type `ERD` (w.r.t. the type definition given in module *pakcshome*/`currytools/erd2curry/ERD.curry`) and store it in some file, e.g., "`myerd.term`". This description can be compiled into a Curry program by the command

```
erd2curry -t myerd.term
```

The directory *pakcshome*/`currytools/erd2curry/` contains two examples for such ERD term files:

`Blog.erdterm`: This is a simple ERD model for a blog with entries, comments, and tags.

`Uni.erdterm`: This is an ERD model for university lectures as presented in the paper [10].

There is also the possibility to visualize an ERD term as a graph with the graph visualization program `dotty` (for this purpose, it might be necessary to adapt the definition of `dotviewcommand` in your "`.pakcsrc`" file, see Section 2.6, according to your local environment). The visualization can be performed by the command

```
erd2curry -v myerd.term
```

9 Spicey: An ER-based Web Framework

Spicey is a framework to support the implementation of web-based systems in Curry. Spicey generates an initial implementation from an entity-relationship (ER) description of the underlying data. The generated implementation contains operations to create and manipulate entities of the data model, supports authentication, authorization, session handling, and the composition of individual operations to user processes. Furthermore, the implementation ensures the consistency of the database w.r.t. the data dependencies specified in the ER model, i.e., updates initiated by the user cannot lead to an inconsistent state of the database.

The idea of this tool, which is part of the distribution of PAKCS, is described in detail in [18]. Thus, we describe only the basic steps to use this tool in order to generate a web application.

First, one has to create a textual description of the entity-relationship model as a Curry term of type `ERD` (w.r.t. the type definitions given in module *pakcshome*/currytools/erd2curry/ERD.curry) and store it in some file, e.g., "mymodel.erdterm". The directory *pakcshome*/currytools/spicey/ contains two examples for such ERD term files:

`Blog.erdterm`: This is a simple ER model for a blog with entries, comments, and tags, as presented in the paper [18].

`Uni.erdterm`: This is an ER model for university lectures as presented in the paper [10].

Then change to the directory in which you want to create the project sources. Execute the command

```
spiceup .../mymodel.erdterm
```

with the path to the ERD term file as a parameter (`spiceup` is a program stored in *pakcshome*/bin where *pakcshome* is the installation directory of PAKCS; see Section 1.1). You can also provide a path name, i.e., the name of a directory, where the database files should be stored, e.g.,

```
spiceup --dbpath DBDIR .../mymodel.erdterm
```

If the parameter "`--dbpath DBDIR`" is not provided, then DBDIR is set to the current directory ("."). Since this specification will be used in the *generated* web programs, a relative database directory name will be relative to the place where the web programs are stored. In order to avoid such confusion, it might be better to specify an absolute path name for the database directory.

After the generation of this project (see the generated file `README.txt` for information about the generated project structure), one can compile the generated programs by

```
make compile
```

In order to generate the executable web application, configure the generated `Makefile` by adapting the variable `WEBSERVERDIR` to the location where the compiled cgi programs should be stored, and run

```
make deploy
```

After the successful compilation and deployment of all files, the application is executable in a web browser by selecting the URL `<URL of web dir>/spicey.cgi`.

10 UI: Declarative Programming of User Interfaces

The PAKCS distribution contains a collection of libraries to implement graphical user interfaces as well as web-based user interfaces from declarative descriptions. Exploiting these libraries, it is possible to define the structure and functionality of a user interface independent from the concrete technology. Thus, a graphical user interface or a web-based user interface can be generated from the same description by simply changing the imported libraries. This programming technique is described in detail in [17].

The libraries implementing these user interfaces are contained in the directory

  pakcshome/tools/ui

Thus, in order to compile programs containing such user interface specifications, one has to include the directory *pakcshome*/tools/ui into the Curry load path (e.g., by setting the environment variable "CURRYPATH", see also Section 1.3). The directory

  pakcshome/tools/ui/examples

contains a few examples for such user interface specifications.

11 Preprocessing FlatCurry Files

After the invocation of the Curry front end to parse Curry programs and translate them into the intermediate FlatCurry representation, one can apply transformations on the FlatCurry files before they are passed to the back end which translates the FlatCurry files into Prolog code. These transformation are invoked by the FlatCurry preprocessor `pakcs/bin/fycpp`. Currently, only the FlatCurry file corresponding to the main module can be transformed.

A transformation can be specified as follows:

1. **Options to `pakcs/bin/fcypp`:**

   `--fpopt` Apply functional pattern optimization (see `pakcs/tools/optimize/NonStrictOpt.curry` for details).

   `--compact` Apply code compactification after parsing, i.e., transform the main module and all its imported into one module and delete all non-accessible functions.

   `--compactexport` Similar to `--compact` but delete all functions that are not accessible from the exported functions of the main module.

   `--compactmain:f` Similar to `--compact` but delete all functions that are not accessible from the function "`f`" of the main module.

   `--fcypp cmd` Apply command `cmd` to the main module after parsing. This is useful to integrate your own transformation into the compilation process. Note that the command "`cmd prog`" should perform a transformation on the FlatCurry file `prog.fcy`, i.e., it replaces the FlatCurry file by a new one.

2. **Setting the environment variable `FCYPP`:**
   For instance, setting `FCYPP` by

   ```
   export FCYPP="--fpopt"
   ```

   will apply the functional pattern optimization if programs are compiled and loaded in the PAKCS programming environment.

3. **Putting options into the source code:**
   If the source code contains a line with a comment of the form (the comment must start at the beginning of the line)

   ```
   {-# PAKCS_OPTION_FCYPP <options> #-}
   ```

   then the transformations specified by `<options>` are applied after translating the source code into FlatCurry code. For instance, the functional pattern optimization can be set by the comment

   ```
   {-# PAKCS_OPTION_FCYPP --fpopt #-}
   ```

   in the source code. Note that this comment must be in a single line of the source program. If there are multiple lines containing such comments, only the first one will be considered.

Multiple options: Note that an arbitrary number of transformations can be specified by the methods described above. If several specifications for preprocessing FlatCurry files are used, they are executed in the following order:

1. all transformations specified by the environemnt variable `FCYPP` (from left to right)

2. all transformations specified as command line options of `fcypp` (from left to right)

3. all transformations specified by a comment line in the source code (from left to right)

12 Technical Problems

Due to the fact that Curry is intended to implement distributed systems (see Appendix A.1.3), it might be possible that some technical problems arise due to the use of sockets for implementing these features. Therefore, this section gives some information about the technical requirements of PAKCS and how to solve problems due to these requirements.

There is one fixed port that is used by the implementation of PAKCS:

Port 8766: This port is used by the **Curry Port Name Server** (CPNS) to implement symbolic names for ports in Curry (see Appendix A.1.3). If some other process uses this port on the machine, the distribution facilities defined in the module `Ports` (see Appendix A.1.3) cannot be used.

If these features do not work, you can try to find out whether this port is in use by the shell command "`netstat -a | fgrep 8766`" (or similar).

The CPNS is implemented as a demon listening on its port 8766 in order to serve requests about registering a new symbolic name for a Curry port or asking the physical port number of a Curry port. The demon will be automatically started for the first time on a machine when a user compiles a program using Curry ports. It can also be manually started and terminated by the scripts *pakcshome*/cpns/start and *pakcshome*/cpns/stop. If the demon is already running, the command *pakcshome*/cpns/start does nothing (so it can be always executed before invoking a Curry program using ports).

If you detect any further technical problem, please write to

<div align="center">

`pakcs@curry-language.org`

</div>

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A Libraries of the PAKCS Distribution

The PAKCS distribution comes with an extensive collection of libraries for application programming. The libraries for arithmetic constraints over real numbers, finite domain constraints, ports for concurrent and distributed programming, and meta-programming by representing Curry programs in Curry are described in the following subsection in more detail. The complete set of libraries with all exported types and functions are described in the further subsections. For a more detailed online documentation of all libraries of PAKCS, see http://www.informatik.uni-kiel.de/~pakcs/lib/index.html.

A.1 Constraints, Ports, Meta-Programming

A.1.1 Arithmetic Constraints

The primitive entities for the use of arithmetic constraints are defined in the system module `CLPR` (cf. Section 1.3), i.e., in order to use them, the program must contain the import declaration

```
import CLPR
```

Floating point arithmetic is supported in PAKCS via arithmetic constraints, i.e., the equational constraint "`2.3 +. x =:= 5.5`" is solved by binding `x` to `3.2` (rather than suspending the evaluation of the addition, as in corresponding constraints on integers like "`3+x=:=5`"). All operations related to floating point numbers are suffixed by ".". The following functions and constraints on floating point numbers are supported in PAKCS:

`(+.) :: Float -> Float -> Float`
> Addition on floating point numbers.

`(-.) :: Float -> Float -> Float`
> Subtraction on floating point numbers.

`(*.) :: Float -> Float -> Float`
> Multiplication on floating point numbers.

`(/.) :: Float -> Float -> Float`
> Division on floating point numbers.

`(<.) :: Float -> Float -> Success`
> Comparing two floating point numbers with the "less than" relation.

`(>.) :: Float -> Float -> Success`
> Comparing two floating point numbers with the "greater than" relation.

`(<=.) :: Float -> Float -> Success`
> Comparing two floating point numbers with the "less than or equal" relation.

`(>=.) :: Float -> Float -> Success`
> Comparing two floating point numbers with the "greater than or equal" relation.

```
i2f ::  Int -> Float
```
   Converting an integer number into a floating point number.

As an example, consider a constraint `mortgage` which relates the principal `p`, the lifetime of the mortgage in months `t`, the monthly interest rate `ir`, the monthly repayment `r`, and the outstanding balance at the end of the lifetime `b`. The financial calculations can be defined by the following two rules in Curry (the second rule describes the repeated accumulation of the interest):

```
  import CLPR

  mortgage p t ir r b | t >. 0.0 \& t <=. 1.0  --lifetime not more than 1 month?
                    =  b =:= p *. (1.0 +. t *. ir) -. t*.r
  mortgage p t ir r b | t >. 1.0                --lifetime more than 1 month?
                    =  mortgage (p *. (1.0+.ir)-.r) (t-.1.0) ir r b
```

Then we can calculate the monthly payment for paying back a loan of \$100,000 in 15 years with a monthly interest rate of 1% by solving the goal

```
  mortgage 100000.0 180.0 0.01 r 0.0
```

which yields the solution `r=1200.17`.
Note that only linear arithmetic equalities or inequalities are solved by the constraint solver. Nonlinear constraints like "`x *. x =:= 4.0`" are suspended until they become linear.

A.1.2   Finite Domain Constraints

Finite domain constraints are constraints where all variables can only take a finite number of possible values. For simplicity, the domain of finite domain variables are identified with a subset of the integers, i.e., the type of a finite domain variable is `Int`. The arithmetic operations related to finite domain variables are suffixed by "`#`". The following functions and constraints for finite domain constraint solving are currently supported in PAKCS:[6]

```
domain ::  [Int] -> Int -> Int -> Success
```
   The constraint "`domain [x_1,...,x_n] l u`" is satisfied if the domain of all variables x_i is the interval $[l, u]$.

```
(+#) ::  Int -> Int -> Int
```
   Addition on finite domain values.

```
(-#) ::  Int -> Int -> Int
```
   Subtraction on finite domain values.

```
(*#) ::  Int -> Int -> Int
```
   Multiplication on finite domain values.

```
(=#) ::  Int -> Int -> Success
```
   Equality of finite domain values.

---

[6]Note that this library is based on the corresponding library of SICStus-Prolog but does not implement the complete functionality of the SICStus-Prolog library. However, using the PAKCS interface for external functions (see Appendix E), it is relatively easy to provide the complete functionality.

```
(/=#) ::  Int -> Int -> Success
```
Disequality of finite domain values.

```
(<#) ::  Int -> Int -> Success
```
"less than" relation on finite domain values.

```
(<=#) ::  Int -> Int -> Success
```
"less than or equal" relation on finite domain values.

```
(>#) ::  Int -> Int -> Success
```
"greater than" relation on finite domain values.

```
(>=#) ::  Int -> Int -> Success
```
"greater than or equal" relation on finite domain values.

```
sum ::  [Int] -> (Int -> Int -> Success) -> Int -> Success
```
The constraint "`sum` $[x_1, \ldots, x_n]$ *op* x" is satisfied if all $x_1 + \cdots + x_n$ *op* x is satisfied, where *op* is one of the above finite domain constraint relations (e.g., "`=#`").

```
scalar_product ::  [Int] -> [Int] -> (Int -> Int -> Success) -> Int -> Success
```
The constraint "`scalar_product` $[c_1, \ldots, c_n]$ $[x_1, \ldots, x_n]$ *op* x" is satisfied if all $c_1 x_1 + \cdots + c_n x_n$ *op* x is satisfied, where *op* is one of the above finite domain constraint relations.

```
count ::  Int -> [Int] -> (Int -> Int -> Success) -> Int -> Success
```
The constraint "`count` k $[x_1, \ldots, x_n]$ *op* x" is satisfied if all k *op* x is satisfied, where n is the number of the x_i that are equal to k and *op* is one of the above finite domain constraint relations.

```
all_different ::  [Int] -> Success
```
The constraint "`all_different` $[x_1, \ldots, x_n]$" is satisfied if all x_i have pairwise different values.

```
labeling ::  [LabelingOption] -> [Int] -> Success
```
The constraint "`labeling` *os* $[x_1, \ldots, x_n]$" non-deterministically instantiates all x_i to the values of their domain according to the options *os* (see the module documentation for further details about these options).

These entities are defined in the system module `CLPFD` (cf. Section 1.3), i.e., in order to use it, the program must contain the import declaration

```
import CLPFD
```

As an example, consider the classical "`send+more=money`" problem where each letter must be replaced by a different digit such that this equation is valid and there are no leading zeros. The usual way to solve finite domain constraint problems is to specify the domain of the involved variables followed by a specification of the constraints and the labeling of the constraint variables in order to start the search for solutions. Thus, the "`send+more=money`" problem can be solved as follows:

```
import CLPFD

smm l =
```

```
        l =:= [s,e,n,d,m,o,r,y] &
        domain l 0 9 &
        s ># 0 &
        m ># 0 &
        all_different l  &
                       1000 *# s +# 100 *# e +# 10 *# n +# d
        +#             1000 *# m +# 100 *# o +# 10 *# r +# e
        =# 10000 *# m +# 1000 *# o +# 100 *# n +# 10 *# e +# y &
        labeling [FirstFail] l
        where s,e,n,d,m,o,r,y free
```

Then we can solve this problem by evaluating the goal "`smm [s,e,n,d,m,o,r,y]`" which yields the unique solution {s=9,e=5,n=6,d=7,m=1,o=0,r=8,y=2}.

A.1.3 Ports: Distributed Programming in Curry

To support the development of concurrent and distributed applications, PAKCS supports internal and external ports as described in [12]. Since [12] contains a detailed description of this concept together with various programming examples, we only summarize here the functions and constraints supported for ports in PAKCS.

The basic datatypes, functions, and constraints for ports are defined in the system module `Ports` (cf. Section 1.3), i.e., in order to use ports, the program must contain the import declaration

```
  import Ports
```

This declaration includes the following entities in the program:

`Port a`

> This is the datatype of a port to which one can send messages of type `a`.

`openPort ::  Port a -> [a] -> Success`

> The constraint "`openPort p s`" establishes a new *internal port* `p` with an associated message stream `s`. `p` and `s` must be unbound variables, otherwise the constraint fails (and causes a runtime error).

`send ::  a -> Port a -> Success`

> The constraint "`send m p`" is satisfied if `p` is constrained to contain the message `m`, i.e., `m` will be sent to the port `p` so that it appears in the corresponding stream.

`doSend ::  a -> Port a -> IO ()`

> The I/O action "`doSend m p`" solves the constraint "`send m p`" and returns nothing.

`openNamedPort ::  String -> IO [a]`

> The I/O action "`openNamedPort n`" opens a new *external port* with symbolic name `n` and returns the associated stream of messages.

`connectPort ::  String -> IO (Port a)`

> The I/O action "`connectPort n`" returns a port with symbolic name `n` (i.e., `n` must have the form "*portname@machine*") to which one can send messages by the `send` constraint. Currently,

no dynamic type checking is done for external ports, i.e., sending messages of the wrong type to a port might lead to a failure of the receiver.

Restrictions: Every expression, possibly containing logical variables, can be sent to a port. However, as discussed in [12], port communication is strict, i.e., the expression is evaluated to normal form before sending it by the constraint `send`. Furthermore, if messages containing logical variables are sent to *external ports*, the behavior is as follows:

1. The sender waits until all logical variables in the message have been bound by the receiver.

2. The binding of a logical variable received by a process is sent back to the sender of this logical variable only if it is bound to a *ground* term, i.e., as long as the binding contains logical variables, the sender is not informed about the binding and, therefore, the sender waits.

External ports on local machines: The implementation of external ports assumes that the host machine running the application is connected to the Internet (i.e., it uses the standard IP address of the host machine for message sending). If this is not the case and the application should be tested by using external ports only on the local host without a connection to the Internet, the environment variable "`PAKCS_LOCALHOST`" must be set to "`yes`" *before PAKCS is started*. In this case, the IP address `127.0.0.1` and the hostname "`localhost`" are used for identifying the local machine.

Selection of Unix sockets for external ports: The implementation of ports uses sockets to communicate messages sent to external ports. Thus, if a Curry program uses the I/O action `openNamedPort` to establish an externally visible server, PAKCS selects a Unix socket for the port communication. Usually, a free socket is selected by the operating system. If the socket number should be fixed in an application (e.g., because of the use of firewalls that allow only communication over particular sockets), then one can set the environment variable "`PAKCS_SOCKET`" to a distinguished socket number before PAKCS is started. This has the effect that PAKCS uses only this socket number for communication (even for several external ports used in the same application program).

Debugging: To debug distributed systems, it is sometimes helpful to see all messages sent to external ports. This is supported by the environment variable "`PAKCS_TRACEPORTS`". If this variable is set to "`yes`" *before PAKCS is started*, then all connections to external ports and all messages sent and received on external ports are printed on the standard error stream.

A.1.4 AbstractCurry and FlatCurry: Meta-Programming in Curry

To support meta-programming, i.e., the manipulation of Curry programs in Curry, there are system modules `AbstractCurry.Types` and `FlatCurry` which define datatypes for the representation of Curry programs. `AbstractCurry.Types` is a more direct representation of a Curry program, whereas `FlatCurry` is a simplified representation where local function definitions are replaced by global definitions (i.e., lambda lifting has been performed) and pattern matching is translated into explicit

case/or expressions. Thus, `FlatCurry` can be used for more back-end oriented program manipulations (or, for writing new back ends for Curry), whereas `AbstractCurry.Types` is intended for manipulations of programs that are more oriented towards the source program.

There are predefined I/O actions to read AbstractCurry and FlatCurry programs: `AbstractCurry.Files.readCurry`) and `FlatCurry.readFlatCurry`). These actions parse the corresponding source program and return a data term representing this program (according to the definitions in the modules `AbstractCurry.Types` and `FlatCurry`).

Since all datatypes are explained in detail in these modules, we refer to the online documentation[7] of these modules.

As an example, consider a program file "`test.curry`" containing the following two lines:

```
rev []     = []
rev (x:xs) = (rev xs) ++ [x]
```

Then the I/O action (`FlatCurry.readFlatCurry "test"`) returns the following term:

```
(Prog "test"
 ["Prelude"]
 []
 [Func ("test","rev") 1 Public
       (FuncType (TCons ("Prelude","[]") [(TVar 0)])
                 (TCons ("Prelude","[]") [(TVar 0)]))
       (Rule [0]
          (Case Flex (Var 1)
             [Branch (Pattern ("Prelude","[]") [])
                 (Comb ConsCall ("Prelude","[]") []),
              Branch (Pattern ("Prelude",":") [2,3])
                 (Comb FuncCall ("Prelude","++")
                       [Comb FuncCall ("test","rev") [Var 3],
                        Comb ConsCall ("Prelude",":")
                              [Var 2,Comb ConsCall ("Prelude","[]") []]
                       ])
             ]))]
  []
 )
```

A.2 General Libraries

A.2.1 Library AllSolutions

This module contains a collection of functions for obtaining lists of solutions to constraints. These operations are useful to encapsulate non-deterministic operations between I/O actions in order to connects the worlds of logic and functional programming and to avoid non-determinism failures on the I/O level.

In contrast the "old" concept of encapsulated search (which could be applied to any subexpression in a computation), the operations to encapsulate search in this module are I/O actions in order to

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[7]http://www.informatik.uni-kiel.de/~pakcs/lib/CDOC/FlatCurry.html and http://www.informatik.uni-kiel.de/~pakcs/lib/CDOC/AbstractCurry.Types.html

avoid some anomalies in the old concept.

Exported types:

`data SearchTree`

    A search tree for representing search structures.

  Exported constructors:

- `SearchBranch :: [(b,SearchTree a b)]` $\rightarrow$ `SearchTree a b`

- `Solutions :: [a]` $\rightarrow$ `SearchTree a b`

Exported functions:

`getAllSolutions :: (a` $\rightarrow$ `Success)` $\rightarrow$ `IO [a]`

    Gets all solutions to a constraint (currently, via an incomplete depth-first left-to-right strategy). Conceptually, all solutions are computed on a copy of the constraint, i.e., the evaluation of the constraint does not share any results. Moreover, this evaluation suspends if the constraints contain unbound variables. Similar to Prolog's findall.

`getAllValues :: a` $\rightarrow$ `IO [a]`

    Gets all values of an expression. Since this is based on `getAllSolutions`, it inherits the same restrictions.

`getOneSolution :: (a` $\rightarrow$ `Success)` $\rightarrow$ `IO (Maybe a)`

    Gets one solution to a constraint (currently, via an incomplete left-to-right strategy). Returns Nothing if the search space is finitely failed.

`getOneValue :: a` $\rightarrow$ `IO (Maybe a)`

    Gets one value of an expression (currently, via an incomplete left-to-right strategy). Returns Nothing if the search space is finitely failed.

`getAllFailures :: a` $\rightarrow$ `(a` $\rightarrow$ `Success)` $\rightarrow$ `IO [a]`

    Returns a list of values that do not satisfy a given constraint.

`getSearchTree :: [a]` $\rightarrow$ `(b` $\rightarrow$ `Success)` $\rightarrow$ `IO (SearchTree b a)`

    Computes a tree of solutions where the first argument determines the branching level of the tree. For each element in the list of the first argument, the search tree contains a branch node with a child tree for each value of this element. Moreover, evaluations of elements in the branch list are shared within corresponding subtrees.

A.2.2 Library Assertion

This module defines the datatype and operations for the Curry module tester "currytest".

Exported types:

`data Assertion`

> Datatype for defining test cases.

> *Exported constructors:*

`data ProtocolMsg`

> The messages sent to the test GUI. Used by the currytest tool.

> *Exported constructors:*

- `TestModule :: String → ProtocolMsg`

- `TestCase :: String → Bool → ProtocolMsg`

- `TestFinished :: ProtocolMsg`

- `TestCompileError :: ProtocolMsg`

Exported functions:

`assertTrue :: String → Bool → Assertion ()`

> (`assertTrue s b`) asserts (with name `s`) that `b` must be true.

`assertEqual :: String → a → a → Assertion a`

> (`assertEqual s e1 e2`) asserts (with name `s`) that `e1` and `e2` must be equal (w.r.t. `==`).

`assertValues :: String → a → [a] → Assertion a`

> (`assertValues s e vs`) asserts (with name `s`) that `vs` is the multiset of all values of `e`. All values of `e` are compared with the elements in `vs` w.r.t. `==`.

`assertSolutions :: String → (a → Success) → [a] → Assertion a`

> (`assertSolutions s c vs`) asserts (with name `s`) that constraint abstraction `c` has the multiset of solutions `vs`. The solutions of `c` are compared with the elements in `vs` w.r.t. `==`.

`assertIO :: String → IO a → a → Assertion a`

> (`assertIO s a r`) asserts (with name `s`) that I/O action `a` yields the result value `r`.

`assertEqualIO :: String → IO a → IO a → Assertion a`

> (`assertEqualIO s a1 a2`) asserts (with name `s`) that I/O actions `a1` and `a2` yield equal (w.r.t. `==`) results.

```
seqStrActions :: IO (String,Bool) → IO (String,Bool) → IO (String,Bool)
```

Combines two actions and combines their results. Used by the currytest tool.

```
checkAssertion :: String → ((String,Bool) → IO (String,Bool)) → Assertion a →
IO (String,Bool)
```

Executes and checks an assertion, and process the result by an I/O action. Used by the currytest tool.

```
writeAssertResult :: (String,Bool) → IO Int
```

Prints the results of assertion checking. If failures occurred, the return code is positive. Used by the currytest tool.

```
showTestMod :: Int → String → IO ()
```

Sends message to GUI for showing test of a module. Used by the currytest tool.

```
showTestCase :: Int → (String,Bool) → IO (String,Bool)
```

Sends message to GUI for showing result of executing a test case. Used by the currytest tool.

```
showTestEnd :: Int → IO ()
```

Sends message to GUI for showing end of module test. Used by the currytest tool.

```
showTestCompileError :: Int → IO ()
```

Sends message to GUI for showing compilation errors in a module test. Used by the currytest tool.

A.2.3 Library Char

Library with some useful functions on characters.

Exported functions:

```
isAscii :: Char → Bool
```

Returns true if the argument is an ASCII character.

```
isLatin1 :: Char → Bool
```

Returns true if the argument is an Latin-1 character.

```
isAsciiLower :: Char → Bool
```

Returns true if the argument is an ASCII lowercase letter.

```
isAsciiUpper :: Char → Bool
```

Returns true if the argument is an ASCII uppercase letter.

`isControl :: Char → Bool`

>   Returns true if the argument is a control character.

`isUpper :: Char → Bool`

>   Returns true if the argument is an uppercase letter.

`isLower :: Char → Bool`

>   Returns true if the argument is an lowercase letter.

`isAlpha :: Char → Bool`

>   Returns true if the argument is a letter.

`isDigit :: Char → Bool`

>   Returns true if the argument is a decimal digit.

`isAlphaNum :: Char → Bool`

>   Returns true if the argument is a letter or digit.

`isBinDigit :: Char → Bool`

>   Returns true if the argument is a binary digit.

`isOctDigit :: Char → Bool`

>   Returns true if the argument is an octal digit.

`isHexDigit :: Char → Bool`

>   Returns true if the argument is a hexadecimal digit.

`isSpace :: Char → Bool`

>   Returns true if the argument is a white space.

`toUpper :: Char → Char`

>   Converts lowercase into uppercase letters.

`toLower :: Char → Char`

>   Converts uppercase into lowercase letters.

`digitToInt :: Char → Int`

>   Converts a (hexadecimal) digit character into an integer.

`intToDigit :: Int → Char`

>   Converts an integer into a (hexadecimal) digit character.

A.2.4   Library CHR

A representation of CHR rules in Curry, an interpreter for CHR rules based on the refined operational semantics of Duck et al. (ICLP 2004), and a compiler into CHR(Prolog).

To use CHR(Curry), specify the CHR(Curry) rules in a Curry program, load it, add module `CHR` and interpret or compile the rules with `runCHR` or `compileCHR`, respectively. This can be done in one shot with

```
> pakcs :l MyRules :add CHR :eval 'compileCHR "MyCHR" [rule1,rule2]' :q
```

Exported types:

`data CHR`

      The basic data type of Constraint Handling Rules.

    Exported constructors:

`data Goal`

      A CHR goal is a list of CHR constraints (primitive or user-defined).

    Exported constructors:

Exported functions:

`(<=>) :: Goal a b → Goal a b → CHR a b`

      Simplification rule.

`(==>) :: Goal a b → Goal a b → CHR a b`

      Propagation rule.

`(\\) :: Goal a b → CHR a b → CHR a b`

      Simpagation rule: if rule is applicable, the first constraint is kept and the second constraint is deleted.

`(|>) :: CHR a b → Goal a b → CHR a b`

      A rule with a guard.

`(/\) :: Goal a b → Goal a b → Goal a b`

      Conjunction of CHR goals.

`true :: Goal a b`

      The always satisfiable CHR constraint.

`fail :: Goal a b`

The always failing constraint.

`andCHR :: [Goal a b] → Goal a b`

Join a list of CHR goals into a single CHR goal (by conjunction).

`allCHR :: (a → Goal b c) → [a] → Goal b c`

Is a given constraint abstraction satisfied by all elements in a list?

`chrsToGoal :: [a] → Goal b a`

Transforms a list of CHR constraints into a CHR goal.

`toGoal1 :: (a → b) → a → Goal c b`

Transform unary CHR constraint into a CHR goal.

`toGoal2 :: (a → b → c) → a → b → Goal d c`

Transforms binary CHR constraint into a CHR goal.

`toGoal3 :: (a → b → c → d) → a → b → c → Goal e d`

Transforms a ternary CHR constraint into a CHR goal.

`toGoal4 :: (a → b → c → d → e) → a → b → c → d → Goal f e`

Transforms a CHR constraint of arity 4 into a CHR goal.

`toGoal5 :: (a → b → c → d → e → f) → a → b → c → d → e → Goal g f`

Transforms a CHR constraint of arity 5 into a CHR goal.

`toGoal6 :: (a → b → c → d → e → f → g) → a → b → c → d → e → f → Goal h g`

Transforms a CHR constraint of arity 6 into a CHR goal.

`(.=.) :: a → a → Goal a b`

Primitive syntactic equality on arbitrary terms.

`(./=.) :: a → a → Goal a b`

Primitive syntactic disequality on ground(!) terms.

`(.<=.) :: a → a → Goal a b`

Primitive less-or-equal constraint.

`(.>=.) :: a → a → Goal a b`

Primitive greater-or-equal constraint.

`(.<.) :: a → a → Goal a b`

Primitive less-than constraint.

`(.>.) :: a → a → Goal a b`

Primitive greater-than constraint.

`ground :: a → Goal a b`

Primitive groundness constraint (useful for guards).

`nonvar :: a → Goal a b`

Primitive nonvar constraint (useful for guards).

`anyPrim :: (() → Success) → Goal a b`

Embed user-defined primitive constraint.

`solveCHR :: [[a] → CHR a b] → Goal a b → Success`

Interpret CHR rules (parameterized over domain variables) for a given CHR goal (second argument) and embed this as a constraint solver in Curry. If user-defined CHR constraints remain after applying all CHR rules, a warning showing the residual constraints is issued.

`runCHR :: [[a] → CHR a b] → Goal a b → [b]`

Interpret CHR rules (parameterized over domain variables) for a given CHR goal (second argument) and return the remaining CHR constraints.

`runCHRwithTrace :: [[a] → CHR a b] → Goal a b → [b]`

Interpret CHR rules (parameterized over domain variables) for a given CHR goal (second argument) and return the remaining CHR constraints. Trace also the active and passive constraints as well as the applied rule number during computation.

`compileCHR :: String → [[a] → CHR a b] → IO ()`

Compile a list of CHR(Curry) rules into CHR(Prolog) and store its interface in a Curry program (name given as first argument).

`chr2success :: Goal a b → Success`

Transforms a primitive CHR constraint into a Curry constraint. Used in the generated CHR(Prolog) code to evaluated primitive constraints.

A.2.5 Library CHRcompiled

This module defines the structure of CHR goals and some constructors to be used in compiled CHR(Curry) rules. Furthermore, it defines an operation `solveCHR` to solve a CHR goal as a constraint.
This module is imported in compiled CHR(Curry) programs, compare library `CHR`.

Exported types:

`data Goal`

> A typed CHR goal. Since types are not present at run-time in compiled, we use a phantom type to parameterize goals over CHR constraints. The argument of the goal is the constraint implementing the goal with the compiled CHR(Prolog) program.

> *Exported constructors:*

> - `Goal :: Success → Goal a`

Exported functions:

`(/\) :: Goal a → Goal a → Goal a`

> Conjunction of CHR goals.

`true :: Goal a`

> The always satisfiable CHR constraint.

`fail :: Goal a`

> The always failing constraint.

`andCHR :: [Goal a] → Goal a`

> Join a list of CHR goals into a single CHR goal (by conjunction).

`allCHR :: (a → Goal b) → [a] → Goal b`

> Is a given constraint abstraction satisfied by all elements in a list?

`solveCHR :: Goal a → Success`

> Evaluate a given CHR goal and embed this as a constraint in Curry. Note: due to limitations of the CHR(Prolog) implementation, no warning is issued if residual constraints remain after the evaluation.

`warnSuspendedConstraints :: Bool → Success`

> Primitive operation that issues a warning if there are some suspended constraints in the CHR constraint store. If the argument is true, then all suspended constraints are shown, otherwise only the first one.

A.2.6   Library CLP.FD

Library for finite domain constraint solving.

An FD problem is specified as an expression of type `FDConstr` using the constraints and expressions offered in this library. FD variables are created by the operation `domain`. An FD problem is solved by calling `solveFD` with labeling options, the FD variables whose values should be included in the output, and a constraint. Hence, the typical program structure to solve an FD problem is as follows:

```
main :: [Int]
main =
  let fdvars  = take n (domain u o)
      fdmodel = {description of FD problem}
   in solveFD {options} fdvars fdmodel
```

where `n` are the number of variables and `[u..o]` is the range of their possible values.

Exported types:

`data FDRel`

> Possible relations between FD values.

Exported constructors:

- `Equ :: FDRel`

  `Equ`

  – Equal

- `Neq :: FDRel`

  `Neq`

  – Not equal

- `Lt :: FDRel`

  `Lt`

  – Less than

- `Leq :: FDRel`

  `Leq`

  – Less than or equal

- `Gt :: FDRel`

  `Gt`

  – Greater than

- Geq :: FDRel

  Geq

  – Greater than or equal

data Option

This datatype defines options to control the instantiation of FD variables in the solver (`solveFD`).

Exported constructors:

- LeftMost :: Option

  LeftMost

  – The leftmost variable is selected for instantiation (default)

- FirstFail :: Option

  FirstFail

  – The leftmost variable with the smallest domain is selected (also known as first-fail principle)

- FirstFailConstrained :: Option

  FirstFailConstrained

  – The leftmost variable with the smallest domain and the most constraints on it is selected.

- Min :: Option

  Min

  – The leftmost variable with the smalled lower bound is selected.

- Max :: Option

  Max

  – The leftmost variable with the greatest upper bound is selected.

- Step :: Option

  Step

  – Make a binary choice between `x=#b` and `x/=#b` for the selected variable `x` where `b` is the lower or upper bound of `x` (default).

- Enum :: Option

  Enum

  – Make a multiple choice for the selected variable for all the values in its domain.

- `Bisect :: Option`

  `Bisect`

  – Make a binary choice between `x<=#m` and `x>#m` for the selected variable `x` where `m` is the midpoint of the domain `x` (also known as domain splitting).

- `Up :: Option`

  `Up`

  – The domain is explored for instantiation in ascending order (default).

- `Down :: Option`

  `Down`

  – The domain is explored for instantiation in descending order.

- `All :: Option`

  `All`

  – Enumerate all solutions by backtracking (default).

- `Minimize :: Int → Option`

  `Minimize v`

  – Find a solution that minimizes the domain variable `v` (using a branch-and-bound algorithm).

- `Maximize :: Int → Option`

  `Maximize v`

  – Find a solution that maximizes the domain variable `v` (using a branch-and-bound algorithm).

- `Assumptions :: Int → Option`

  `Assumptions x`

  – The variable `x` is unified with the number of choices made by the selected enumeration strategy when a solution is found.

`data FDExpr`

Exported constructors:

`data FDConstr`

Exported constructors:

Exported functions:

`domain :: Int → Int → [FDExpr]`

Operations to construct basic constraints. Returns infinite list of FDVars with a given domain.

`fd :: Int → FDExpr`

Represent an integer value as an FD expression.

`(+#) :: FDExpr → FDExpr → FDExpr`

Addition of FD expressions.

`(-#) :: FDExpr → FDExpr → FDExpr`

Subtraction of FD expressions.

`(*#) :: FDExpr → FDExpr → FDExpr`

Multiplication of FD expressions.

`(=#) :: FDExpr → FDExpr → FDConstr`

Equality of FD expressions.

`(/=#) :: FDExpr → FDExpr → FDConstr`

Disequality of FD expressions.

`(<#) :: FDExpr → FDExpr → FDConstr`

"Less than" constraint on FD expressions.

`(<=#) :: FDExpr → FDExpr → FDConstr`

"Less than or equal" constraint on FD expressions.

`(>#) :: FDExpr → FDExpr → FDConstr`

"Greater than" constraint on FD expressions.

`(>=#) :: FDExpr → FDExpr → FDConstr`

"Greater than or equal" constraint on FD expressions.

`true :: FDConstr`

The always satisfied FD constraint.

`(/\) :: FDConstr → FDConstr → FDConstr`

Conjunction of FD constraints.

`andC :: [FDConstr] → FDConstr`

Conjunction of a list of FD constraints.

`allC :: (a → FDConstr) → [a] → FDConstr`

Maps a constraint abstraction to a list of FD constraints and joins them.

`allDifferent :: [FDExpr] → FDConstr`

"All different" constraint on FD variables.

`sum :: [FDExpr] → FDRel → FDExpr → FDConstr`

Relates the sum of FD variables with some integer of FD variable.

`scalarProduct :: [FDExpr] → [FDExpr] → FDRel → FDExpr → FDConstr`

(`scalarProduct cs vs relop v`) is satisfied if (`sum (cs*vs) relop v`) is satisfied. The first argument must be a list of integers. The other arguments are as in `sum`.

`count :: FDExpr → [FDExpr] → FDRel → FDExpr → FDConstr`

(`count v vs relop c`) is satisfied if (`n relop c`), where `n` is the number of elements in the list of FD variables `vs` that are equal to `v`, is satisfied. The first argument must be an integer. The other arguments are as in `sum`.

`solveFD :: [Option] → [FDExpr] → FDConstr → [Int]`

Computes (non-deterministically) a solution for the FD variables (second argument) w.r.t. constraint (third argument). The first argument contains options to control the labeling/instantiation of FD variables.

A.2.7 Library CLPFD

Library for finite domain constraint solving.
The general structure of a specification of an FD problem is as follows:
domain*constraint & fd*constraint & `labeling`
where:
domain_`constraint` specifies the possible range of the FD variables (see constraint `domain`)
fd_`constraint` specifies the constraint to be satisfied by a valid solution (see constraints #+, #-, allDifferent, etc below)
`labeling` is a labeling function to search for a concrete solution.
Note: This library is based on the corresponding library of Sicstus-Prolog but does not implement the complete functionality of the Sicstus-Prolog library. However, using the PAKCS interface for external functions, it is relatively easy to provide the complete functionality.

Exported types:

`data Constraint`

> A datatype to represent reifyable constraints.

Exported constructors:

`data LabelingOption`

> This datatype contains all options to control the instantiated of FD variables with the enumeration constraint `labeling`.

Exported constructors:

- `LeftMost :: LabelingOption`

  `LeftMost`

  - The leftmost variable is selected for instantiation (default)

- `FirstFail :: LabelingOption`

  `FirstFail`

  - The leftmost variable with the smallest domain is selected (also known as first-fail principle)

- `FirstFailConstrained :: LabelingOption`

  `FirstFailConstrained`

  - The leftmost variable with the smallest domain and the most constraints on it is selected.

- `Min :: LabelingOption`

  `Min`

  - The leftmost variable with the smalled lower bound is selected.

- `Max :: LabelingOption`

  `Max`

  - The leftmost variable with the greatest upper bound is selected.

- `Step :: LabelingOption`

  `Step`

  - Make a binary choice between `x=#b` and `x/=#b` for the selected variable `x` where `b` is the lower or upper bound of `x` (default).

- `Enum :: LabelingOption`

  `Enum`

– Make a multiple choice for the selected variable for all the values in its domain.

- `Bisect :: LabelingOption`

  `Bisect`

    – Make a binary choice between `x<=#m` and `x>#m` for the selected variable `x` where `m` is the midpoint of the domain `x` (also known as domain splitting).

- `Up :: LabelingOption`

  `Up`

    – The domain is explored for instantiation in ascending order (default).

- `Down :: LabelingOption`

  `Down`

    – The domain is explored for instantiation in descending order.

- `All :: LabelingOption`

  `All`

    – Enumerate all solutions by backtracking (default).

- `Minimize :: Int → LabelingOption`

  `Minimize v`

    – Find a solution that minimizes the domain variable `v` (using a branch-and-bound algorithm).

- `Maximize :: Int → LabelingOption`

  `Maximize v`

    – Find a solution that maximizes the domain variable `v` (using a branch-and-bound algorithm).

- `Assumptions :: Int → LabelingOption`

  `Assumptions x`

    – The variable `x` is unified with the number of choices made by the selected enumeration strategy when a solution is found.

Exported functions:

`domain :: [Int] → Int → Int → Success`

   Constraint to specify the domain of all finite domain variables.

`(+#) :: Int → Int → Int`

Addition of FD variables.

`(-#) :: Int → Int → Int`

Subtraction of FD variables.

`(*#) :: Int → Int → Int`

Multiplication of FD variables.

`(=#) :: Int → Int → Success`

Equality of FD variables.

`(/=#) :: Int → Int → Success`

Disequality of FD variables.

`(<#) :: Int → Int → Success`

"Less than" constraint on FD variables.

`(<=#) :: Int → Int → Success`

"Less than or equal" constraint on FD variables.

`(>#) :: Int → Int → Success`

"Greater than" constraint on FD variables.

`(>=#) :: Int → Int → Success`

"Greater than or equal" constraint on FD variables.

`(#=#) :: Int → Int → Constraint`

Reifyable equality constraint on FD variables.

`(#/=#) :: Int → Int → Constraint`

Reifyable inequality constraint on FD variables.

`(#<#) :: Int → Int → Constraint`

Reifyable "less than" constraint on FD variables.

`(#<=#) :: Int → Int → Constraint`

Reifyable "less than or equal" constraint on FD variables.

`(#>#) :: Int → Int → Constraint`

Reifyable "greater than" constraint on FD variables.

`(#>=#) :: Int → Int → Constraint`

Reifyable "greater than or equal" constraint on FD variables.

`neg :: Constraint → Constraint`

The resulting constraint is satisfied if both argument constraints are satisfied.

`(#/\#) :: Constraint → Constraint → Constraint`

The resulting constraint is satisfied if both argument constraints are satisfied.

`(#\/#) :: Constraint → Constraint → Constraint`

The resulting constraint is satisfied if both argument constraints are satisfied.

`(#=>#) :: Constraint → Constraint → Constraint`

The resulting constraint is satisfied if the first argument constraint do not hold or both argument constraints are satisfied.

`(#<=>#) :: Constraint → Constraint → Constraint`

The resulting constraint is satisfied if both argument constraint are either satisfied and do not hold.

`solve :: Constraint → Success`

Solves a reified constraint.

`sum :: [Int] → (Int → Int → Success) → Int → Success`

Relates the sum of FD variables with some integer of FD variable.

`scalarProduct :: [Int] → [Int] → (Int → Int → Success) → Int → Success`

(scalarProduct cs vs relop v) is satisfied if ((cs*vs) relop v) is satisfied. The first argument must be a list of integers. The other arguments are as in `sum`.

`count :: Int → [Int] → (Int → Int → Success) → Int → Success`

(count v vs relop c) is satisfied if (n relop c), where n is the number of elements in the list of FD variables vs that are equal to v, is satisfied. The first argument must be an integer. The other arguments are as in `sum`.

`allDifferent :: [Int] → Success`

"All different" constraint on FD variables.

`all_different :: [Int] → Success`

For backward compatibility. Use `allDifferent`.

`indomain :: Int → Success`

Instantiate a single FD variable to its values in the specified domain.

`labeling :: [LabelingOption] → [Int] → Success`

Instantiate FD variables to their values in the specified domain.

A.2.8 Library CLPR

Library for constraint programming with arithmetic constraints over reals.

Exported functions:

(+.) :: Float $\to$ Float $\to$ Float

    Addition on floats in arithmetic constraints.

(-.) :: Float $\to$ Float $\to$ Float

    Subtraction on floats in arithmetic constraints.

(*.) :: Float $\to$ Float $\to$ Float

    Multiplication on floats in arithmetic constraints.

(/.) :: Float $\to$ Float $\to$ Float

    Division on floats in arithmetic constraints.

(<.) :: Float $\to$ Float $\to$ Success

    "Less than" constraint on floats.

(>.) :: Float $\to$ Float $\to$ Success

    "Greater than" constraint on floats.

(<=.) :: Float $\to$ Float $\to$ Success

    "Less than or equal" constraint on floats.

(>=.) :: Float $\to$ Float $\to$ Success

    "Greater than or equal" constraint on floats.

i2f :: Int $\to$ Float

    Conversion function from integers to floats. Rigid in the first argument, i.e., suspends until the first argument is ground.

minimumFor :: (a $\to$ Success) $\to$ (a $\to$ Float) $\to$ a

    Computes the minimum with respect to a given constraint. (minimumFor g f) evaluates to x if (g x) is satisfied and (f x) is minimal. The evaluation fails if such a minimal value does not exist. The evaluation suspends if it contains unbound non-local variables.

minimize :: (a $\to$ Success) $\to$ (a $\to$ Float) $\to$ a $\to$ Success

    Minimization constraint. (minimize g f x) is satisfied if (g x) is satisfied and (f x) is minimal. The evaluation suspends if it contains unbound non-local variables.

maximumFor :: (a $\to$ Success) $\to$ (a $\to$ Float) $\to$ a

Computes the maximum with respect to a given constraint. (maximumFor g f) evaluates to x if (g x) is satisfied and (f x) is maximal. The evaluation fails if such a maximal value does not exist. The evaluation suspends if it contains unbound non-local variables.

`maximize :: (a → Success) → (a → Float) → a → Success`

Maximization constraint. (maximize g f x) is satisfied if (g x) is satisfied and (f x) is maximal. The evaluation suspends if it contains unbound non-local variables.

A.2.9 Library CLPB

This library provides a Boolean Constraint Solver based on BDDs.

Exported types:

`data Boolean`

Exported constructors:

Exported functions:

`true :: Boolean`

The always satisfied constraint

`false :: Boolean`

The never satisfied constraint

`neg :: Boolean → Boolean`

Result is true iff argument is false.

`(.&&) :: Boolean → Boolean → Boolean`

Result is true iff both arguments are true.

`(.||) :: Boolean → Boolean → Boolean`

Result is true iff at least one argument is true.

`(./=) :: Boolean → Boolean → Boolean`

Result is true iff exactly one argument is true.

`(.==) :: Boolean → Boolean → Boolean`

Result is true iff both arguments are equal.

`(.<=) :: Boolean → Boolean → Boolean`

Result is true iff the first argument implies the second.

`(.>=) :: Boolean → Boolean → Boolean`

> Result is true iff the second argument implies the first.

`(.<) :: Boolean → Boolean → Boolean`

> Result is true iff the first argument is false and the second is true.

`(.>) :: Boolean → Boolean → Boolean`

> Result is true iff the first argument is true and the second is false.

`count :: [Boolean] → [Int] → Boolean`

> Result is true iff the count of valid constraints in the first list is an element of the second list.

`exists :: Boolean → Boolean → Boolean`

> Result is true, if the first argument is a variable which can be instantiated such that the second argument is true.

`satisfied :: Boolean → Success`

> Checks the consistency of the constraint with regard to the accumulated constraints, and, if the check succeeds, tells the constraint.

`check :: Boolean → Bool`

> Asks whether the argument (or its negation) is now entailed by the accumulated constraints. Fails if it is not.

`bound :: [Boolean] → Success`

> Instantiates given variables with regard to the accumulated constraints.

`simplify :: Boolean → Boolean`

> Simplifies the argument with regard to the accumulated constraints.

`evaluate :: Boolean → Bool`

> Evaluates the argument with regard to the accumulated constraints.

A.2.10 Library Combinatorial

A collection of common non-deterministic and/or combinatorial operations. Many operations are intended to operate on sets. The representation of these sets is not hidden; rather sets are represented as lists. Ideally these lists contains no duplicate elements and the order of their elements cannot be observed. In practice, these conditions are not enforced.

Exported functions:

`permute :: [a] → [a]`

> Compute any permutation of a list. For example, [1,2,3,4] may give [1,3,4,2].

`subset :: [a] → [a]`

> Compute any sublist of a list. The sublist contains some of the elements of the list in the same order. For example, [1,2,3,4] may give [1,3], and [1,2,3] gives [1,2,3], [1,2], [1,3], [1], [2,3], [2], [3], or [].

`splitSet :: [a] → ([a],[a])`

> Split a list into any two sublists. For example, [1,2,3,4] may give ([1,3,4],[2]).

`sizedSubset :: Int → [a] → [a]`

> Compute any sublist of fixed length of a list. Similar to `subset`, but the length of the result is fixed.

`partition :: [a] → [[a]]`

> Compute any partition of a list. The output is a list of non-empty lists such that their concatenation is a permutation of the input list. No guarantee is made on the order of the arguments in the output. For example, [1,2,3,4] may give [[4],[2,3],[1]], and [1,2,3] gives [[1,2,3]], [[2,3],[1]], [[1,3],[2]], [[3],[1,2]], or [[3],[2],[1]].

A.2.11 Library Constraint

Some useful operations for constraint programming.

Exported functions:

`(<:) :: a → a → Success`

> Less-than on ground data terms as a constraint.

`(>:) :: a → a → Success`

> Greater-than on ground data terms as a constraint.

`(<=:) :: a → a → Success`

> Less-or-equal on ground data terms as a constraint.

`(>=:) :: a → a → Success`

> Greater-or-equal on ground data terms as a constraint.

`andC :: [Success] → Success`

> Evaluates the conjunction of a list of constraints.

`orC :: [Success] → Success`

Evaluates the disjunction of a list of constraints.

`allC :: (a → Success) → [a] → Success`

Is a given constraint abstraction satisfied by all elements in a list?

`anyC :: (a → Success) → [a] → Success`

Is there an element in a list satisfying a given constraint?

A.2.12 Library CPNS

Implementation of a Curry Port Name Server based on raw sockets. It is used to implement the library Ports for distributed programming with ports.

Exported functions:

`cpnsStart :: IO ()`

Starts the "Curry Port Name Server" (CPNS) running on the local machine. The CPNS is responsible to resolve symbolic names for ports into physical socket numbers so that a port can be reached under its symbolic name from any machine in the world.

`cpnsShow :: IO ()`

Shows all registered ports at the local CPNS demon (in its logfile).

`cpnsStop :: IO ()`

Terminates the local CPNS demon

`registerPort :: String → Int → Int → IO ()`

Registers a symbolic port at the local host.

`getPortInfo :: String → String → IO (Int,Int)`

Gets the information about a symbolic port at some host.

`unregisterPort :: String → IO ()`

Unregisters a symbolic port at the local host.

`cpnsAlive :: Int → String → IO Bool`

Tests whether the CPNS demon at a host is alive.

`main :: IO ()`

Main function for CPNS demon. Check arguments and execute command.

A.2.13 Library CSV

Library for reading/writing files in CSV format. Files in CSV (comma separated values) format can be imported and exported by most spreadsheed and database applications.

Exported functions:

`writeCSVFile :: String → [[String]] → IO ()`

>   Writes a list of records (where each record is a list of strings) into a file in CSV format.

`showCSV :: [[String]] → String`

>   Shows a list of records (where each record is a list of strings) as a string in CSV format.

`readCSVFile :: String → IO [[String]]`

>   Reads a file in CSV format and returns the list of records (where each record is a list of strings).

`readCSVFileWithDelims :: String → String → IO [[String]]`

>   Reads a file in CSV format and returns the list of records (where each record is a list of strings).

`readCSV :: String → [[String]]`

>   Reads a string in CSV format and returns the list of records (where each record is a list of strings).

`readCSVWithDelims :: String → String → [[String]]`

>   Reads a string in CSV format and returns the list of records (where each record is a list of strings).

A.2.14 Library Database

Library for accessing and storing data in databases. The contents of a database is represented in this library as dynamic predicates that are defined by facts than can change over time and can be persistently stored. All functions in this library distinguishes between *queries* that access the database and *transactions* that manipulates data in the database. Transactions have a monadic structure. Both queries and transactions can be executed as I/O actions. However, arbitrary I/O actions cannot be embedded in transactions.

A dynamic predicate `p` with arguments of type `t1,...,tn` must be declared by:

```
p ::  t1 -> ...  -> tn -> Dynamic
p = dynamic
```

A dynamic predicate where all facts should be persistently stored in the directory `DIR` must be declared by:

```
p ::  t1 -> ...  -> tn -> Dynamic
p = persistent "file:DIR"
```

Exported types:

`data Query`

> Abstract datatype to represent database queries.

Exported constructors:

`data TError`

> The type of errors that might occur during a transaction.

Exported constructors:

- `TError :: TErrorKind → String → TError`

`data TErrorKind`

> The various kinds of transaction errors.

Exported constructors:

- `KeyNotExistsError :: TErrorKind`

- `NoRelationshipError :: TErrorKind`

- `DuplicateKeyError :: TErrorKind`

- `KeyRequiredError :: TErrorKind`

- `UniqueError :: TErrorKind`

- `MinError :: TErrorKind`

- `MaxError :: TErrorKind`

- `UserDefinedError :: TErrorKind`

- `ExecutionError :: TErrorKind`

`data Transaction`

> Abstract datatype for representing transactions.

Exported constructors:

Exported functions:

queryAll :: (a → Dynamic) → Query [a]

    A database query that returns all answers to an abstraction on a dynamic expression.

queryOne :: (a → Dynamic) → Query (Maybe a)

    A database query that returns a single answer to an abstraction on a dynamic expression. It returns Nothing if no answer exists.

queryOneWithDefault :: a → (a → Dynamic) → Query a

    A database query that returns a single answer to an abstraction on a dynamic expression. It returns the first argument if no answer exists.

queryJustOne :: (a → Dynamic) → Query a

    A database query that returns a single answer to an abstraction on a dynamic expression. It fails if no answer exists.

dynamicExists :: Dynamic → Query Bool

    A database query that returns True if there exists the argument facts (without free variables!) and False, otherwise.

transformQ :: (a → b) → Query a → Query b

    Transforms a database query from one result type to another according to a given mapping.

runQ :: Query a → IO a

    Executes a database query on the current state of dynamic predicates. If other processes made changes to persistent predicates, these changes are read and made visible to the currently running program.

showTError :: TError → String

    Transforms a transaction error into a string.

addDB :: Dynamic → Transaction ()

    Adds new facts (without free variables!) about dynamic predicates. Conditional dynamics are added only if the condition holds.

deleteDB :: Dynamic → Transaction ()

    Deletes facts (without free variables!) about dynamic predicates. Conditional dynamics are deleted only if the condition holds.

getDB :: Query a → Transaction a

    Returns the result of a database query in a transaction.

`returnT :: a → Transaction a`

The empty transaction that directly returns its argument.

`doneT :: Transaction ()`

The empty transaction that returns nothing.

`errorT :: TError → Transaction a`

Abort a transaction with a specific transaction error.

`failT :: String → Transaction a`

Abort a transaction with a general error message.

`(|>>=) :: Transaction a → (a → Transaction b) → Transaction b`

Sequential composition of transactions.

`(|>>) :: Transaction a → Transaction b → Transaction b`

Sequential composition of transactions.

`sequenceT :: [Transaction a] → Transaction [a]`

Executes a sequence of transactions and collects all results in a list.

`sequenceT_ :: [Transaction a] → Transaction ()`

Executes a sequence of transactions and ignores the results.

`mapT :: (a → Transaction b) → [a] → Transaction [b]`

Maps a transaction function on a list of elements. The results of all transactions are collected in a list.

`mapT_ :: (a → Transaction b) → [a] → Transaction ()`

Maps a transaction function on a list of elements. The results of all transactions are ignored.

`runT :: Transaction a → IO (Either a TError)`

Executes a possibly composed transaction on the current state of dynamic predicates as a single transaction.

Before the transaction is executed, the access to all persistent predicates is locked (i.e., no other process can perform a transaction in parallel). After the successful transaction, the access is unlocked so that the updates performed in this transaction become persistent and visible to other processes. Otherwise (i.e., in case of a failure or abort of the transaction), the changes of the transaction to persistent predicates are ignored and Nothing is returned.

In general, a transaction should terminate and all failures inside a transaction should be handled (execept for an explicit `failT` that leads to an abort of the transaction). If a transaction is externally interrupted (e.g., by killing the process), some locks might never be removed. However, they can be explicitly removed by deleting the corresponding lock files reported at startup time.

`runJustT :: Transaction a → IO a`

>   Executes a possibly composed transaction on the current state of dynamic predicates
>   as a single transaction. Similarly to `runT` but a run-time error is raised if the execution
>   of the transaction fails.

`runTNA :: Transaction a → IO (Either a TError)`

>   Executes a possibly composed transaction as a Non-Atomic(!) sequence of its individual
>   database updates. Thus, the argument is not executed as a single transaction in contrast
>   to `runT`, i.e., no predicates are locked and individual updates are not undone in case of
>   a transaction error. This operation could be applied to execute a composed transaction
>   without the overhead caused by (the current implementation of) transactions if one is
>   sure that locking is not necessary (e.g., if the transaction contains only database reads
>   and transaction error raising).

A.2.15 Library Debug

This library contains some useful operation for debugging programs.

Exported functions:

`trace :: String → a → a`

>   Prints the first argument as a side effect and behaves as identity on the second argument.

`traceId :: String → String`

>   Prints the first argument as a side effect and returns it afterwards.

`traceShow :: a → b → b`

>   Prints the first argument using `show` and returns the second argument afterwards.

`traceShowId :: a → a`

>   Prints the first argument using `show` and returns it afterwards.

`traceIO :: String → IO ()`

>   Output a trace message from the `IO` monad.

`assert :: Bool → String → a → a`

>   Assert a condition w.r.t. an error message. If the condition is not met it fails with the
>   given error message, otherwise the third argument is returned.

`assertIO :: Bool → String → IO ()`

>   Assert a condition w.r.t. an error message from the `IO` monad. If the condition is not
>   met it fails with the given error message.

A.2.16 Library Directory

Library for accessing the directory structure of the underlying operating system.

Exported functions:

doesFileExist :: String → IO Bool

> Returns true if the argument is the name of an existing file.

doesDirectoryExist :: String → IO Bool

> Returns true if the argument is the name of an existing directory.

fileSize :: String → IO Int

> Returns the size of the file.

getModificationTime :: String → IO ClockTime

> Returns the modification time of the file.

getCurrentDirectory :: IO String

> Returns the current working directory.

setCurrentDirectory :: String → IO ()

> Sets the current working directory.

getDirectoryContents :: String → IO [String]

> Returns the list of all entries in a directory.

createDirectory :: String → IO ()

> Creates a new directory with the given name.

createDirectoryIfMissing :: Bool → String → IO ()

> Creates a new directory with the given name if it does not already exist. If the first
> parameter is True it will also create all missing parent directories.

removeDirectory :: String → IO ()

> Deletes a directory from the file system.

renameDirectory :: String → String → IO ()

> Renames a directory.

getHomeDirectory :: IO String

> Returns the home directory of the current user.

```
getTemporaryDirectory :: IO String
```

Returns the temporary directory of the operating system.

```
getAbsolutePath :: String → IO String
```

Convert a path name into an absolute one. For instance, a leading ˜ is replaced by the current home directory.

```
removeFile :: String → IO ()
```

Deletes a file from the file system.

```
renameFile :: String → String → IO ()
```

Renames a file.

```
copyFile :: String → String → IO ()
```

Copy the contents from one file to another file

A.2.17   Library Distribution

This module contains functions to obtain information concerning the current distribution of the Curry implementation, e.g., compiler version, load paths, front end.

Exported types:

```
data FrontendTarget
```

Data type for representing the different target files that can be produced by the front end of the Curry compiler.

Exported constructors:

- `FCY :: FrontendTarget`

  FCY

  – FlatCurry file ending with .fcy

- `FINT :: FrontendTarget`

  FINT

  – FlatCurry interface file ending with .fint

- `ACY :: FrontendTarget`

  ACY

  – AbstractCurry file ending with .acy

- `UACY :: FrontendTarget`

  UACY

- – Untyped (without type checking) AbstractCurry file ending with .uacy

- HTML :: FrontendTarget

    HTML

    - – colored HTML representation of source program

- CY :: FrontendTarget

    CY

    - – source representation employed by the frontend

`data FrontendParams`

Abstract data type for representing parameters supported by the front end of the Curry compiler.

Exported constructors:

Exported functions:

`curryCompiler :: String`

The name of the Curry compiler (e.g., ”pakcs” or ”kics2”).

`curryCompilerMajorVersion :: Int`

The major version number of the Curry compiler.

`curryCompilerMinorVersion :: Int`

The minor version number of the Curry compiler.

`curryRuntime :: String`

The name of the run-time environment (e.g., ”sicstus”, ”swi”, or ”ghc”)

`curryRuntimeMajorVersion :: Int`

The major version number of the Curry run-time environment.

`curryRuntimeMinorVersion :: Int`

The minor version number of the Curry run-time environment.

`installDir :: String`

Path of the main installation directory of the Curry compiler.

`rcFileName :: IO String`

The name of the file specifying configuration parameters of the current distribution. This file must have the usual format of property files (see description in module PropertyFile).

`rcFileContents :: IO [(String,String)]`

> Returns the current configuration parameters of the distribution. This action yields the list of pairs (var,val).

`getRcVar :: String → IO (Maybe String)`

> Look up a specific configuration variable as specified by user in his rc file. Uppercase/lowercase is ignored for the variable names.

`getRcVars :: [String] → IO [Maybe String]`

> Look up configuration variables as specified by user in his rc file. Uppercase/lowercase is ignored for the variable names.

`splitModuleFileName :: String → String → (String,String)`

> Split the `FilePath` of a module into the directory prefix and the `FilePath` corresponding to the module name. For instance, the call `splitModuleFileName "Data.Set" "lib/Data/Set.curry"` evaluates to `("lib", "Data/Set.curry")`. This can be useful to compute output directories while retaining the hierarchical module structure.

`splitModuleIdentifiers :: String → [String]`

> Split up the components of a module identifier. For instance, `splitModuleIdentifiers "Data.Set"` evaluates to `["Data", "Set"]`.

`joinModuleIdentifiers :: [String] → String`

> Join the components of a module identifier. For instance, `joinModuleIdentifiers ["Data", "Set"]` evaluates to `"Data.Set"`.

`stripCurrySuffix :: String → String`

> Strips the suffix ".curry" or ".lcurry" from a file name.

`modNameToPath :: String → String`

> Transforms a hierarchical module name into a path name, i.e., replace the dots in the name by directory separator chars.

`currySubdir :: String`

> Name of the sub directory where auxiliary files (.fint, .fcy, etc) are stored.

`inCurrySubdir :: String → String`

> Transforms a path to a module name into a file name by adding the `currySubDir` to the path and transforming a hierarchical module name into a path. For instance, `inCurrySubdir "mylib/Data.Char"` evaluates to `"mylib/.curry/Data/Char"`.

`inCurrySubdirModule :: String → String → String`

Transforms a file name by adding the currySubDir to the file name. This version respects hierarchical module names.

`addCurrySubdir :: String → String`

Transforms a directory name into the name of the corresponding sub directory containing auxiliary files.

`lookupFileInLoadPath :: String → IO (Maybe String)`

Adds a directory name to a file by looking up the current load path. An error message is delivered if there is no such file.

`findFileInLoadPath :: String → IO String`

Adds a directory name to a file by looking up the current load path. An error message is delivered if there is no such file.

`readFirstFileInLoadPath :: String → IO String`

Returns the contents of the file found first in the current load path. An error message is delivered if there is no such file.

`getLoadPath :: IO [String]`

Returns the current path (list of directory names) that is used for loading modules.

`getLoadPathForFile :: String → IO [String]`

Returns the current path (list of directory names) that is used for loading modules w.r.t. a given main module file. The directory prefix of the module file (or ”.” if there is no such prefix) is the first element of the load path and the remaining elements are determined by the environment variable CURRYRPATH and the entry ”libraries” of the system's rc file.

`getLoadPathForModule :: String → IO [String]`

Returns the current path (list of directory names) that is used for loading modules w.r.t. a given module path. The directory prefix of the module path (or ”.” if there is no such prefix) is the first element of the load path and the remaining elements are determined by the environment variable CURRYRPATH and the entry ”libraries” of the system's rc file.

`lookupModuleSourceInLoadPath :: String → IO (Maybe (String,String))`

Returns a directory name and the actual source file name for a module by looking up the module source in the current load path. If the module is hierarchical, the directory is the top directory of the hierarchy. Returns Nothing if there is no corresponding source file.

`defaultParams :: FrontendParams`

The default parameters of the front end.

`rcParams :: IO FrontendParams`

The default parameters of the front end as configured by the compiler specific resource configuration file.

`setQuiet :: Bool → FrontendParams → FrontendParams`

Set quiet mode of the front end.

`setExtended :: Bool → FrontendParams → FrontendParams`

Set extended mode of the front end.

`setOverlapWarn :: Bool → FrontendParams → FrontendParams`

Set overlap warn mode of the front end.

`setFullPath :: [String] → FrontendParams → FrontendParams`

Set the full path of the front end. If this parameter is set, the front end searches all modules in this path (instead of using the default path).

`setHtmlDir :: String → FrontendParams → FrontendParams`

Set the htmldir parameter of the front end. Relevant for HTML generation.

`setLogfile :: String → FrontendParams → FrontendParams`

Set the logfile parameter of the front end. If this parameter is set, all messages produced by the front end are stored in this file.

`setSpecials :: String → FrontendParams → FrontendParams`

Set additional specials parameters of the front end. These parameters are specific for the current front end and should be used with care, since their form might change in the future.

`quiet :: FrontendParams → Bool`

Returns the value of the "quiet" parameter.

`extended :: FrontendParams → Bool`

Returns the value of the "extended" parameter.

`overlapWarn :: FrontendParams → Bool`

Returns the value of the "overlapWarn" parameter.

`fullPath :: FrontendParams → Maybe [String]`

Returns the full path parameter of the front end.

```
htmldir :: FrontendParams → Maybe String
```

> Returns the htmldir parameter of the front end.

```
logfile :: FrontendParams → Maybe String
```

> Returns the logfile parameter of the front end.

```
specials :: FrontendParams → String
```

> Returns the special parameters of the front end.

```
callFrontend :: FrontendTarget → String → IO ()
```

> In order to make sure that compiler generated files (like .fcy, .fint, .acy) are up to date, one can call the front end of the Curry compiler with this action. If the front end returns with an error, an exception is raised.

```
callFrontendWithParams :: FrontendTarget → FrontendParams → String → IO ()
```

> In order to make sure that compiler generated files (like .fcy, .fint, .acy) are up to date, one can call the front end of the Curry compiler with this action where various parameters can be set. If the front end returns with an error, an exception is raised.

A.2.18 Library Dynamic

Library for dynamic predicates. [8] _dyn.html"> This paper contains a description of the basic ideas behind this library.
Currently, it is still experimental so that its interface might be slightly changed in the future.
A dynamic predicate p with arguments of type t1,...,tn must be declared by:

```
p ::  t1 -> ...  -> tn -> Dynamic
p = dynamic
```

A dynamic predicate where all facts should be persistently stored in the directory DIR must be declared by:

```
p ::  t1 -> ...  -> tn -> Dynamic
p = persistent "file:DIR"
```

Remark: This library has been revised to the library Database. Thus, it might not be further supported in the future.

Exported types:

```
data Dynamic
```

> The general type of dynamic predicates.

Exported constructors:

---

[8]`http://www.informatik.uni-kiel.de/~mh/papers/JFLP04`

Exported functions:

`dynamic :: a`

> `dynamic` is only used for the declaration of a dynamic predicate and should not be used elsewhere.

`persistent :: String` → `a`

> `persistent` is only used for the declaration of a persistent dynamic predicate and should not be used elsewhere.

`(<>) :: Dynamic` → `Dynamic` → `Dynamic`

> Combine two dynamics.

`(|>) :: Dynamic` → `Bool` → `Dynamic`

> Restrict a dynamic with a condition.

`(|&>) :: Dynamic` → `Success` → `Dynamic`

> Restrict a dynamic with a constraint.

`assert :: Dynamic` → `IO ()`

> Asserts new facts (without free variables!) about dynamic predicates. Conditional dynamics are asserted only if the condition holds.

`retract :: Dynamic` → `IO Bool`

> Deletes facts (without free variables!) about dynamic predicates. Conditional dynamics are retracted only if the condition holds. Returns True if all facts to be retracted exist, otherwise False is returned.

`getKnowledge :: IO (Dynamic` → `Success)`

> Returns the knowledge at a particular point of time about dynamic predicates. If other processes made changes to persistent predicates, these changes are read and made visible to the currently running program.

`getDynamicSolutions :: (a` → `Dynamic)` → `IO [a]`

> Returns all answers to an abstraction on a dynamic expression. If other processes made changes to persistent predicates, these changes are read and made visible to the currently running program.

`getDynamicSolution :: (a` → `Dynamic)` → `IO (Maybe a)`

> Returns an answer to an abstraction on a dynamic expression. Returns Nothing if no answer exists. If other processes made changes to persistent predicates, these changes are read and made visible to the currently running program.

```
isKnown :: Dynamic → IO Bool
```

>   Returns True if there exists the argument facts (without free variables!) and False,
>   otherwise.

```
transaction :: IO a → IO (Maybe a)
```

>   Perform an action (usually containing updates of various dynamic predicates) as a single
>   transaction. This is the preferred way to execute any changes to persistent dynamic
>   predicates if there might be more than one process that may modify the definition of
>   such predicates in parallel.

>   Before the transaction is executed, the access to all persistent predicates is locked (i.e.,
>   no other process can perform a transaction in parallel). After the successful transac-
>   tion, the access is unlocked so that the updates performed in this transaction become
>   persistent and visible to other processes. Otherwise (i.e., in case of a failure or abort
>   of the transaction), the changes of the transaction to persistent predicates are ignored
>   and Nothing is returned.

>   In general, a transaction should terminate and all failures inside a transaction should
>   be handled (execept for abortTransaction). If a transaction is externally interrupted
>   (e.g., by killing the process), some locks might never be removed. However, they can
>   be explicitly removed by deleting the corresponding lock files reported at startup time.

>   Nested transactions are not supported and lead to a failure.

```
transactionWithErrorCatch :: IO a → IO (Either a IOError)
```

>   Perform an action (usually containing updates of various dynamic predicates) as a
>   single transaction. This is similar to `transaction` but an execution error is caught and
>   returned instead of printing it.

```
abortTransaction :: IO a
```

>   Aborts the current transaction. If a transaction is aborted, the remaining actions of the
>   transaction are not executed and all changes to **persistent** dynamic predicates made
>   in this transaction are ignored.

>   abortTransaction should only be used in a transaction. Although the execution of
>   abortTransaction always fails (basically, it writes an abort record in log files, unlock
>   them and then fails), the failure is handled inside `transaction`.

A.2.19 Library Either

Library with some useful operations for the `Either` data type.

Exported functions:

```
lefts :: [Either a b] → [a]
```

>   Extracts from a list of `Either` all the `Left` elements in order.

`rights :: [Either a b]` → `[b]`

> Extracts from a list of `Either` all the `Right` elements in order.

`isLeft :: Either a b` → `Bool`

> Return `True` if the given value is a `Left`-value, `False` otherwise.

`isRight :: Either a b` → `Bool`

> Return `True` if the given value is a `Right`-value, `False` otherwise.

`fromLeft :: Either a b` → `a`

> Extract the value from a `Left` constructor.

`fromRight :: Either a b` → `b`

> Extract the value from a `Right` constructor.

`partitionEithers :: [Either a b]` → `([a],[b])`

> Partitions a list of `Either` into two lists. All the `Left` elements are extracted, in order, to the first component of the output. Similarly the `Right` elements are extracted to the second component of the output.

A.2.20 Library FileGoodies

A collection of useful operations when dealing with files.

Exported functions:

`separatorChar :: Char`

> The character for separating hierarchies in file names. On UNIX systems the value is `/`.

`pathSeparatorChar :: Char`

> The character for separating names in path expressions. On UNIX systems the value is `:`.

`suffixSeparatorChar :: Char`

> The character for separating suffixes in file names. On UNIX systems the value is `.`.

`isAbsolute :: String` → `Bool`

> Is the argument an absolute name?

`dirName :: String` → `String`

> Extracts the directoy prefix of a given (Unix) file name. Returns ”.” if there is no prefix.

`baseName :: String → String`

>   Extracts the base name without directoy prefix of a given (Unix) file name.

`splitDirectoryBaseName :: String → (String,String)`

>   Splits a (Unix) file name into the directory prefix and the base name. The directory
>   prefix is "." if there is no real prefix in the name.

`stripSuffix :: String → String`

>   Strips a suffix (the last suffix starting with a dot) from a file name.

`fileSuffix :: String → String`

>   Yields the suffix (the last suffix starting with a dot) from given file name.

`splitBaseName :: String → (String,String)`

>   Splits a file name into prefix and suffix (the last suffix starting with a dot and the rest).

`splitPath :: String → [String]`

>   Splits a path string into list of directory names.

`lookupFileInPath :: String → [String] → [String] → IO (Maybe String)`

>   Looks up the first file with a possible suffix in a list of directories. Returns Nothing if
>   such a file does not exist.

`getFileInPath :: String → [String] → [String] → IO String`

>   Gets the first file with a possible suffix in a list of directories. An error message is
>   delivered if there is no such file.

A.2.21   Library FilePath

This library is a direct port of the Haskell library System.FilePath of Neil Mitchell.

Exported types:

`type FilePath = String`

Exported functions:

`pathSeparator :: Char`

`pathSeparators :: String`

isPathSeparator :: Char → Bool

searchPathSeparator :: Char

isSearchPathSeparator :: Char → Bool

extSeparator :: Char

isExtSeparator :: Char → Bool

splitSearchPath :: String → [String]

getSearchPath :: IO [String]

splitExtension :: String → (String,String)

takeExtension :: String → String

replaceExtension :: String → String → String

(<.>) :: String → String → String

dropExtension :: String → String

addExtension :: String → String → String

hasExtension :: String → Bool

```haskell
splitExtensions :: String → (String,String)


dropExtensions :: String → String


takeExtensions :: String → String


splitDrive :: String → (String,String)


joinDrive :: String → String → String


takeDrive :: String → String


dropDrive :: String → String


hasDrive :: String → Bool


isDrive :: String → Bool


splitFileName :: String → (String,String)


replaceFileName :: String → String → String


dropFileName :: String → String


takeFileName :: String → String


takeBaseName :: String → String
```

```
replaceBaseName :: String → String → String


hasTrailingPathSeparator :: String → Bool


addTrailingPathSeparator :: String → String


dropTrailingPathSeparator :: String → String


takeDirectory :: String → String


replaceDirectory :: String → String → String


combine :: String → String → String


(</>) :: String → String → String


splitPath :: String → [String]


splitDirectories :: String → [String]


joinPath :: [String] → String


equalFilePath :: String → String → Bool


makeRelative :: String → String → String


normalise :: String → String
```

```
isValid :: String → Bool
```

```
makeValid :: String → String
```

```
isRelative :: String → Bool
```

```
isAbsolute :: String → Bool
```

A.2.22 Library Findall

Library with some operations for encapsulating search. Note that some of these operations are not fully declarative, i.e., the results depend on the order of evaluation and program rules. There are newer and better approaches the encpasulate search, in particular, set functions (see module `SetFunctions`), which should be used.

In previous versions of PAKCS, some of these operations were part of the standard prelude. We keep them in this separate module in order to support a more portable standard prelude.

Exported functions:

```
getAllValues :: a → IO [a]
```

> Gets all values of an expression (currently, via an incomplete depth-first strategy). Conceptually, all values are computed on a copy of the expression, i.e., the evaluation of the expression does not share any results. Moreover, the evaluation suspends as long as the expression contains unbound variables. Similar to Prolog's findall.

```
getSomeValue :: a → IO a
```

> Gets a value of an expression (currently, via an incomplete depth-first strategy). The expression must have a value, otherwise the computation fails. Conceptually, the value is computed on a copy of the expression, i.e., the evaluation of the expression does not share any results. Moreover, the evaluation suspends as long as the expression contains unbound variables.

```
allValues :: a → [a]
```

> Returns all values of an expression (currently, via an incomplete depth-first strategy). Conceptually, all values are computed on a copy of the expression, i.e., the evaluation of the expression does not share any results. Moreover, the evaluation suspends as long as the expression contains unbound variables.

> Note that this operation is not purely declarative since the ordering of the computed values depends on the ordering of the program rules.

`someValue :: a → a`

Returns some value for an expression (currently, via an incomplete depth-first strategy). If the expression has no value, the computation fails. Conceptually, the value is computed on a copy of the expression, i.e., the evaluation of the expression does not share any results. Moreover, the evaluation suspends as long as the expression contains unbound variables.

Note that this operation is not purely declarative since the computed value depends on the ordering of the program rules. Thus, this operation should be used only if the expression has a single value.

`allSolutions :: (a → Bool) → [a]`

Returns all values satisfying a predicate, i.e., all arguments such that the predicate applied to the argument can be evaluated to `True` (currently, via an incomplete depth-first strategy). The evaluation suspends as long as the predicate expression contains unbound variables.

Note that this operation is not purely declarative since the ordering of the computed values depends on the ordering of the program rules.

`someSolution :: (a → Bool) → a`

Returns some values satisfying a predicate, i.e., some argument such that the predicate applied to the argument can be evaluated to `True` (currently, via an incomplete depth-first strategy). If there is no value satisfying the predicate, the computation fails.

Note that this operation is not purely declarative since the ordering of the computed values depends on the ordering of the program rules. Thus, this operation should be used only if the predicate has a single solution.

`try :: (a → Success) → [a → Success]`

Basic search control operator.

`inject :: (a → Success) → (a → Success) → a → Success`

Inject operator which adds the application of the unary procedure p to the search variable to the search goal taken from Oz. p x comes before g x to enable a test+generate form in a sequential implementation.

`solveAll :: (a → Success) → [a → Success]`

Computes all solutions via a a depth-first strategy.

`once :: (a → Success) → a → Success`

Gets the first solution via a depth-first strategy.

`best :: (a → Success) → (a → a → Bool) → [a → Success]`

Gets the best solution via a depth-first strategy according to a specified operator that can always take a decision which of two solutions is better. In general, the comparison operation should be rigid in its arguments!

findall :: (a → Success) → [a]

Gets all solutions via a depth-first strategy and unpack the values from the lambda-abstractions. Similar to Prolog's findall.

findfirst :: (a → Success) → a

Gets the first solution via a depth-first strategy and unpack the values from the search goals.

browse :: (a → Success) → IO ()

Shows the solution of a solved constraint.

browseList :: [a → Success] → IO ()

Unpacks solutions from a list of lambda abstractions and write them to the screen.

unpack :: (a → Success) → a

Unpacks a solution's value from a (solved) search goal.

rewriteAll :: a → [a]

Gets all values computable by term rewriting. In contrast to `findall`, this operation does not wait until all "outside" variables are bound to values, but it returns all values computable by term rewriting and ignores all computations that requires bindings for outside variables.

rewriteSome :: a → Maybe a

Similarly to `rewriteAll` but returns only some value computable by term rewriting. Returns `Nothing` if there is no such value.

A.2.23 Library Float

A collection of operations on floating point numbers.

Exported functions:

pi :: Float

The number pi.

(+.) :: Float → Float → Float

Addition on floats.

(-.) :: Float → Float → Float

Subtraction on floats.

`(*.) :: Float → Float → Float`

Multiplication on floats.

`(/.) :: Float → Float → Float`

Division on floats.

`(^.) :: Float → Int → Float`

The value of `a ^.   b` is `a` raised to the power of `b`. Executes in `O(log b)` steps.

`i2f :: Int → Float`

Conversion function from integers to floats.

`truncate :: Float → Int`

Conversion function from floats to integers. The result is the closest integer between the argument and 0.

`round :: Float → Int`

Conversion function from floats to integers. The result is the nearest integer to the argument. If the argument is equidistant between two integers, it is rounded to the closest even integer value.

`recip :: Float → Float`

Reciprocal

`sqrt :: Float → Float`

Square root.

`log :: Float → Float`

Natural logarithm.

`logBase :: Float → Float → Float`

Logarithm to arbitrary Base.

`exp :: Float → Float`

Natural exponent.

`sin :: Float → Float`

Sine.

`cos :: Float → Float`

Cosine.

`tan :: Float` $\rightarrow$ `Float`

Tangent.

`asin :: Float` $\rightarrow$ `Float`

Arc sine.

`acos :: Float` $\rightarrow$ `Float`

`atan :: Float` $\rightarrow$ `Float`

Arc tangent.

`sinh :: Float` $\rightarrow$ `Float`

Hyperbolic sine.

`cosh :: Float` $\rightarrow$ `Float`

`tanh :: Float` $\rightarrow$ `Float`

Hyperbolic tangent.

`asinh :: Float` $\rightarrow$ `Float`

Hyperbolic Arc sine.

`acosh :: Float` $\rightarrow$ `Float`

`atanh :: Float` $\rightarrow$ `Float`

Hyperbolic Arc tangent.

A.2.24 Library Function

This module provides some utility functions for function application.

Exported functions:

```
fix :: (a → a) → a
```

> `fix f` is the least fixed point of the function `f`, i.e. the least defined `x` such that `f x = x`.

```
on :: (a → a → b) → (c → a) → c → c → b
```

> (*) `` `on` `` `f = \x y -> f x * f y`. Typical usage: `sortBy (compare `` `on` `` fst)`.

```
first :: (a → b) → (a,c) → (b,c)
```

> Apply a function to the first component of a tuple.

```
second :: (a → b) → (c,a) → (c,b)
```

> Apply a function to the second component of a tuple.

```
(***) :: (a → b) → (c → d) → (a,c) → (b,d)
```

> Apply two functions to the two components of a tuple.

```
(&&&) :: (a → b) → (a → c) → a → (b,c)
```

> Apply two functions to a value and returns a tuple of the results.

```
both :: (a → b) → (a,a) → (b,b)
```

> Apply a function to both components of a tuple.

A.2.25 Library FunctionInversion

This module provides some utility functions for inverting functions.

Exported functions:

```
invf1 :: (a → b) → b → a
```

> Inverts a unary function.

```
invf2 :: (a → b → c) → c → (a,b)
```

> Inverts a binary function.

```
invf3 :: (a → b → c → d) → d → (a,b,c)
```

> Inverts a ternary function.

```
invf4 :: (a → b → c → d → e) → e → (a,b,c,d)
```

> Inverts a function of arity 4.

```
invf5 :: (a → b → c → d → e → f) → f → (a,b,c,d,e)
```

> Inverts a function of arity 5.

A.2.26 Library GetOpt

This Module is a modified version of the Module System.Console.GetOpt by Sven Panne from the ghc-base package it has been adapted for Curry by Bjoern Peemoeller

Exported types:

data ArgOrder

Exported constructors:

- RequireOrder :: ArgOrder a

- Permute :: ArgOrder a

- ReturnInOrder :: (String → a) → ArgOrder a

data OptDescr

Exported constructors:

- Option :: String → [String] → (ArgDescr a) → String → OptDescr a

data ArgDescr

Exported constructors:

- NoArg :: a → ArgDescr a

- ReqArg :: (String → a) → String → ArgDescr a

- OptArg :: (Maybe String → a) → String → ArgDescr a

Exported functions:

usageInfo :: String → [OptDescr a] → String

getOpt :: ArgOrder a → [OptDescr a] → [String] → ([a],[String],[String])

getOpt' :: ArgOrder a → [OptDescr a] → [String] → ([a],[String],[String],[String])

A.2.27   Library Global

Library for handling global entities. A global entity has a name declared in the program. Its value can be accessed and modified by IO actions. Furthermore, global entities can be declared as persistent so that their values are stored across different program executions.
Currently, it is still experimental so that its interface might be slightly changed in the future.
A global entity g with an initial value v of type t must be declared by:

g :: Global t
g = global v spec

Here, the type t must not contain type variables and spec specifies the storage mechanism for the global entity (see type GlobalSpec).

Exported types:

data Global

The type of a global entity.

Exported constructors:

data GlobalSpec

The storage mechanism for the global entity.

Exported constructors:

- Temporary :: GlobalSpec

  Temporary

  – the global value exists only during a single execution of a program

- Persistent :: String $\rightarrow$ GlobalSpec

  Persistent f

  – the global value is stored persisently in file f (which is created and initialized if it does not exists)

Exported functions:

global :: a $\rightarrow$ GlobalSpec $\rightarrow$ Global a

global is only used for the declaration of a global value and should not be used elsewhere. In the future, it might become a keyword.

readGlobal :: Global a $\rightarrow$ IO a

Reads the current value of a global.

writeGlobal :: Global a $\rightarrow$ a $\rightarrow$ IO ()

Updates the value of a global. The value is evaluated to a ground constructor term before it is updated.

A.2.28 Library GlobalVariable

Library for handling global variables. A global variable has a name declared in the program. Its value (a data term possibly containing free variables) can be accessed and modified by IO actions. In contast to global entities (as defined in the library Global), global variables can contain logic variables shared with computations running in the same computation space. As a consequence, global variables cannot be persistent, their values are not kept across different program executions. Currently, it is still experimental so that its interface might be slightly changed in the future.

A global variable g with an initial value v of type t must be declared by:

g :: GVar t

g = gvar v

Here, the type t must not contain type variables. v is the initial value for every program run.

Note: the implementation in PAKCS is based on threading a state through the execution. Thus, it might be the case that some updates of global variables are lost if fancy features like unsafe operations or debugging support are used.

Exported types:

data GVar

The general type of global variables.

Exported constructors:

Exported functions:

`gvar :: a → GVar a`

> `gvar` is only used for the declaration of a global variable and should not be used elsewhere. In the future, it might become a keyword.

`readGVar :: GVar a → IO a`

> Reads the current value of a global variable.

`writeGVar :: GVar a → a → IO ()`

> Updates the value of a global variable. The associated term is evaluated to a data term and might contain free variables.

A.2.29 Library GUI

This library contains definitions and functions to implement graphical user interfaces for Curry programs. It is based on Tcl/Tk and its basic ideas are described in detail in this paper

Exported types:

`data GuiPort`

> The port to a GUI is just the stream connection to a GUI where Tcl/Tk communication is done.

> *Exported constructors:*

`data Widget`

> The type of possible widgets in a GUI.

> *Exported constructors:*

> - `PlainButton :: [ConfItem] → Widget`
>   `PlainButton`
>
>   – a button in a GUI whose event handler is activated if the user presses the button
>
> - `Canvas :: [ConfItem] → Widget`
>   `Canvas`
>
>   – a canvas to draw pictures containing CanvasItems
>
> - `CheckButton :: [ConfItem] → Widget`
>   `CheckButton`
>
>   – a check button: it has value "0" if it is unchecked and value "1" if it is checked

- `Entry :: [ConfItem] → Widget`

  `Entry`

  – an entry widget for entering single lines

- `Label :: [ConfItem] → Widget`

  `Label`

  – a label for showing a text

- `ListBox :: [ConfItem] → Widget`

  `ListBox`

  – a widget containing a list of items for selection

- `Message :: [ConfItem] → Widget`

  `Message`

  – a message for showing simple string values

- `MenuButton :: [ConfItem] → Widget`

  `MenuButton`

  – a button with a pull-down menu

- `Scale :: Int → Int → [ConfItem] → Widget`

  `Scale`

  – a scale widget to input values by a slider

- `ScrollH :: WidgetRef → [ConfItem] → Widget`

  `ScrollH`

  – a horizontal scroll bar

- `ScrollV :: WidgetRef → [ConfItem] → Widget`

  `ScrollV`

  – a vertical scroll bar

- `TextEdit :: [ConfItem] → Widget`

  `TextEdit`

  – a text editor widget to show and manipulate larger text paragraphs

- `Row :: [ConfCollection] → [Widget] → Widget`

  `Row`

  – a horizontal alignment of widgets

- Col :: [ConfCollection] → [Widget] → Widget

  Col

  - a vertical alignment of widgets

- Matrix :: [ConfCollection] → [[Widget]] → Widget

  Matrix

  - a 2-dimensional (matrix) alignment of widgets

data ConfItem

The data type for possible configurations of a widget.

Exported constructors:

- Active :: Bool → ConfItem

  Active

  - define the active state for buttons, entries, etc.

- Anchor :: String → ConfItem

  Anchor

  - alignment of information inside a widget where the argument must be: n, ne, e, se, s, sw, w, nw, or center

- Background :: String → ConfItem

  Background

  - the background color

- Foreground :: String → ConfItem

  Foreground

  - the foreground color

- Handler :: Event → (GuiPort → IO [ReconfigureItem]) → ConfItem

  Handler

  - an event handler associated to a widget. The event handler returns a list of widget ref/configuration pairs that are applied after the handler in order to configure GUI widgets

- Height :: Int → ConfItem

  Height

  - the height of a widget (chars for text, pixels for graphics)

- CheckInit :: String → ConfItem

  CheckInit

    – initial value for checkbuttons

- CanvasItems :: [CanvasItem] → ConfItem

  CanvasItems

    – list of items contained in a canvas

- List :: [String] → ConfItem

  List

    – list of values shown in a listbox

- Menu :: [MenuItem] → ConfItem

  Menu

    – the items of a menu button

- WRef :: WidgetRef → ConfItem

  WRef

    – a reference to this widget

- Text :: String → ConfItem

  Text

    – an initial text contents

- Width :: Int → ConfItem

  Width

    – the width of a widget (chars for text, pixels for graphics)

- Fill :: ConfItem

  Fill

    – fill widget in both directions

- FillX :: ConfItem

  FillX

    – fill widget in horizontal direction

- FillY :: ConfItem

  FillY

    – fill widget in vertical direction

- TclOption :: String → ConfItem

  TclOption

    – further options in Tcl syntax (unsafe!)

data ReconfigureItem

Data type for describing configurations that are applied to a widget or GUI by some event handler.

Exported constructors:

- WidgetConf :: WidgetRef → ConfItem → ReconfigureItem

  WidgetConf wref conf

    – reconfigure the widget referred by wref with configuration item conf

- StreamHandler :: Handle → (Handle → GuiPort → IO [ReconfigureItem]) → ReconfigureItem

  StreamHandler hdl handler

    – add a new handler to the GUI that processes inputs on an input stream referred by hdl

- RemoveStreamHandler :: Handle → ReconfigureItem

  RemoveStreamHandler hdl

    – remove a handler for an input stream referred by hdl from the GUI (usually used to remove handlers for closed streams)

data Event

The data type of possible events on which handlers can react. This list is still incomplete and might be extended or restructured in future releases of this library.

Exported constructors:

- DefaultEvent :: Event

  DefaultEvent

    – the default event of the widget

- MouseButton1 :: Event

  MouseButton1

    – left mouse button pressed

- MouseButton2 :: Event

  MouseButton2

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– middle mouse button pressed

- **MouseButton3 :: Event**

  `MouseButton3`

  – right mouse button pressed

- **KeyPress :: Event**

  `KeyPress`

  – any key is pressed

- **Return :: Event**

  `Return`

  – return key is pressed

data ConfCollection

The data type for possible configurations of widget collections (e.g., columns, rows).

Exported constructors:

- **CenterAlign :: ConfCollection**

  `CenterAlign`

  – centered alignment

- **LeftAlign :: ConfCollection**

  `LeftAlign`

  – left alignment

- **RightAlign :: ConfCollection**

  `RightAlign`

  – right alignment

- **TopAlign :: ConfCollection**

  `TopAlign`

  – top alignment

- **BottomAlign :: ConfCollection**

  `BottomAlign`

  – bottom alignment

data MenuItem

The data type for specifying items in a menu.

Exported constructors:

- MButton :: (GuiPort → IO [ReconfigureItem]) → String → MenuItem

  MButton

  – a button with an associated command and a label string

- MSeparator :: MenuItem

  MSeparator

  – a separator between menu entries

- MMenuButton :: String → [MenuItem] → MenuItem

  MMenuButton

  – a submenu with a label string

data CanvasItem

The data type of items in a canvas. The last argument are further options in Tcl/Tk (for testing).

Exported constructors:

- CLine :: [(Int,Int)] → String → CanvasItem

- CPolygon :: [(Int,Int)] → String → CanvasItem

- CRectangle :: (Int,Int) → (Int,Int) → String → CanvasItem

- COval :: (Int,Int) → (Int,Int) → String → CanvasItem

- CText :: (Int,Int) → String → String → CanvasItem

data WidgetRef

The (hidden) data type of references to a widget in a GUI window. Note that the constructor WRefLabel will not be exported so that values can only be created inside this module.

Exported constructors:

data Style

The data type of possible text styles.

Exported constructors:

- Bold :: Style

  Bold

    – text in bold font

- Italic :: Style

  Italic

    – text in italic font

- Underline :: Style

  Underline

    – underline text

- Fg :: Color → Style

  Fg

    – foreground color, i.e., color of the text font

- Bg :: Color → Style

  Bg

    – background color of the text

data Color

The data type of possible colors.

Exported constructors:

- Black :: Color

- Blue :: Color

- Brown :: Color

- Cyan :: Color

- Gold :: Color

- Gray :: Color

- Green :: Color

- Magenta :: Color

- Navy :: Color

- Orange :: Color

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- Pink :: Color

- Purple :: Color

- Red :: Color

- Tomato :: Color

- Turquoise :: Color

- Violet :: Color

- White :: Color

- Yellow :: Color

Exported functions:

row :: [Widget] → Widget

    Horizontal alignment of widgets.

col :: [Widget] → Widget

    Vertical alignment of widgets.

matrix :: [[Widget]] → Widget

    Matrix alignment of widgets.

debugTcl :: Widget → IO ()

    Prints the generated Tcl commands of a main widget (useful for debugging).

runPassiveGUI :: String → Widget → IO GuiPort

    IO action to show a Widget in a new GUI window in passive mode, i.e., ignore all GUI events.

runGUI :: String → Widget → IO ()

    IO action to run a Widget in a new window.

runGUIwithParams :: String → String → Widget → IO ()

    IO action to run a Widget in a new window.

runInitGUI :: String → Widget → (GuiPort → IO [ReconfigureItem]) → IO ()

    IO action to run a Widget in a new window. The GUI events are processed after executing an initial action on the GUI.

runInitGUIwithParams :: String → String → Widget → (GuiPort → IO [ReconfigureItem]) → IO ()

IO action to run a Widget in a new window. The GUI events are processed after executing an initial action on the GUI.

runControlledGUI :: String → (Widget,String → GuiPort → IO ()) → Handle → IO ()

> Runs a Widget in a new GUI window and process GUI events. In addition, an event handler is provided that process messages received from an external stream identified by a handle (third argument). This operation is useful to run a GUI that should react on user events as well as messages written to the given handle.

runConfigControlledGUI :: String → (Widget,String → GuiPort → IO [ReconfigureItem]) → Handle → IO ()

> Runs a Widget in a new GUI window and process GUI events. In addition, an event handler is provided that process messages received from an external stream identified by a handle (third argument). This operation is useful to run a GUI that should react on user events as well as messages written to the given handle.

runInitControlledGUI :: String → (Widget,String → GuiPort → IO ()) → (GuiPort → IO [ReconfigureItem]) → Handle → IO ()

> Runs a Widget in a new GUI window and process GUI events after executing an initial action on the GUI window. In addition, an event handler is provided that process messages received from an external message stream. This operation is useful to run a GUI that should react on user events as well as messages written to the given handle.

runHandlesControlledGUI :: String → (Widget,[Handle → GuiPort → IO [ReconfigureItem]]) → [Handle] → IO ()

> Runs a Widget in a new GUI window and process GUI events. In addition, a list of event handlers is provided that process inputs received from a corresponding list of handles to input streams. Thus, if the i-th handle has some data available, the i-th event handler is executed with the i-th handle as a parameter. This operation is useful to run a GUI that should react on inputs provided by other processes, e.g., via sockets.

runInitHandlesControlledGUI :: String → (Widget,[Handle → GuiPort → IO [ReconfigureItem]]) → (GuiPort → IO [ReconfigureItem]) → [Handle] → IO ()

> Runs a Widget in a new GUI window and process GUI events after executing an initial action on the GUI window. In addition, a list of event handlers is provided that process inputs received from a corresponding list of handles to input streams. Thus, if the i-th handle has some data available, the i-th event handler is executed with the i-th handle as a parameter. This operation is useful to run a GUI that should react on inputs provided by other processes, e.g., via sockets.

setConfig :: WidgetRef → ConfItem → GuiPort → IO ()

> Changes the current configuration of a widget (deprecated operation, only included for backward compatibility). Warning: does not work for Command options!

`exitGUI :: GuiPort → IO ()`

An event handler for terminating the GUI.

`getValue :: WidgetRef → GuiPort → IO String`

Gets the (String) value of a variable in a GUI.

`setValue :: WidgetRef → String → GuiPort → IO ()`

Sets the (String) value of a variable in a GUI.

`updateValue :: (String → String) → WidgetRef → GuiPort → IO ()`

Updates the (String) value of a variable w.r.t. to an update function.

`appendValue :: WidgetRef → String → GuiPort → IO ()`

Appends a String value to the contents of a TextEdit widget and adjust the view to the end of the TextEdit widget.

`appendStyledValue :: WidgetRef → String → [Style] → GuiPort → IO ()`

Appends a String value with style tags to the contents of a TextEdit widget and adjust the view to the end of the TextEdit widget. Different styles can be combined, e.g., to get bold blue text on a red background. If `Bold`, `Italic` and `Underline` are combined, currently all but one of these are ignored. This is an experimental function and might be changed in the future.

`addRegionStyle :: WidgetRef → (Int,Int) → (Int,Int) → Style → GuiPort → IO ()`

Adds a style value in a region of a TextEdit widget. The region is specified a start and end position similarly to `getCursorPosition`. Different styles can be combined, e.g., to get bold blue text on a red background. If `Bold`, `Italic` and `Underline` are combined, currently all but one of these are ignored. This is an experimental function and might be changed in the future.

`removeRegionStyle :: WidgetRef → (Int,Int) → (Int,Int) → Style → GuiPort → IO ()`

Removes a style value in a region of a TextEdit widget. The region is specified a start and end position similarly to `getCursorPosition`. This is an experimental function and might be changed in the future.

`getCursorPosition :: WidgetRef → GuiPort → IO (Int,Int)`

Get the position (line,column) of the insertion cursor in a TextEdit widget. Lines are numbered from 1 and columns are numbered from 0.

`seeText :: WidgetRef → (Int,Int) → GuiPort → IO ()`

Adjust the view of a TextEdit widget so that the specified line/column character is visible. Lines are numbered from 1 and columns are numbered from 0.

`focusInput :: WidgetRef → GuiPort → IO ()`

Sets the input focus of this GUI to the widget referred by the first argument. This is useful for automatically selecting input entries in an application.

`addCanvas :: WidgetRef → [CanvasItem] → GuiPort → IO ()`

Adds a list of canvas items to a canvas referred by the first argument.

`popupMessage :: String → IO ()`

A simple popup message.

`Cmd :: (GuiPort → IO ()) → ConfItem`

A simple event handler that can be associated to a widget. The event handler takes a GUI port as parameter in order to read or write values from/into the GUI.

`Command :: (GuiPort → IO [ReconfigureItem]) → ConfItem`

An event handler that can be associated to a widget. The event handler takes a GUI port as parameter (in order to read or write values from/into the GUI) and returns a list of widget reference/configuration pairs which is applied after the handler in order to configure some GUI widgets.

`Button :: (GuiPort → IO ()) → [ConfItem] → Widget`

A button with an associated event handler which is activated if the button is pressed.

`ConfigButton :: (GuiPort → IO [ReconfigureItem]) → [ConfItem] → Widget`

A button with an associated event handler which is activated if the button is pressed. The event handler is a configuration handler (see Command) that allows the configuration of some widgets.

`TextEditScroll :: [ConfItem] → Widget`

A text edit widget with vertical and horizontal scrollbars. The argument contains the configuration options for the text edit widget.

`ListBoxScroll :: [ConfItem] → Widget`

A list box widget with vertical and horizontal scrollbars. The argument contains the configuration options for the list box widget.

`CanvasScroll :: [ConfItem] → Widget`

A canvas widget with vertical and horizontal scrollbars. The argument contains the configuration options for the text edit widget.

`EntryScroll :: [ConfItem] → Widget`

An entry widget with a horizontal scrollbar. The argument contains the configuration options for the entry widget.

`getOpenFile :: IO String`

> Pops up a GUI for selecting an existing file. The file with its full path name will be returned (or "" if the user cancels the selection).

`getOpenFileWithTypes :: [(String,String)] → IO String`

> Pops up a GUI for selecting an existing file. The parameter is a list of pairs of file types that could be selected. A file type pair consists of a name and an extension for that file type. The file with its full path name will be returned (or "" if the user cancels the selection).

`getSaveFile :: IO String`

> Pops up a GUI for choosing a file to save some data. If the user chooses an existing file, she/he will asked to confirm to overwrite it. The file with its full path name will be returned (or "" if the user cancels the selection).

`getSaveFileWithTypes :: [(String,String)] → IO String`

> Pops up a GUI for choosing a file to save some data. The parameter is a list of pairs of file types that could be selected. A file type pair consists of a name and an extension for that file type. If the user chooses an existing file, she/he will asked to confirm to overwrite it. The file with its full path name will be returned (or "" if the user cancels the selection).

`chooseColor :: IO String`

> Pops up a GUI dialog box to select a color. The name of the color will be returned (or "" if the user cancels the selection).

A.2.30 Library Integer

A collection of common operations on integer numbers. Most operations make no assumption on the precision of integers. Operation `bitNot` is necessarily an exception.

Exported functions:

`(^) :: Int → Int → Int`

> The value of `a ^ b` is `a` raised to the power of `b`. Fails if `b < 0`. Executes in `O(log b)` steps.

`pow :: Int → Int → Int`

> The value of `pow a b` is `a` raised to the power of `b`. Fails if `b < 0`. Executes in `O(log b)` steps.

`ilog :: Int → Int`

The value of `ilog n` is the floor of the logarithm in the base 10 of `n`. Fails if `n` <=
0. For positive integers, the returned value is 1 less the number of digits in the decimal
representation of `n`.

`isqrt :: Int → Int`

The value of `isqrt n` is the floor of the square root of `n`. Fails if `n` < 0. Executes
in `O(log n)` steps, but there must be a better way.

`factorial :: Int → Int`

The value of `factorial n` is the factorial of `n`. Fails if `n` < 0.

`binomial :: Int → Int → Int`

The value of `binomial n m` is n*(n-1)...(n-m+1)/m*(m-1)*...1 Fails if 'm <= 0' or 'n <
m'.

`abs :: Int → Int`

The value of `abs n` is the absolute value of `n`.

`max3 :: a → a → a → a`

Returns the maximum of the three arguments.

`min3 :: a → a → a → a`

Returns the minimum of the three arguments.

`maxlist :: [a] → a`

Returns the maximum of a list of integer values. Fails if the list is empty.

`minlist :: [a] → a`

Returns the minimum of a list of integer values. Fails if the list is empty.

`bitTrunc :: Int → Int → Int`

The value of `bitTrunc n m` is the value of the `n` least significant bits of `m`.

`bitAnd :: Int → Int → Int`

Returns the bitwise AND of the two arguments.

`bitOr :: Int → Int → Int`

Returns the bitwise inclusive OR of the two arguments.

`bitNot :: Int → Int`

Returns the bitwise NOT of the argument. Since integers have unlimited precision, only
the 32 least significant bits are computed.

```
bitXor :: Int → Int → Int
```

      Returns the bitwise exclusive OR of the two arguments.

```
even :: Int → Bool
```

      Returns whether an integer is even

```
odd :: Int → Bool
```

      Returns whether an integer is odd

A.2.31 Library IO

Library for IO operations like reading and writing files that are not already contained in the prelude.

Exported types:

```
data Handle
```

      The abstract type of a handle for a stream.

   Exported constructors:

```
data IOMode
```

      The modes for opening a file.

   Exported constructors:

- `ReadMode :: IOMode`

- `WriteMode :: IOMode`

- `AppendMode :: IOMode`

```
data SeekMode
```

      The modes for positioning with `hSeek` in a file.

   Exported constructors:

- `AbsoluteSeek :: SeekMode`

- `RelativeSeek :: SeekMode`

- `SeekFromEnd :: SeekMode`

Exported functions:

`stdin :: Handle`

> Standard input stream.

`stdout :: Handle`

> Standard output stream.

`stderr :: Handle`

> Standard error stream.

`openFile :: String → IOMode → IO Handle`

> Opens a file in specified mode and returns a handle to it.

`hClose :: Handle → IO ()`

> Closes a file handle and flushes the buffer in case of output file.

`hFlush :: Handle → IO ()`

> Flushes the buffer associated to handle in case of output file.

`hIsEOF :: Handle → IO Bool`

> Is handle at end of file?

`isEOF :: IO Bool`

> Is standard input at end of file?

`hSeek :: Handle → SeekMode → Int → IO ()`

> Set the position of a handle to a seekable stream (e.g., a file). If the second argument is `AbsoluteSeek`, `SeekFromEnd`, or `RelativeSeek`, the position is set relative to the beginning of the file, to the end of the file, or to the current position, respectively.

`hWaitForInput :: Handle → Int → IO Bool`

> Waits until input is available on the given handle. If no input is available within t milliseconds, it returns False, otherwise it returns True.

`hWaitForInputs :: [Handle] → Int → IO Int`

> Waits until input is available on some of the given handles. If no input is available within t milliseconds, it returns -1, otherwise it returns the index of the corresponding handle with the available data.

`hWaitForInputOrMsg :: Handle → [a] → IO (Either Handle [a])`

Waits until input is available on a given handles or a message in the message stream. Usually, the message stream comes from an external port. Thus, this operation implements a committed choice over receiving input from an IO handle or an external port.

Note that the implementation of this operation works only with Sicstus-Prolog 3.8.5 or higher (due to a bug in previous versions of Sicstus-Prolog).

`hWaitForInputsOrMsg :: [Handle]` → `[a]` → `IO (Either Int [a])`

Waits until input is available on some of the given handles or a message in the message stream. Usually, the message stream comes from an external port. Thus, this operation implements a committed choice over receiving input from IO handles or an external port.

Note that the implementation of this operation works only with Sicstus-Prolog 3.8.5 or higher (due to a bug in previous versions of Sicstus-Prolog).

`hReady :: Handle` → `IO Bool`

Checks whether an input is available on a given handle.

`hGetChar :: Handle` → `IO Char`

Reads a character from an input handle and returns it. Throws an error if the end of file has been reached.

`hGetLine :: Handle` → `IO String`

Reads a line from an input handle and returns it. Throws an error if the end of file has been reached while reading the *first* character. If the end of file is reached later in the line, it ist treated as a line terminator and the (partial) line is returned.

`hGetContents :: Handle` → `IO String`

Reads the complete contents from an input handle and closes the input handle before returning the contents.

`getContents :: IO String`

Reads the complete contents from the standard input stream until EOF.

`hPutChar :: Handle` → `Char` → `IO ()`

Puts a character to an output handle.

`hPutStr :: Handle` → `String` → `IO ()`

Puts a string to an output handle.

`hPutStrLn :: Handle` → `String` → `IO ()`

Puts a string with a newline to an output handle.

```
hPrint :: Handle → a → IO ()
```

Converts a term into a string and puts it to an output handle.

```
hIsReadable :: Handle → IO Bool
```

Is the handle readable?

```
hIsWritable :: Handle → IO Bool
```

Is the handle writable?

```
hIsTerminalDevice :: Handle → IO Bool
```

Is the handle connected to a terminal?

A.2.32 Library IOExts

Library with some useful extensions to the IO monad.

Exported types:

```
data IORef
```

Mutable variables containing values of some type. The values are not evaluated when they are assigned to an IORef.

Exported constructors:

Exported functions:

```
execCmd :: String → IO (Handle,Handle,Handle)
```

Executes a command with a new default shell process. The standard I/O streams of the new process (stdin,stdout,stderr) are returned as handles so that they can be explicitly manipulated. They should be closed with `IO.hClose` since they are not closed automatically when the process terminates.

```
evalCmd :: String → [String] → String → IO (Int,String,String)
```

Executes a command with the given arguments as a new default shell process and provides the input via the process' stdin input stream. The exit code of the process and the contents written to the standard I/O streams stdout and stderr are returned.

```
connectToCommand :: String → IO Handle
```

Executes a command with a new default shell process. The input and output streams of the new process is returned as one handle which is both readable and writable. Thus, writing to the handle produces input to the process and output from the process can be retrieved by reading from this handle. The handle should be closed with `IO.hClose` since they are not closed automatically when the process terminates.

`readCompleteFile :: String → IO String`

An action that reads the complete contents of a file and returns it. This action can be used instead of the (lazy) `readFile` action if the contents of the file might be changed.

`updateFile :: (String → String) → String → IO ()`

An action that updates the contents of a file.

`exclusiveIO :: String → IO a → IO a`

Forces the exclusive execution of an action via a lock file. For instance, (exclusiveIO "myaction.lock" act) ensures that the action "act" is not executed by two processes on the same system at the same time.

`setAssoc :: String → String → IO ()`

Defines a global association between two strings. Both arguments must be evaluable to ground terms before applying this operation.

`getAssoc :: String → IO (Maybe String)`

Gets the value associated to a string. Nothing is returned if there does not exist an associated value.

`newIORef :: a → IO (IORef a)`

Creates a new IORef with an initial values.

`readIORef :: IORef a → IO a`

Reads the current value of an IORef.

`writeIORef :: IORef a → a → IO ()`

Updates the value of an IORef.

`modifyIORef :: IORef a → (a → a) → IO ()`

Modify the value of an IORef.

A.2.33 Library JavaScript

A library to represent JavaScript programs.

Exported types:

`data JSExp`

Type of JavaScript expressions.

Exported constructors:

- `JSString :: String → JSExp`

  `JSString`

    – string constant

- `JSInt :: Int → JSExp`

  `JSInt`

    – integer constant

- `JSBool :: Bool → JSExp`

  `JSBool`

    – Boolean constant

- `JSIVar :: Int → JSExp`

  `JSIVar`

    – indexed variable

- `JSIArrayIdx :: Int → Int → JSExp`

  `JSIArrayIdx`

    – array access to index array variable

- `JSOp :: String → JSExp → JSExp → JSExp`

  `JSOp`

    – infix operator expression

- `JSFCall :: String → [JSExp] → JSExp`

  `JSFCall`

    – function call

- `JSApply :: JSExp → JSExp → JSExp`

  `JSApply`

    – function call where the function is an expression

- `JSLambda :: [Int] → [JSStat] → JSExp`

  `JSLambda`

    – (anonymous) function with indexed variables as arguments

`data JSStat`

Type of JavaScript statements.

Exported constructors:

- JSAssign :: JSExp $\rightarrow$ JSExp $\rightarrow$ JSStat

  JSAssign

    – assignment

- JSIf :: JSExp $\rightarrow$ [JSStat] $\rightarrow$ [JSStat] $\rightarrow$ JSStat

  JSIf

    – conditional

- JSSwitch :: JSExp $\rightarrow$ [JSBranch] $\rightarrow$ JSStat

  JSSwitch

    – switch statement

- JSPCall :: String $\rightarrow$ [JSExp] $\rightarrow$ JSStat

  JSPCall

    – procedure call

- JSReturn :: JSExp $\rightarrow$ JSStat

  JSReturn

    – return statement

- JSVarDecl :: Int $\rightarrow$ JSStat

  JSVarDecl

    – local variable declaration

data JSBranch

Exported constructors:

- JSCase :: String $\rightarrow$ [JSStat] $\rightarrow$ JSBranch

  JSCase

    – case branch

- JSDefault :: [JSStat] $\rightarrow$ JSBranch

  JSDefault

    – default branch

data JSFDecl

Exported constructors:

- JSFDecl :: String → [Int] → [JSStat] → JSFDecl

Exported functions:

showJSExp :: JSExp → String

    Shows a JavaScript expression as a string in JavaScript syntax.

showJSStat :: Int → JSStat → String

    Shows a JavaScript statement as a string in JavaScript syntax with indenting.

showJSFDecl :: JSFDecl → String

    Shows a JavaScript function declaration as a string in JavaScript syntax.

jsConsTerm :: String → [JSExp] → JSExp

    Representation of constructor terms in JavaScript.

A.2.34 Library KeyDatabase

This module provides a general interface for databases (persistent predicates) where each entry consists of a key and an info part. The key is an integer and the info is arbitrary. All functions are parameterized with a dynamic predicate that takes an integer key as a first parameter.

Exported functions:

existsDBKey :: (Int → a → Dynamic) → Int → Query Bool

    Exists an entry with a given key in the database?

allDBKeys :: (Int → a → Dynamic) → Query [Int]

    Query that returns all keys of entries in the database.

allDBInfos :: (Int → a → Dynamic) → Query [a]

    Query that returns all infos of entries in the database.

allDBKeyInfos :: (Int → a → Dynamic) → Query [(Int,a)]

    Query that returns all key/info pairs of the database.

getDBInfo :: (Int → a → Dynamic) → Int → Query (Maybe a)

    Gets the information about an entry in the database.

index :: a → [a] → Int

compute the position of an entry in a list fail, if given entry is not an element.

`sortByIndex :: [(Int,a)] → [a]`

> Sorts a given list by associated index .

`groupByIndex :: [(Int,a)] → [[a]]`

> Sorts a given list by associated index and group for identical index. Empty lists are added for missing indexes

`getDBInfos :: (Int → a → Dynamic) → [Int] → Query (Maybe [a])`

> Gets the information about a list of entries in the database.

`deleteDBEntry :: (Int → a → Dynamic) → Int → Transaction ()`

> Deletes an entry with a given key in the database. No error is raised if the given key does not exist.

`deleteDBEntries :: (Int → a → Dynamic) → [Int] → Transaction ()`

> Deletes all entries with the given keys in the database. No error is raised if some of the given keys does not exist.

`updateDBEntry :: (Int → a → Dynamic) → Int → a → Transaction ()`

> Overwrites an existing entry in the database.

`newDBEntry :: (Int → a → Dynamic) → a → Transaction Int`

> Stores a new entry in the database and return the key of the new entry.

`newDBKeyEntry :: (Int → a → Dynamic) → Int → a → Transaction ()`

> Stores a new entry in the database under a given key. The transaction fails if the key already exists.

`cleanDB :: (Int → a → Dynamic) → Transaction ()`

> Deletes all entries in the database.

A.2.35 Library KeyDatabaseSQLite

This module provides a general interface for databases (persistent predicates) where each entry consists of a key and an info part. The key is an integer and the info is arbitrary. All functions are parameterized with a dynamic predicate that takes an integer key as a first parameter.
This module reimplements the interface of the module `KeyDatabase` based on the SQLite database engine. In order to use it you need to have `sqlite3` in your `PATH` environment variable or adjust the value of the constant path<code>to</code>sqlite3.
Programs that use the `KeyDatabase` module can be adjusted to use this module instead by replacing the imports of `Dynamic`, `Database`, and `KeyDatabase` with this module and changing the

declarations of database predicates to use the function `persistentSQLite` instead of `dynamic` or `persistent`. This module redefines the types `Dynamic`, `Query`, and `Transaction` and although both implementations can be used in the same program (by importing modules qualified) they cannot be mixed.

Compared with the interface of `KeyDatabase`, this module lacks definitions for `index`, `sortByIndex`, `groupByIndex`, and `runTNA` and adds the functions `deleteDBEntries` and `closeDBHandles`.

Exported types:

```
type Key = Int
```

```
type KeyPred a = Int → a → Dynamic
```

```
data Query
```

Queries can read but not write to the database.

Exported constructors:

```
data Transaction
```

Transactions can modify the database and are executed atomically.

Exported constructors:

```
data Dynamic
```

Result type of database predicates.

Exported constructors:

```
data ColVal
```

Abstract type for value restrictions

Exported constructors:

```
data TError
```

The type of errors that might occur during a transaction.

Exported constructors:

- `TError :: TErrorKind → String → TError`

```
data TErrorKind
```

The various kinds of transaction errors.

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Exported constructors:

- `KeyNotExistsError :: TErrorKind`

- `NoRelationshipError :: TErrorKind`

- `DuplicateKeyError :: TErrorKind`

- `KeyRequiredError :: TErrorKind`

- `UniqueError :: TErrorKind`

- `MinError :: TErrorKind`

- `MaxError :: TErrorKind`

- `UserDefinedError :: TErrorKind`

- `ExecutionError :: TErrorKind`

Exported functions:

`runQ :: Query a → IO a`

> Runs a database query in the IO monad.

`transformQ :: (a → b) → Query a → Query b`

> Applies a function to the result of a database query.

`runT :: Transaction a → IO (Either a TError)`

> Runs a transaction atomically in the IO monad.
>
> Transactions are *immediate*, which means that locks are acquired on all databases as soon as the transaction is started. After one transaction is started, no other database connection will be able to write to the database or start a transaction. Other connections *can* read the database during a transaction of another process.
>
> The choice to use immediate rather than deferred transactions is conservative. It might also be possible to allow multiple simultaneous transactions that lock tables on the first database access (which is the default in SQLite). However this leads to unpredictable order in which locks are taken when multiple databases are involved. The current implementation fixes the locking order by sorting databases by their name and locking them in order immediately when a transaction begins.
>
> More information on [9] _transaction.html">transactions in SQLite is available online.

`runJustT :: Transaction a → IO a`

> Executes a possibly composed transaction on the current state of dynamic predicates as a single transaction. Similar to `runT` but a run-time error is raised if the execution of the transaction fails.

---

[9] `http://sqlite.org/lang`

`getDB :: Query a → Transaction a`

> Lifts a database query to the transaction type such that it can be composed with other transactions. Run-time errors that occur during the execution of the given query are transformed into transaction errors.

`returnT :: a → Transaction a`

> Returns the given value in a transaction that does not access the database.

`doneT :: Transaction ()`

> Returns the unit value in a transaction that does not access the database. Useful to ignore results when composing transactions.

`errorT :: TError → Transaction a`

> Aborts a transaction with an error.

`failT :: String → Transaction a`

> Aborts a transaction with a user-defined error message.

`(|>>=) :: Transaction a → (a → Transaction b) → Transaction b`

> Combines two transactions into a single transaction that executes both in sequence. The first transaction is executed, its result passed to the function which computes the second transaction, which is then executed to compute the final result.

> If the first transaction is aborted with an error, the second transaction is not executed.

`(|>>) :: Transaction a → Transaction b → Transaction b`

> Combines two transactions to execute them in sequence. The result of the first transaction is ignored.

`sequenceT :: [Transaction a] → Transaction [a]`

> Executes a list of transactions sequentially and computes a list of all results.

`sequenceT_ :: [Transaction a] → Transaction ()`

> Executes a list of transactions sequentially, ignoring their results.

`mapT :: (a → Transaction b) → [a] → Transaction [b]`

> Applies a function that yields transactions to all elements of a list, executes the transaction sequentially, and collects their results.

`mapT_ :: (a → Transaction b) → [a] → Transaction ()`

> Applies a function that yields transactions to all elements of a list, executes the transactions sequentially, and ignores their results.

`persistentSQLite :: String → String → [String] → Int → a → Dynamic`

> This function is used instead of `dynamic` or `persistent` to declare predicates whose facts are stored in an SQLite database.

> If the provided database or the table do not exist they are created automatically when the declared predicate is accessed for the first time.

> Multiple column names can be provided if the second argument of the predicate is a tuple with a matching arity. Other record types are not supported. If no column names are provided a table with a single column called `info` is created. Columns of name *rowid* are not supported and lead to a run-time error.

`existsDBKey :: (Int → a → Dynamic) → Int → Query Bool`

> Checks whether the predicate has an entry with the given key.

`allDBKeys :: (Int → a → Dynamic) → Query [Int]`

> Returns a list of all stored keys. Do not use this function unless the database is small.

`allDBInfos :: (Int → a → Dynamic) → Query [a]`

> Returns a list of all info parts of stored entries. Do not use this function unless the database is small.

`allDBKeyInfos :: (Int → a → Dynamic) → Query [(Int,a)]`

> Returns a list of all stored entries. Do not use this function unless the database is small.

`(@=) :: Int → a → ColVal`

> Constructs a value restriction for the column given as first argument

`someDBKeys :: (Int → a → Dynamic) → [ColVal] → Query [Int]`

> Returns a list of those stored keys where the corresponding info part matches the gioven value restriction. Safe to use even on large databases if the number of results is small.

`someDBInfos :: (Int → a → Dynamic) → [ColVal] → Query [a]`

> Returns a list of those info parts of stored entries that match the given value restrictions for columns. Safe to use even on large databases if the number of results is small.

`someDBKeyInfos :: (Int → a → Dynamic) → [ColVal] → Query [(Int,a)]`

> Returns a list of those entries that match the given value restrictions for columns. Safe to use even on large databases if the number of results is small.

`someDBKeyProjections :: (Int → a → Dynamic) → [Int] → [ColVal] → Query [(Int,b)]`

> Returns a list of column projections on those entries that match the given value restrictions for columns. Safe to use even on large databases if the number of results is small.

```
getDBInfo :: (Int → a → Dynamic) → Int → Query (Maybe a)
```

Queries the information stored under the given key. Yields `Nothing` if the given key is not present.

```
getDBInfos :: (Int → a → Dynamic) → [Int] → Query (Maybe [a])
```

Queries the information stored under the given keys. Yields `Nothing` if a given key is not present.

```
deleteDBEntry :: (Int → a → Dynamic) → Int → Transaction ()
```

Deletes the information stored under the given key. If the given key does not exist this transaction is silently ignored and no error is raised.

```
deleteDBEntries :: (Int → a → Dynamic) → [Int] → Transaction ()
```

Deletes the information stored under the given keys. No error is raised if (some of) the keys do not exist.

```
updateDBEntry :: (Int → a → Dynamic) → Int → a → Transaction ()
```

Updates the information stored under the given key. The transaction is aborted with a `KeyNotExistsError` if the given key is not present in the database.

```
newDBEntry :: (Int → a → Dynamic) → a → Transaction Int
```

Stores new information in the database and yields the newly generated key.

```
newDBKeyEntry :: (Int → a → Dynamic) → Int → a → Transaction ()
```

Stores a new entry in the database under a given key. The transaction fails if the key already exists.

```
cleanDB :: (Int → a → Dynamic) → Transaction ()
```

Deletes all entries from the database associated with a predicate.

```
closeDBHandles :: IO ()
```

Closes all database connections. Should be called when no more database access will be necessary.

```
showTError :: TError → String
```

Transforms a transaction error into a string.

A.2.36 Library KeyDB

This module provides a general interface for databases (persistent predicates) where each entry consists of a key and an info part. The key is an integer and the info is arbitrary. All functions are parameterized with a dynamic predicate that takes an integer key as a first parameter.
Remark: This library has been revised to the library `KeyDatabase`. Thus, it might not be further supported in the future.

Exported functions:

existsDBKey :: (Int → a → Dynamic) → Int → IO Bool

      Exists an entry with a given key in the database?

allDBKeys :: (Int → a → Dynamic) → IO [Int]

      Returns all keys of entries in the database.

getDBInfo :: (Int → a → Dynamic) → Int → IO a

      Gets the information about an entry in the database.

index :: a → [a] → Int

      compute the position of an entry in a list fail, if given entry is not an element.

sortByIndex :: [(Int,a)] → [a]

      Sorts a given list by associated index .

groupByIndex :: [(Int,a)] → [[a]]

      Sorts a given list by associated index and group for identical index. Empty lists are added for missing indexes

getDBInfos :: (Int → a → Dynamic) → [Int] → IO [a]

      Gets the information about a list of entries in the database.

deleteDBEntry :: (Int → a → Dynamic) → Int → IO ()

      Deletes an entry with a given key in the database.

updateDBEntry :: (Int → a → Dynamic) → Int → a → IO ()

      Overwrites an existing entry in the database.

newDBEntry :: (Int → a → Dynamic) → a → IO Int

      Stores a new entry in the database and return the key of the new entry.

cleanDB :: (Int → a → Dynamic) → IO ()

      Deletes all entries in the database.

A.2.37 Library List

Library with some useful operations on lists.

Exported functions:

`elemIndex :: a → [a] → Maybe Int`

    Returns the index `i` of the first occurrence of an element in a list as (`Just i`), otherwise `Nothing` is returned.

`elemIndices :: a → [a] → [Int]`

    Returns the list of indices of occurrences of an element in a list.

`find :: (a → Bool) → [a] → Maybe a`

    Returns the first element `e` of a list satisfying a predicate as (`Just e`), otherwise `Nothing` is returned.

`findIndex :: (a → Bool) → [a] → Maybe Int`

    Returns the index `i` of the first occurrences of a list element satisfying a predicate as (`Just i`), otherwise `Nothing` is returned.

`findIndices :: (a → Bool) → [a] → [Int]`

    Returns the list of indices of list elements satisfying a predicate.

`nub :: [a] → [a]`

    Removes all duplicates in the argument list.

`nubBy :: (a → a → Bool) → [a] → [a]`

    Removes all duplicates in the argument list according to an equivalence relation.

`delete :: a → [a] → [a]`

    Deletes the first occurrence of an element in a list.

`deleteBy :: (a → a → Bool) → a → [a] → [a]`

    Deletes the first occurrence of an element in a list according to an equivalence relation.

`(\\) :: [a] → [a] → [a]`

    Computes the difference of two lists.

`union :: [a] → [a] → [a]`

    Computes the union of two lists.

`unionBy :: (a → a → Bool) → [a] → [a] → [a]`

    Computes the union of two lists according to the given equivalence relation

`intersect :: [a] → [a] → [a]`

Computes the intersection of two lists.

`intersectBy :: (a → a → Bool) → [a] → [a] → [a]`

Computes the intersection of two lists according to the given equivalence relation

`intersperse :: a → [a] → [a]`

Puts a separator element between all elements in a list.

Example: `(intersperse 9 [1,2,3,4]) = [1,9,2,9,3,9,4]`

`intercalate :: [a] → [[a]] → [a]`

`intercalate xs xss` is equivalent to `(concat (intersperse xs xss))`. It inserts the list `xs` in between the lists in `xss` and concatenates the result.

`transpose :: [[a]] → [[a]]`

Transposes the rows and columns of the argument.

Example: `(transpose [[1,2,3],[4,5,6]]) = [[1,4],[2,5],[3,6]]`

`permutations :: [a] → [[a]]`

Returns the list of all permutations of the argument.

`partition :: (a → Bool) → [a] → ([a],[a])`

Partitions a list into a pair of lists where the first list contains those elements that satisfy the predicate argument and the second list contains the remaining arguments.

Example: `(partition (<4) [8,1,5,2,4,3]) = ([1,2,3],[8,5,4])`

`group :: [a] → [[a]]`

Splits the list argument into a list of lists of equal adjacent elements.

Example: `(group [1,2,2,3,3,3,4]) = [[1],[2,2],[3,3,3],[4]]`

`groupBy :: (a → a → Bool) → [a] → [[a]]`

Splits the list argument into a list of lists of related adjacent elements.

`splitOn :: [a] → [a] → [[a]]`

Breaks the second list argument into pieces separated by the first list argument, consuming the delimiter. An empty delimiter is invalid, and will cause an error to be raised.

`split :: (a → Bool) → [a] → [[a]]`

Splits a list into components delimited by separators, where the predicate returns True for a separator element. The resulting components do not contain the separators. Two adjacent separators result in an empty component in the output.

$$\text{split } (==\mathtt{a}) \text{ "aabbaca"} == [\text{""},\text{""},\text{"bb"},\text{"c"},\text{""}] \text{ split } (==\mathtt{a}) \text{ ""} == [\text{""}]$$

`inits :: [a] → [[a]]`

> Returns all initial segments of a list, starting with the shortest. Example: `inits [1,2,3] == [[],[1],[1,2],[1,2,3]]`

`tails :: [a] → [[a]]`

> Returns all final segments of a list, starting with the longest. Example: `tails [1,2,3] == [[1,2,3],[2,3],[3],[]]`

`replace :: a → Int → [a] → [a]`

> Replaces an element in a list.

`isPrefixOf :: [a] → [a] → Bool`

> Checks whether a list is a prefix of another.

`isSuffixOf :: [a] → [a] → Bool`

> Checks whether a list is a suffix of another.

`isInfixOf :: [a] → [a] → Bool`

> Checks whether a list is contained in another.

`sortBy :: (a → a → Bool) → [a] → [a]`

> Sorts a list w.r.t. an ordering relation by the insertion method.

`insertBy :: (a → a → Bool) → a → [a] → [a]`

> Inserts an object into a list according to an ordering relation.

`last :: [a] → a`

> Returns the last element of a non-empty list.

`init :: [a] → [a]`

> Returns the input list with the last element removed.

`sum :: [Int] → Int`

> Returns the sum of a list of integers.

`product :: [Int] → Int`

> Returns the product of a list of integers.

`maximum :: [a] → a`

> Returns the maximum of a non-empty list.

maximumBy :: (a → a → Ordering) → [a] → a

    Returns the maximum of a non-empty list according to the given comparison function

minimum :: [a] → a

    Returns the minimum of a non-empty list.

minimumBy :: (a → a → Ordering) → [a] → a

    Returns the minimum of a non-empty list according to the given comparison function

scanl :: (a → b → a) → a → [b] → [a]

    scanl is similar to foldl, but returns a list of successive reduced values from the left:
scanl f z [x1, x2, ...] == [z, z f x1, (z f x1) f x2, ...]

scanl1 :: (a → a → a) → [a] → [a]

    scanl1 is a variant of scanl that has no starting value argument: scanl1 f [x1, x2, ...]
== [x1, x1 f x2, ...]

scanr :: (a → b → b) → b → [a] → [b]

    scanr is the right-to-left dual of scanl.

scanr1 :: (a → a → a) → [a] → [a]

    scanr1 is a variant of scanr that has no starting value argument.

mapAccumL :: (a → b → (a,c)) → a → [b] → (a,[c])

    The mapAccumL function behaves like a combination of map and foldl; it applies a
function to each element of a list, passing an accumulating parameter from left to right,
and returning a final value of this accumulator together with the new list.

mapAccumR :: (a → b → (a,c)) → a → [b] → (a,[c])

    The mapAccumR function behaves like a combination of map and foldr; it applies a
function to each element of a list, passing an accumulating parameter from right to left,
and returning a final value of this accumulator together with the new list.

cycle :: [a] → [a]

    Builds an infinite list from a finite one.

unfoldr :: (a → Maybe (b,a)) → a → [b]

    Builds a list from a seed value.

A.2.38 Library Maybe

Library with some useful functions on the Maybe datatype.

Exported functions:

isJust :: Maybe a → Bool

> Return `True` iff the argument is of the form `Just _`.

isNothing :: Maybe a → Bool

> Return `True` iff the argument is of the form `Nothing`.

fromJust :: Maybe a → a

> Extract the argument from the `Just` constructor and throw an error if the argument is `Nothing`.

fromMaybe :: a → Maybe a → a

> Extract the argument from the `Just` constructor or return the provided default value if the argument is `Nothing`.

listToMaybe :: [a] → Maybe a

> Return `Nothing` on an empty list or `Just x` where `x` is the first list element.

maybeToList :: Maybe a → [a]

> Return an empty list for `Nothing` or a singleton list for `Just x`.

catMaybes :: [Maybe a] → [a]

> Return the list of all `Just` values.

mapMaybe :: (a → Maybe b) → [a] → [b]

> Apply a function which may throw out elements using the `Nothing` constructor to a list of elements.

(>>-) :: Maybe a → (a → Maybe b) → Maybe b

> Monadic bind for Maybe. Maybe can be interpreted as a monad where Nothing is interpreted as the error case by this monadic binding.

sequenceMaybe :: [Maybe a] → Maybe [a]

> Monadic `sequence` for `Maybe`.

mapMMaybe :: (a → Maybe b) → [a] → Maybe [b]

> Monadic `map` for `Maybe`.

mplus :: Maybe a → Maybe a → Maybe a

> Combine two `Maybes`, returning the first `Just` value, if any.

A.2.39 Library NamedSocket

Library to support network programming with sockets that are addressed by symbolic names. In contrast to raw sockets (see library `Socket`), this library uses the Curry Port Name Server to provide sockets that are addressed by symbolic names rather than numbers.
In standard applications, the server side uses the operations `listenOn` and `socketAccept` to provide some service on a named socket, and the client side uses the operation `connectToSocket` to request a service.

Exported types:

`data Socket`

> Abstract type for named sockets.

Exported constructors:

Exported functions:

`listenOn :: String → IO Socket`

> Creates a server side socket with a symbolic name.

`socketAccept :: Socket → IO (String,Handle)`

> Returns a connection of a client to a socket. The connection is returned as a pair consisting of a string identifying the client (the format of this string is implementation-dependent) and a handle to a stream communication with the client. The handle is both readable and writable.

`waitForSocketAccept :: Socket → Int → IO (Maybe (String,Handle))`

> Waits until a connection of a client to a socket is available. If no connection is available within the time limit, it returns Nothing, otherwise the connection is returned as a pair consisting of a string identifying the client (the format of this string is implementation-dependent) and a handle to a stream communication with the client.

`sClose :: Socket → IO ()`

> Closes a server socket.

`socketName :: Socket → String`

> Returns a the symbolic name of a named socket.

`connectToSocketRepeat :: Int → IO a → Int → String → IO (Maybe Handle)`

> Waits for connection to a Unix socket with a symbolic name. In contrast to `connectToSocket`, this action waits until the socket has been registered with its symbolic name.

connectToSocketWait :: String → IO Handle

> Waits for connection to a Unix socket with a symbolic name and return the handle of
> the connection. This action waits (possibly forever) until the socket with the symbolic
> name is registered.

connectToSocket :: String → IO Handle

> Creates a new connection to an existing(!) Unix socket with a symbolic name. If the
> symbolic name is not registered, an error is reported.

A.2.40 Library Parser

Library with functional logic parser combinators.
Adapted from: Rafael Caballero and Francisco J. Lopez-Fraguas: A Functional Logic Perspective
of Parsing. In Proc. FLOPS'99, Springer LNCS 1722, pp. 85-99, 1999

Exported types:

type Parser a = [a] → [a]

type ParserRep a b = a → [b] → [b]

Exported functions:

(<|>) :: ([a] → [a]) → ([a] → [a]) → [a] → [a]

> Combines two parsers without representation in an alternative manner.

(<||>) :: (a → [b] → [b]) → (a → [b] → [b]) → a → [b] → [b]

> Combines two parsers with representation in an alternative manner.

(<*>) :: ([a] → [a]) → ([a] → [a]) → [a] → [a]

> Combines two parsers (with or without representation) in a sequential manner.

(>>>) :: ([a] → [a]) → b → b → [a] → [a]

> Attaches a representation to a parser without representation.

empty :: [a] → [a]

> The empty parser which recognizes the empty word.

terminal :: a → [a] → [a]

> A parser recognizing a particular terminal symbol.

```
satisfy :: (a → Bool) → a → [a] → [a]
```

> A parser (with representation) recognizing a terminal satisfying a given predicate.

```
star :: (a → [b] → [b]) → [a] → [b] → [b]
```

> A star combinator for parsers. The returned parser repeats zero or more times a parser
> p with representation and returns the representation of all parsers in a list.

```
some :: (a → [b] → [b]) → [a] → [b] → [b]
```

> A some combinator for parsers. The returned parser repeats the argument parser (with
> representation) at least once.

A.2.41   Library Ports

Library for distributed programming with ports.   This paper[10]   contains a description of the basic
ideas behind this library.

Exported types:

```
data Port
```

> The internal constructor for the port datatype is not visible to the user.

Exported constructors:

```
data SP_Msg
```

> A "stream port" is an adaption of the port concept to model the communication with
> bidirectional streams, i.e., a stream port is a port connection to a bidirectional stream
> (e.g., opened by openProcessPort) where the communication is performed via the fol-
> lowing stream port messages.

Exported constructors:

- `SP_Put :: String → SP_Msg`

  `SP_Put s`

  – write the argument s on the output stream

- `SP_GetLine :: String → SP_Msg`

  `SP_GetLine s`

  – unify the argument s with the next text line of the input stream

- `SP_GetChar :: Char → SP_Msg`

  `SP_GetChar c`

– unify the argument c with the next character of the input stream

- **SP_EOF :: Bool → SP_Msg**

  SP_EOF b

  – unify the argument b with True if we are at the end of the input stream, otherwise with False

- **SP_Close :: SP_Msg**

  SP_Close

  – close the input/output streams

Exported functions:

openPort :: Port a → [a] → Success

  Opens an internal port for communication.

send :: a → Port a → Success

  Sends a message to a port.

doSend :: a → Port a → IO ()

  I/O action that sends a message to a port.

ping :: Int → Port a → IO (Maybe Int)

  Checks whether port p is still reachable.

timeoutOnStream :: Int → [a] → Maybe [a]

  Checks for instantiation of a stream within some amount of time.

openProcessPort :: String → IO (Port SP_Msg)

  Opens a new connection to a process that executes a shell command.

openNamedPort :: String → IO [a]

  Opens an external port with a symbolic name.

connectPortRepeat :: Int → IO a → Int → String → IO (Maybe (Port b))

  Waits for connection to an external port. In contrast to connectPort, this action waits until the external port has been registered with its symbolic name.

connectPortWait :: String → IO (Port a)

  Waits for connection to an external port and return the connected port. This action waits (possibly forever) until the external port is registered.

`connectPort :: String → IO (Port a)`

> Connects to an external port. The external port must be already registered, otherwise an error is reported.

`choiceSPEP :: Port SP_Msg → [a] → Either String [a]`

> This function implements a committed choice over the receiving of messages via a stream port and an external port.
>
> *Note that the implementation of choiceSPEP works only with Sicstus-Prolog 3.8.5 or higher (due to a bug in previous versions of Sicstus-Prolog).*

`newObject :: (a → [b] → Success) → a → Port b → Success`

> Creates a new object (of type State `-> [msg] -> Success`) with an initial state and a port to which messages for this object can be sent.

`newNamedObject :: (a → [b] → Success) → a → String → IO ()`

> Creates a new object (of type State `-> [msg] -> Success`) with a symbolic port name to which messages for this object can be sent.

`runNamedServer :: ([a] → IO b) → String → IO b`

> Runs a new server (of type `[msg] -> IO a`) on a named port to which messages can be sent.

A.2.42   Library Pretty

This library provides pretty printing combinators. The interface is that of Daan Leijen's library linear-time, bounded implementation by Olaf Chitil. Note that the implementation of `fill` and `fillBreak` is not linear-time bounded Support of ANSI escape codes for formatting and colorisation of documents in text terminals (see https://en.wikipedia.org/wiki/ANSI*escape*code)

Exported types:

`data Doc`

> The abstract data type Doc represents pretty documents.

Exported constructors:

Exported functions:

`pPrint :: Doc → String`

> Standard printing with a column length of 80.

`empty :: Doc`

> The empty document

`isEmpty :: Doc → Bool`

Is the document empty?

`text :: String → Doc`

The document (`text s`) contains the literal string `s`. The string shouldn't contain any newline (`\n`) characters. If the string contains newline characters, the function `string` should be used.

`linesep :: String → Doc`

The document (`linesep s`) advances to the next line and indents to the current nesting level. Document (`linesep s`) behaves like (`text s`) if the line break is undone by `group`.

`hardline :: Doc`

The document `hardline` advances to the next line and indents to the current nesting level. `hardline` cannot be undone by `group`.

`line :: Doc`

The document `line` advances to the next line and indents to the current nesting level. Document `line` behaves like (`text " "`) if the line break is undone by `group`.

`linebreak :: Doc`

The document `linebreak` advances to the next line and indents to the current nesting level. Document `linebreak` behaves like (`text ""`) if the line break is undone by `group`.

`softline :: Doc`

The document `softline` behaves like `space` if the resulting output fits the page, otherwise it behaves like `line`. `softline = group line`

`softbreak :: Doc`

The document `softbreak` behaves like (`text ""`) if the resulting output fits the page, otherwise it behaves like `line`. `softbreak = group linebreak`

`group :: Doc → Doc`

The combinator `group` is used to specify alternative layouts. The document (`group x`) undoes all line breaks in document `x`. The resulting line is added to the current line if that fits the page. Otherwise, the document `x` is rendered without any changes.

`nest :: Int → Doc → Doc`

The document (`nest i d`) renders document `d` with the current indentation level increased by `i` (See also `hang`, `align` and `indent`).

```
nest 2 (text "hello" $$ text "world") $$ text "!"
```

outputs as:

```
hello
  world
!
```

`hang :: Int → Doc → Doc`

The combinator `hang` implements hanging indentation. The document (`hang i d`) renders document `d` with a nesting level set to the current column plus `i`. The following example uses hanging indentation for some text:

```
test = hang 4
          (fillSep
             (map text
                  (words "the hang combinator indents these words !")))
```

Which lays out on a page with a width of 20 characters as:

```
the hang combinator
    indents these
    words !
```

The hang combinator is implemented as:

```
hang i x  = align (nest i x)
```

`align :: Doc → Doc`

The document (`align d`) renders document `d` with the nesting level set to the current column. It is used for example to implement hang`.

As an example, we will put a document right above another one, regardless of the current nesting level:

```
x $$ y  = align (x $$ y)
test    = text "hi" <+> (text "nice" $$ text "world")
```

which will be layed out as:

```
hi nice
   world
```

```
indent :: Int → Doc → Doc
```

The document (`indent i d`) indents document `d` with `i` spaces.

```
test  = indent 4 (fillSep (map text
          (words "the indent combinator indents these words !")))
```

Which lays out with a page width of 20 as:

```
the indent
combinator
indents these
words !
```

```
combine :: Doc → Doc → Doc → Doc
```

The document (`combine c d1 d2`) combines document `d1` and `d2` with document `c` in between using (`<>`) with identity `empty`. Thus, the following equations hold.

```
combine c d1    empty == d1
combine c empty d2    == d2
combine c d1    d2    == d1 <> c <> d2 if neither d1 nor d2 are empty
```

```
(<>) :: Doc → Doc → Doc
```

The document (`x <> y`) concatenates document `x` and document `y`. It is an associative operation having `empty` as a left and right unit.

```
(<+>) :: Doc → Doc → Doc
```

The document (`x <+> y`) concatenates document `x` and `y` with a `space` in between with identity `empty`.

```
($$) :: Doc → Doc → Doc
```

The document (`x $$ y`) concatenates document `x` and `y` with a `line` in between with identity `empty`.

```
(<$+$>) :: Doc → Doc → Doc
```

The document (`x <$+$> y`) concatenates document `x` and `y` with a blank line in between with identity `empty`.

```
(</>) :: Doc → Doc → Doc
```

The document (`x </> y`) concatenates document `x` and `y` with a `softline` in between with identity `empty`. This effectively puts `x` and `y` either next to each other (with a `space` in between) or underneath each other.

(<$$>) :: Doc → Doc → Doc

The document (x <$$> y) concatenates document x and y with a `linebreak` in between with identity `empty`.

(<//>) :: Doc → Doc → Doc

The document (x <//> y) concatenates document x and y with a `softbreak` in between with identity `empty`. This effectively puts x and y either right next to each other or underneath each other.

(<$!$>) :: Doc → Doc → Doc

The document (x <$!$> y) concatenates document x and y with a `hardline` in between with identity `empty`. This effectively puts x and y underneath each other.

compose :: (Doc → Doc → Doc) → [Doc] → Doc

The document (`compose f xs`) concatenates all documents xs with function f. Function f should be like (<+>), ($$) and so on.

hsep :: [Doc] → Doc

The document (`hsep xs`) concatenates all documents xs horizontally with (<+>).

vsep :: [Doc] → Doc

The document (`vsep xs`) concatenates all documents xs vertically with ($$). If a group undoes the line breaks inserted by `vsep`, all documents are separated with a `space`.

```
someText = map text (words ("text to lay out"))
test     = text "some" <+> vsep someText
```

This is layed out as:

```
some text
to
lay
out
```

The `align` combinator can be used to align the documents under their first element:

```
test     = text "some" <+> align (vsep someText)
```

This is printed as:

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```
some text
     to
     lay
     out
```

vsepBlank :: [Doc] → Doc

> The document `vsep xs` concatenates all documents `xs` vertically with (`<$+$>`). If a group undoes the line breaks inserted by `vsepBlank`, all documents are separated with a `space`.

fillSep :: [Doc] → Doc

> The document (`fillSep xs`) concatenates documents `xs` horizontally with (`</>`) as long as its fits the page, than inserts a `line` and continues doing that for all documents in `xs`. `fillSep xs = foldr (</>) empty xs`

sep :: [Doc] → Doc

> The document (`sep xs`) concatenates all documents `xs` either horizontally with (`<+>`), if it fits the page, or vertically with (`$$`). `sep xs = group (vsep xs)`

hcat :: [Doc] → Doc

> The document (`hcat xs`) concatenates all documents `xs` horizontally with (`<>`).

vcat :: [Doc] → Doc

> The document (`vcat xs`) concatenates all documents `xs` vertically with (`<$$>`). If a `group` undoes the line breaks inserted by `vcat`, all documents are directly concatenated.

fillCat :: [Doc] → Doc

> The document (`fillCat xs`) concatenates documents `xs` horizontally with (`<//>`) as long as its fits the page, than inserts a `linebreak` and continues doing that for all documents in `xs`. `fillCat xs = foldr (<//>) empty xs`

cat :: [Doc] → Doc

> The document (`cat xs`) concatenates all documents `xs` either horizontally with (`<>`), if it fits the page, or vertically with (`<$$>`). `cat xs = group (vcat xs)`

punctuate :: Doc → [Doc] → [Doc]

> (`punctuate p xs`) concatenates all documents `xs` with document `p` except for the last document.
>
> ```
> someText = map text ["words","in","a","tuple"]
> test     = parens (align (cat (punctuate comma someText)))
> ```

This is layed out on a page width of 20 as:

```
(words,in,a,tuple)
```

But when the page width is 15, it is layed out as:

```
(words,
 in,
 a,
 tuple)
```

(If you want put the commas in front of their elements instead of at the end, you should use `tupled` or, in general, `encloseSep`.)

`encloseSep :: Doc → Doc → Doc → [Doc] → Doc`

The document (`encloseSep l r s xs`) concatenates the documents `xs` seperated by `s` and encloses the resulting document by `l` and `r`. The documents are rendered horizontally if that fits the page. Otherwise they are aligned vertically. All seperators are put in front of the elements.

For example, the combinator `list` can be defined with `encloseSep`:

```
list xs  = encloseSep lbracket rbracket comma xs
test     = text "list" <+> (list (map int [10,200,3000]))
```

Which is layed out with a page width of 20 as:

```
list [10,200,3000]
```

But when the page width is 15, it is layed out as:

```
list [10
     ,200
     ,3000]
```

`encloseSepSpaced :: Doc → Doc → Doc → [Doc] → Doc`

The document (`encloseSepSpaced l r s xs`) concatenates the documents `xs` seperated by `s` and encloses the resulting document by `l` and `r`. In addition, after each occurrence of `s`, after `l`, and before `r`, a `space` is inserted. The documents are rendered horizontally if that fits the page. Otherwise they are aligned vertically. All seperators are put in front of the elements.

`hEncloseSep :: Doc → Doc → Doc → [Doc] → Doc`

The document (`hEncloseSep l r s xs`) concatenates the documents `xs` seperated by `s` and encloses the resulting document by `l` and `r`.

The documents are rendered horizontally.

`fillEncloseSep :: Doc → Doc → Doc → [Doc] → Doc`

The document (`fillEncloseSep l r s xs`) concatenates the documents `xs` seperated by `s` and encloses the resulting document by `l` and `r`.

The documents are rendered horizontally if that fits the page. Otherwise they are aligned vertically. All seperators are put in front of the elements.

`fillEncloseSepSpaced :: Doc → Doc → Doc → [Doc] → Doc`

The document (`fillEncloseSepSpaced l r s xs`) concatenates the documents `xs` seperated by `s` and encloses the resulting document by `l` and `r`. In addition, after each occurrence of `s`, after `l`, and before `r`, a `space` is inserted.

The documents are rendered horizontally if that fits the page. Otherwise, they are aligned vertically. All seperators are put in front of the elements.

`list :: [Doc] → Doc`

The document (`list xs`) comma seperates the documents `xs` and encloses them in square brackets. The documents are rendered horizontally if that fits the page. Otherwise they are aligned vertically. All comma seperators are put in front of the elements.

`listSpaced :: [Doc] → Doc`

Spaced version of `list`

`set :: [Doc] → Doc`

The document (`set xs`) comma seperates the documents `xs` and encloses them in braces. The documents are rendered horizontally if that fits the page. Otherwise they are aligned vertically. All comma seperators are put in front of the elements.

`setSpaced :: [Doc] → Doc`

Spaced version of `set`

`tupled :: [Doc] → Doc`

The document (`tupled xs`) comma seperates the documents `xs` and encloses them in parenthesis. The documents are rendered horizontally if that fits the page. Otherwise they are aligned vertically. All comma seperators are put in front of the elements.

`tupledSpaced :: [Doc] → Doc`

Spaced version of `tupled`

`semiBraces :: [Doc] → Doc`

The document (`semiBraces` `xs`) seperates the documents `xs` with semi colons and encloses them in braces. The documents are rendered horizontally if that fits the page. Otherwise they are aligned vertically. All semi colons are put in front of the elements.

`semiBracesSpaced :: [Doc]` $\rightarrow$ `Doc`

Spaced version of `semiBraces`

`enclose :: Doc` $\rightarrow$ `Doc` $\rightarrow$ `Doc` $\rightarrow$ `Doc`

The document (`enclose l r x`) encloses document `x` between documents `l` and `r` using ($<>$). `enclose l r x = l <> x <> r`

`squotes :: Doc` $\rightarrow$ `Doc`

Document (`squotes x`) encloses document `x` with single quotes `"'"`.

`dquotes :: Doc` $\rightarrow$ `Doc`

Document (`dquotes x`) encloses document `x` with double quotes.

`bquotes :: Doc` $\rightarrow$ `Doc`

Document (`bquotes x`) encloses document `x` with back quotes `"`"`.

`parens :: Doc` $\rightarrow$ `Doc`

Document (`parens x`) encloses document `x` in parenthesis, `"("` and `")"`.

`parensIf :: Bool` $\rightarrow$ `Doc` $\rightarrow$ `Doc`

Document (`parensIf x`) encloses document `x` in parenthesis,`"("` and `")"`, iff the condition is true.

`angles :: Doc` $\rightarrow$ `Doc`

Document (`angles x`) encloses document `x` in angles, `"<"` and `">"`.

`braces :: Doc` $\rightarrow$ `Doc`

Document (`braces x`) encloses document `x` in braces, `"{"` and `"}"`.

`brackets :: Doc` $\rightarrow$ `Doc`

Document (`brackets x`) encloses document `x` in square brackets, `"["` and `"]"`.

`char :: Char` $\rightarrow$ `Doc`

The document (`char c`) contains the literal character `c`. The character should not be a newline (\n), the function `line` should be used for line breaks.

`string :: String` $\rightarrow$ `Doc`

The document (string s) concatenates all characters in s using line for newline characters and char for all other characters. It is used instead of text whenever the text contains newline characters.

int :: Int → Doc

The document (int i) shows the literal integer i using text.

float :: Float → Doc

The document (float f) shows the literal float f using text.

lparen :: Doc

The document lparen contains a left parenthesis, "(".

rparen :: Doc

The document rparen contains a right parenthesis, ")".

langle :: Doc

The document langle contains a left angle, "<".

rangle :: Doc

The document rangle contains a right angle, ">".

lbrace :: Doc

The document lbrace contains a left brace, "{".

rbrace :: Doc

The document rbrace contains a right brace, "}".

lbracket :: Doc

The document lbracket contains a left square bracket, "[".

rbracket :: Doc

The document rbracket contains a right square bracket, "]".

squote :: Doc

The document squote contains a single quote, "'".

dquote :: Doc

The document dquote contains a double quote.

semi :: Doc

The document semi contains a semi colon, ";".

```
colon :: Doc
```

 The document `colon` contains a colon, `":"`.

```
comma :: Doc
```

 The document `comma` contains a comma, `","`.

```
space :: Doc
```

 The document `space` contains a single space, `" "`.

```
x <+> y    = x <> space <> y
```

```
dot :: Doc
```

 The document `dot` contains a single dot, `"."`.

```
backslash :: Doc
```

 The document `backslash` contains a back slash, `"\"`.

```
equals :: Doc
```

 The document `equals` contains an equal sign, `"="`.

```
larrow :: Doc
```

 The document `larrow` contains a left arrow sign, `"<-"`.

```
rarrow :: Doc
```

 The document `rarrow` contains a right arrow sign, `"->"`.

```
doubleArrow :: Doc
```

 The document `doubleArrow` contains an double arrow sign, `"=>"`.

```
doubleColon :: Doc
```

 The document `doubleColon` contains a double colon sign, `"::"`.

```
bar :: Doc
```

 The document `bar` contains a vertical bar sign, `"|"`.

```
at :: Doc
```

 The document `at` contains an at sign, `"@"`.

```
tilde :: Doc
```

 The document `tilde` contains a tilde sign, `"~"`.

```
fill :: Int → Doc → Doc
```

The document (`fill i d`) renders document `d`. It than appends `space`s until the width is equal to `i`. If the width of `d` is already larger, nothing is appended. This combinator is quite useful in practice to output a list of bindings. The following example demonstrates this.

```
types  = [("empty","Doc")
         ,("nest","Int -> Doc -> Doc")
         ,("linebreak","Doc")]

ptype (name,tp)
       = fill 6 (text name) <+> text "::" <+> text tp

test   = text "let" <+> align (vcat (map ptype types))
```

Which is layed out as:

```
let empty  :: Doc
    nest    :: Int -> Doc -> Doc
    linebreak :: Doc
```

Note that `fill` is not guaranteed to be linear-time bounded since it has to compute the width of a document before pretty printing it

`fillBreak :: Int → Doc → Doc`

The document (`fillBreak i d`) first renders document `d`. It than appends `space`s until the width is equal to `i`. If the width of `d` is already larger than `i`, the nesting level is increased by `i` and a `line` is appended. When we redefine `ptype` in the previous example to use `fillBreak`, we get a useful variation of the previous output:

```
ptype (name,tp)
       = fillBreak 6 (text name) <+> text "::" <+> text tp
```

The output will now be:

```
let empty  :: Doc
    nest    :: Int -> Doc -> Doc
    linebreak
           :: Doc
```

Note that `fillBreak` is not guaranteed to be linear-time bounded since it has to compute the width of a document before pretty printing it

`bold :: Doc → Doc`

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The document (`bold` `d`) displays document `d` with bold text

`faint :: Doc → Doc`

The document (`faint` `d`) displays document `d` with faint text

`blinkSlow :: Doc → Doc`

The document (`blinkSlow` `d`) displays document `d` with slowly blinking text (rarely supported)

`blinkRapid :: Doc → Doc`

The document (`blinkRapid` `d`) displays document `d` with rapidly blinking text (rarely supported)

`italic :: Doc → Doc`

The document (`italic` `d`) displays document `d` with italicized text (rarely supported)

`underline :: Doc → Doc`

The document (`underline` `d`) displays document `d` with underlined text

`crossout :: Doc → Doc`

The document (`crossout` `d`) displays document `d` with crossed out text

`inverse :: Doc → Doc`

The document (`inverse` `d`) displays document `d` with inversed coloring, i.e. use text color of `d` as background color and background color of `d` as text color

`black :: Doc → Doc`

The document (`black` `d`) displays document `d` with black text color

`red :: Doc → Doc`

The document (`red` `d`) displays document `d` with red text color

`green :: Doc → Doc`

The document (`green` `d`) displays document `d` with green text color

`yellow :: Doc → Doc`

The document (`yellow` `d`) displays document `d` with yellow text color

`blue :: Doc → Doc`

The document (`blue` `d`) displays document `d` with blue text color

`magenta :: Doc → Doc`

The document (`magenta d`) displays document `d` with magenta text color

`cyan :: Doc → Doc`

    The document (`cyan d`) displays document `d` with cyan text color

`white :: Doc → Doc`

    The document (`white d`) displays document `d` with white text color

`bgBlack :: Doc → Doc`

    The document (`bgBlack d`) displays document `d` with black background color

`bgRed :: Doc → Doc`

    The document (`bgRed d`) displays document `d` with red background color

`bgGreen :: Doc → Doc`

    The document (`bgGreen d`) displays document `d` with green background color

`bgYellow :: Doc → Doc`

    The document (`bgYellow d`) displays document `d` with yellow background color

`bgBlue :: Doc → Doc`

    The document (`bgBlue d`) displays document `d` with blue background color

`bgMagenta :: Doc → Doc`

    The document (`bgMagenta d`) displays document `d` with magenta background color

`bgCyan :: Doc → Doc`

    The document (`bgCyan d`) displays document `d` with cyan background color

`bgWhite :: Doc → Doc`

    The document (`bgWhite d`) displays document `d` with white background color

`pretty :: Int → Doc → String`

    (`pretty w d`) pretty prints document `d` with a page width of `w` characters

A.2.43   Library Profile

Preliminary library to support profiling.

Exported types:

`data ProcessInfo`

> The data type for representing information about the state of a Curry process.

Exported constructors:

- `RunTime :: ProcessInfo`

  RunTime

  – the run time in milliseconds

- `ElapsedTime :: ProcessInfo`

  ElapsedTime

  – the elapsed time in milliseconds

- `Memory :: ProcessInfo`

  Memory

  – the total memory in bytes

- `Code :: ProcessInfo`

  Code

  – the size of the code area in bytes

- `Stack :: ProcessInfo`

  Stack

  – the size of the local stack for recursive functions in bytes

- `Heap :: ProcessInfo`

  Heap

  – the size of the heap to store term structures in bytes

- `Choices :: ProcessInfo`

  Choices

  – the size of the choicepoint stack

- `GarbageCollections :: ProcessInfo`

  GarbageCollections

  – the number of garbage collections performed

Exported functions:

`getProcessInfos :: IO [(ProcessInfo,Int)]`

>   Returns various informations about the current state of the Curry process. Note that the returned values are very implementation dependent so that one should interpret them with care!

`garbageCollectorOff :: IO ()`

>   Turns off the garbage collector of the run-time system (if possible). This could be useful to get more precise data of memory usage.

`garbageCollectorOn :: IO ()`

>   Turns on the garbage collector of the run-time system (if possible).

`garbageCollect :: IO ()`

>   Invoke the garbage collector (if possible). This could be useful before run-time critical operations.

`showMemInfo :: [(ProcessInfo,Int)]` → `String`

>   Get a human readable version of the memory situation from the process infos.

`printMemInfo :: IO ()`

>   Print a human readable version of the current memory situation of the Curry process.

`profileTime :: IO a` → `IO a`

>   Print the time needed to execute a given IO action.

`profileTimeNF :: a` → `IO ()`

>   Evaluates the argument to normal form and print the time needed for this evaluation.

`profileSpace :: IO a` → `IO a`

>   Print the time and space needed to execute a given IO action. During the executation, the garbage collector is turned off to get the total space usage.

`profileSpaceNF :: a` → `IO ()`

>   Evaluates the argument to normal form and print the time and space needed for this evaluation. During the evaluation, the garbage collector is turned off to get the total space usage.

`evalTime :: a` → `a`

>   Evaluates the argument to normal form (and return the normal form) and print the time needed for this evaluation on standard error. Included for backward compatibility only, use profileTime!

`evalSpace :: a` → `a`

>   Evaluates the argument to normal form (and return the normal form) and print the time and space needed for this evaluation on standard error. During the evaluation, the garbage collector is turned off. Included for backward compatibility only, use profileSpace!

A.2.44   Library Prolog

A library defining a representation for Prolog programs together with a simple pretty printer. It does not cover all aspects of Prolog but might be useful for applications generating Prolog programs.

Exported types:

`data PlClause`

> A Prolog clause is either a program clause consisting of a head and a body, or a directive or a query without a head.

Exported constructors:

- `PlClause :: String → [PlTerm] → [PlGoal] → PlClause`

- `PlDirective :: [PlGoal] → PlClause`

- `PlQuery :: [PlGoal] → PlClause`

`data PlGoal`

> A Prolog goal is a literal, a negated goal, or a conditional.

Exported constructors:

- `PlLit :: String → [PlTerm] → PlGoal`

- `PlNeg :: [PlGoal] → PlGoal`

- `PlCond :: [PlGoal] → [PlGoal] → [PlGoal] → PlGoal`

`data PlTerm`

> A Prolog term is a variable, atom, number, or structure.

Exported constructors:

- `PlVar :: String → PlTerm`

- `PlAtom :: String → PlTerm`

- `PlInt :: Int → PlTerm`

- `PlFloat :: Float → PlTerm`

- `PlStruct :: String → [PlTerm] → PlTerm`

Exported functions:

plList :: [PlTerm] → PlTerm

    A Prolog list of Prolog terms.

showPlProg :: [PlClause] → String

    Shows a Prolog program in standard Prolog syntax.

showPlClause :: PlClause → String

showPlGoals :: [PlGoal] → String

showPlGoal :: PlGoal → String

showPlTerm :: PlTerm → String

A.2.45 Library PropertyFile

A library to read and update files containing properties in the usual equational syntax, i.e., a property is defined by a line of the form `prop=value` where `prop` starts with a letter. All other lines (e.g., blank lines or lines starting with # are considered as comment lines and are ignored.

Exported functions:

readPropertyFile :: String → IO [(String,String)]

    Reads a property file and returns the list of properties. Returns empty list if the property file does not exist.

updatePropertyFile :: String → String → String → IO ()

    Update a property in a property file or add it, if it is not already there.

A.2.46 Library Read

Library with some functions for reading special tokens.
This library is included for backward compatibility. You should use the library ReadNumeric which provides a better interface for these functions.

Exported functions:

`readNat :: String → Int`

> Read a natural number in a string. The string might contain leadings blanks and the the number is read up to the first non-digit.

`readInt :: String → Int`

> Read a (possibly negative) integer in a string. The string might contain leadings blanks and the the integer is read up to the first non-digit.

`readHex :: String → Int`

> Read a hexadecimal number in a string. The string might contain leadings blanks and the the integer is read up to the first non-heaxdecimal digit.

A.2.47 Library ReadNumeric

Library with some functions for reading and converting numeric tokens.

Exported functions:

`readInt :: String → Maybe (Int,String)`

> Read a (possibly negative) integer as a first token in a string. The string might contain leadings blanks and the integer is read up to the first non-digit. If the string does not start with an integer token, `Nothing` is returned, otherwise the result is `Just (v, s)`, where v is the value of the integer and s is the remaing string without the integer token.

`readNat :: String → Maybe (Int,String)`

> Read a natural number as a first token in a string. The string might contain leadings blanks and the number is read up to the first non-digit. If the string does not start with a natural number token, `Nothing` is returned, otherwise the result is `Just (v, s)` where v is the value of the number and s is the remaing string without the number token.

`readHex :: String → Maybe (Int,String)`

> Read a hexadecimal number as a first token in a string. The string might contain leadings blanks and the number is read up to the first non-hexadecimal digit. If the string does not start with a hexadecimal number token, `Nothing` is returned, otherwise the result is `Just (v, s)` where v is the value of the number and s is the remaing string without the number token.

`readOct :: String → Maybe (Int,String)`

> Read an octal number as a first token in a string. The string might contain leadings blanks and the number is read up to the first non-octal digit. If the string does not start with an octal number token, `Nothing` is returned, otherwise the result is `Just (v, s)` where v is the value of the number and s is the remaing string without the number token.

A.2.48 Library ReadShowTerm

Library for converting ground terms to strings and vice versa.

Exported functions:

showTerm :: a → String

> Transforms a ground(!) term into a string representation in standard prefix notation.
> Thus, showTerm suspends until its argument is ground. This function is similar to
> the prelude function `show` but can read the string back with `readUnqualifiedTerm`
> (provided that the constructor names are unique without the module qualifier).

showQTerm :: a → String

> Transforms a ground(!) term into a string representation in standard prefix notation.
> Thus, showTerm suspends until its argument is ground. Note that this function differs
> from the prelude function `show` since it prefixes constructors with their module name
> in order to read them back with `readQTerm`.

readsUnqualifiedTerm :: [String] → String → [(a,String)]

> Transform a string containing a term in standard prefix notation without module qual-
> ifiers into the corresponding data term. The first argument is a non-empty list of
> module qualifiers that are tried to prefix the constructor in the string in order to get
> the qualified constructors (that must be defined in the current program!). In case of a
> successful parse, the result is a one element list containing a pair of the data term and
> the remaining unparsed string.

readUnqualifiedTerm :: [String] → String → a

> Transforms a string containing a term in standard prefix notation without module
> qualifiers into the corresponding data term. The first argument is a non-empty list of
> module qualifiers that are tried to prefix the constructor in the string in order to get
> the qualified constructors (that must be defined in the current program!).
>
> Example: readUnqualifiedTerm `["Prelude"]` `"Just 3"` evaluates to (`Just 3`)

readsTerm :: String → [(a,String)]

> For backward compatibility. Should not be used since their use can be problematic in
> case of constructors with identical names in different modules.

readTerm :: String → a

> For backward compatibility. Should not be used since their use can be problematic in
> case of constructors with identical names in different modules.

readsQTerm :: String → [(a,String)]

Transforms a string containing a term in standard prefix notation with qualified constructor names into the corresponding data term. In case of a successful parse, the result is a one element list containing a pair of the data term and the remaining unparsed string.

`readQTerm :: String → a`

Transforms a string containing a term in standard prefix notation with qualified constructor names into the corresponding data term.

`readQTermFile :: String → IO a`

Reads a file containing a string representation of a term in standard prefix notation and returns the corresponding data term.

`readQTermListFile :: String → IO [a]`

Reads a file containing lines with string representations of terms of the same type and returns the corresponding list of data terms.

`writeQTermFile :: String → a → IO ()`

Writes a ground term into a file in standard prefix notation.

`writeQTermListFile :: String → [a] → IO ()`

Writes a list of ground terms into a file. Each term is written into a separate line which might be useful to modify the file with a standard text editor.

A.2.49 Library SetFunctions

This module contains an implementation of set functions. The general idea of set functions is described in:

> S. Antoy, M. Hanus: Set Functions for Functional Logic Programming Proc. 11th International Conference on Principles and Practice of Declarative Programming (PPDP'09), pp. 73-82, ACM Press, 2009

Intuition: If `f` is an n-ary function, then (`setn f`) is a set-valued function that collects all non-determinism caused by f (but not the non-determinism caused by evaluating arguments!) in a set. Thus, (`setn f a1 ...  an`) returns the set of all values of (`f b1 ...  bn`) where `b1`,...,`bn` are values of the arguments `a1`,...,`an` (i.e., the arguments are evaluated "outside" this capsule so that the non-determinism caused by evaluating these arguments is not captured in this capsule but yields several results for (`setn...`). Similarly, logical variables occuring in `a1`,...,`an` are not bound inside this capsule (but causes a suspension until they are bound). The set of values returned by a set function is represented by an abstract type `Values` on which several operations are defined in this module. Actually, it is a multiset of values, i.e., duplicates are not removed.
Restrictions:

1. The set is a multiset, i.e., it might contain multiple values.

2. The multiset of values is completely evaluated when demanded. Thus, if it is infinite, its evaluation will not terminate even if only some elements (e.g., for a containment test) are demanded. However, for the emptiness test, at most one value will be computed

3. The arguments of a set function are strictly evaluated before the set functions itself will be evaluated.

Since this implementation is restricted and prototypical, the interface is not stable and might change.

Exported types:

`data Values`

> Abstract type representing multisets of values.

Exported constructors:

Exported functions:

`set0 :: a → Values a`

> Combinator to transform a 0-ary function into a corresponding set function.

`set1 :: (a → b) → a → Values b`

> Combinator to transform a unary function into a corresponding set function.

`set2 :: (a → b → c) → a → b → Values c`

> Combinator to transform a binary function into a corresponding set function.

`set3 :: (a → b → c → d) → a → b → c → Values d`

> Combinator to transform a function of arity 3 into a corresponding set function.

`set4 :: (a → b → c → d → e) → a → b → c → d → Values e`

> Combinator to transform a function of arity 4 into a corresponding set function.

`set5 :: (a → b → c → d → e → f) → a → b → c → d → e → Values f`

> Combinator to transform a function of arity 5 into a corresponding set function.

`set6 :: (a → b → c → d → e → f → g) → a → b → c → d → e → f → Values g`

> Combinator to transform a function of arity 6 into a corresponding set function.

`set7 :: (a → b → c → d → e → f → g → h) → a → b → c → d → e → f → g → Values h`

> Combinator to transform a function of arity 7 into a corresponding set function.

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`isEmpty :: Values a → Bool`

>   Is a multiset of values empty?

`notEmpty :: Values a → Bool`

>   Is a multiset of values not empty?

`valueOf :: a → Values a → Bool`

>   Is some value an element of a multiset of values?

`choose :: Values a → (a,Values a)`

>   Chooses (non-deterministically) some value in a multiset of values and returns the chosen value and the remaining multiset of values. Thus, if we consider the operation `chooseValue` by

```
chooseValue x = fst (choose x)
```

>   then (`set1 chooseValue`) is the identity on value sets, i.e., (`set1 chooseValue s`) contains the same elements as the value set `s`.

`chooseValue :: Values a → a`

>   Chooses (non-deterministically) some value in a multiset of values and returns the chosen value. Thus, (`set1 chooseValue`) is the identity on value sets, i.e., (`set1 chooseValue s`) contains the same elements as the value set `s`.

`select :: Values a → (a,Values a)`

>   Selects (indeterministically) some value in a multiset of values and returns the selected value and the remaining multiset of values. Thus, `select` has always at most one value. It fails if the value set is empty.

>   **NOTE:** The usage of this operation is only safe (i.e., does not destroy completeness) if all values in the argument set are identical.

`selectValue :: Values a → a`

>   Selects (indeterministically) some value in a multiset of values and returns the selected value. Thus, `selectValue` has always at most one value. It fails if the value set is empty.

>   **NOTE:** The usage of this operation is only safe (i.e., does not destroy completeness) if all values in the argument set are identical. It returns a single value even for infinite value sets (in contrast to `select` or `choose`).

`mapValues :: (a → b) → Values a → Values b`

Accumulates all elements of a multiset of values by applying a binary operation. This is similarly to fold on lists, but the binary operation must be **commutative** so that the result is independent of the order of applying this operation to all elements in the multiset.

`foldValues :: (a → a → a) → a → Values a → a`

Accumulates all elements of a multiset of values by applying a binary operation. This is similarly to fold on lists, but the binary operation must be **commutative** so that the result is independent of the order of applying this operation to all elements in the multiset.

`minValue :: (a → a → Bool) → Values a → a`

Returns the minimal element of a non-empty multiset of values with respect to a given total ordering on the elements.

`maxValue :: (a → a → Bool) → Values a → a`

Returns the maximal element of a non-empty multiset of value with respect to a given total ordering on the elements.

`values2list :: Values a → IO [a]`

Puts all elements of a multiset of values in a list. Since the order of the elements in the list might depend on the time of the computation, this operation is an I/O action.

`printValues :: Values a → IO ()`

Prints all elements of a multiset of values.

`sortValues :: Values a → [a]`

Transforms a multiset of values into a list sorted by the standard term ordering. As a consequence, the multiset of values is completely evaluated.

`sortValuesBy :: (a → a → Bool) → Values a → [a]`

Transforms a multiset of values into a list sorted by a given ordering on the values. As a consequence, the multiset of values is completely evaluated. In order to ensure that the result of this operation is independent of the evaluation order, the given ordering must be a total order.

A.2.50   Library Socket

Library to support network programming with sockets. In standard applications, the server side uses the operations `listenOn` and `socketAccept` to provide some service on a socket, and the client side uses the operation `connectToSocket` to request a service.

Exported types:

`data Socket`

> The abstract type of sockets.

Exported constructors:

Exported functions:

`listenOn :: Int → IO Socket`

> Creates a server side socket bound to a given port number.

`listenOnFresh :: IO (Int,Socket)`

> Creates a server side socket bound to a free port. The port number and the socket is returned.

`socketAccept :: Socket → IO (String,Handle)`

> Returns a connection of a client to a socket. The connection is returned as a pair consisting of a string identifying the client (the format of this string is implementation-dependent) and a handle to a stream communication with the client. The handle is both readable and writable.

`waitForSocketAccept :: Socket → Int → IO (Maybe (String,Handle))`

> Waits until a connection of a client to a socket is available. If no connection is available within the time limit, it returns Nothing, otherwise the connection is returned as a pair consisting of a string identifying the client (the format of this string is implementation-dependent) and a handle to a stream communication with the client.

`sClose :: Socket → IO ()`

> Closes a server socket.

`connectToSocket :: String → Int → IO Handle`

> Creates a new connection to a Unix socket.

A.2.51 Library System

Library to access parts of the system environment.

Exported functions:

`getCPUTime :: IO Int`

> Returns the current cpu time of the process in milliseconds.

`getElapsedTime :: IO Int`

Returns the current elapsed time of the process in milliseconds. This operation is not supported in KiCS2 (there it always returns 0), but only included for compatibility reasons.

`getArgs :: IO [String]`

Returns the list of the program's command line arguments. The program name is not included.

`getEnviron :: String → IO String`

Returns the value of an environment variable. The empty string is returned for undefined environment variables.

`setEnviron :: String → String → IO ()`

Set an environment variable to a value. The new value will be passed to subsequent shell commands (see `system`) and visible to subsequent calls to `getEnviron` (but it is not visible in the environment of the process that started the program execution).

`unsetEnviron :: String → IO ()`

Removes an environment variable that has been set by `setEnviron`.

`getHostname :: IO String`

Returns the hostname of the machine running this process.

`getPID :: IO Int`

Returns the process identifier of the current Curry process.

`getProgName :: IO String`

Returns the name of the current program, i.e., the name of the main module currently executed.

`system :: String → IO Int`

Executes a shell command and return with the exit code of the command. An exit status of zero means successful execution.

`exitWith :: Int → IO a`

Terminates the execution of the current Curry program and returns the exit code given by the argument. An exit code of zero means successful execution.

`sleep :: Int → IO ()`

The evaluation of the action (sleep n) puts the Curry process asleep for n seconds.

`isPosix :: Bool`

Is the underlying operating system a POSIX system (unix, MacOS)?

`isWindows :: Bool`

Is the underlying operating system a Windows system?

A.2.52 Library Time

Library for handling date and time information.

Exported types:

`data ClockTime`

> ClockTime represents a clock time in some internal representation.

Exported constructors:

`data CalendarTime`

> A calendar time is presented in the following form: (CalendarTime year month day hour minute second timezone) where timezone is an integer representing the timezone as a difference to UTC time in seconds.

Exported constructors:

- `CalendarTime :: Int → Int → Int → Int → Int → Int → Int → CalendarTime`

Exported functions:

`ctYear :: CalendarTime → Int`

> The year of a calendar time.

`ctMonth :: CalendarTime → Int`

> The month of a calendar time.

`ctDay :: CalendarTime → Int`

> The day of a calendar time.

`ctHour :: CalendarTime → Int`

> The hour of a calendar time.

`ctMin :: CalendarTime → Int`

> The minute of a calendar time.

`ctSec :: CalendarTime → Int`

> The second of a calendar time.

`ctTZ :: CalendarTime → Int`

> The time zone of a calendar time. The value of the time zone is the difference to UTC time in seconds.

`getClockTime :: IO ClockTime`

Returns the current clock time.

`getLocalTime :: IO CalendarTime`

Returns the local calendar time.

`clockTimeToInt :: ClockTime → Int`

Transforms a clock time into a unique integer. It is ensured that clock times that differs in at least one second are mapped into different integers.

`toCalendarTime :: ClockTime → IO CalendarTime`

Transforms a clock time into a calendar time according to the local time (if possible). Since the result depends on the local environment, it is an I/O operation.

`toUTCTime :: ClockTime → CalendarTime`

Transforms a clock time into a standard UTC calendar time. Thus, this operationa is independent on the local time.

`toClockTime :: CalendarTime → ClockTime`

Transforms a calendar time (interpreted as UTC time) into a clock time.

`calendarTimeToString :: CalendarTime → String`

Transforms a calendar time into a readable form.

`toDayString :: CalendarTime → String`

Transforms a calendar time into a string containing the day, e.g., "September 23, 2006".

`toTimeString :: CalendarTime → String`

Transforms a calendar time into a string containing the time.

`addSeconds :: Int → ClockTime → ClockTime`

Adds seconds to a given time.

`addMinutes :: Int → ClockTime → ClockTime`

Adds minutes to a given time.

`addHours :: Int → ClockTime → ClockTime`

Adds hours to a given time.

`addDays :: Int → ClockTime → ClockTime`

Adds days to a given time.

`addMonths :: Int → ClockTime → ClockTime`

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Adds months to a given time.

`addYears :: Int → ClockTime → ClockTime`

Adds years to a given time.

`daysOfMonth :: Int → Int → Int`

Gets the days of a month in a year.

`validDate :: Int → Int → Int → Bool`

Is a date consisting of year/month/day valid?

`compareDate :: CalendarTime → CalendarTime → Ordering`

Compares two dates (don't use it, just for backward compatibility!).

`compareCalendarTime :: CalendarTime → CalendarTime → Ordering`

Compares two calendar times.

`compareClockTime :: ClockTime → ClockTime → Ordering`

Compares two clock times.

A.2.53   Library Unsafe

Library containing unsafe operations. These operations should be carefully used (e.g., for testing or debugging). These operations should not be used in application programs!

Exported functions:

`unsafePerformIO :: IO a → a`

Performs and hides an I/O action in a computation (use with care!).

`trace :: String → a → a`

Prints the first argument as a side effect and behaves as identity on the second argument.

`spawnConstraint :: Success → a → a`

Spawns a constraint and returns the second argument. This function can be considered as defined by "`spawnConstraint c x | c = x`". However, the evaluation of the constraint and the right-hand side are performed concurrently, i.e., a suspension of the constraint does not imply a blocking of the right-hand side and the right-hand side might be evaluated before the constraint is successfully solved. Thus, a computation might return a result even if some of the spawned constraints are suspended (use the PAKCS/Curry2Prolog option "`+suspend`" to show such suspended goals).

`isVar :: a → Bool`

Tests whether the first argument evaluates to a currently unbound variable (use with care!).

`identicalVar :: a → a → Bool`

Tests whether both arguments evaluate to the identical currently unbound variable (use with care!). For instance, `identicalVar (id x) (fst (x,1))` evaluates to `True` whereas `identicalVar x y` and `let x=1 in identicalVar x x` evaluate to `False`

`isGround :: a → Bool`

Tests whether the argument evaluates to a ground value (use with care!).

`compareAnyTerm :: a → a → Ordering`

Comparison of any data terms, possibly containing variables. Data constructors are compared in the order of their definition in the datatype declarations and recursively in the arguments. Variables are compared in some internal order.

`showAnyTerm :: a → String`

Transforms the normal form of a term into a string representation in standard prefix notation. Thus, showAnyTerm evaluates its argument to normal form. This function is similar to the function `ReadShowTerm.showTerm` but it also transforms logic variables into a string representation that can be read back by `Unsafe.read(s)AnyUnqualifiedTerm`. Thus, the result depends on the evaluation and binding status of logic variables so that it should be used with care!

`showAnyQTerm :: a → String`

Transforms the normal form of a term into a string representation in standard prefix notation. Thus, showAnyQTerm evaluates its argument to normal form. This function is similar to the function `ReadShowTerm.showQTerm` but it also transforms logic variables into a string representation that can be read back by `Unsafe.read(s)AnyQTerm`. Thus, the result depends on the evaluation and binding status of logic variables so that it should be used with care!

`readsAnyUnqualifiedTerm :: [String] → String → [(a,String)]`

Transform a string containing a term in standard prefix notation without module qualifiers into the corresponding data term. The string might contain logical variable encodings produced by showAnyTerm. In case of a successful parse, the result is a one element list containing a pair of the data term and the remaining unparsed string.

`readAnyUnqualifiedTerm :: [String] → String → a`

Transforms a string containing a term in standard prefix notation without module qualifiers into the corresponding data term. The string might contain logical variable encodings produced by showAnyTerm.

`readsAnyQTerm :: String → [(a,String)]`

Transforms a string containing a term in standard prefix notation with qualified constructor names into the corresponding data term. The string might contain logical variable encodings produced by showAnyQTerm. In case of a successful parse, the result is a one element list containing a pair of the data term and the remaining unparsed string.

`readAnyQTerm :: String → a`

Transforms a string containing a term in standard prefix notation with qualified constructor names into the corresponding data term. The string might contain logical variable encodings produced by showAnyQTerm.

`showAnyExpression :: a → String`

Transforms any expression (even not in normal form) into a string representation in standard prefix notation without module qualifiers. The result depends on the evaluation and binding status of logic variables so that it should be used with care!

`showAnyQExpression :: a → String`

Transforms any expression (even not in normal form) into a string representation in standard prefix notation with module qualifiers. The result depends on the evaluation and binding status of logic variables so that it should be used with care!

`readsAnyQExpression :: String → [(a,String)]`

Transforms a string containing an expression in standard prefix notation with qualified constructor names into the corresponding expression. The string might contain logical variable and defined function encodings produced by showAnyQExpression. In case of a successful parse, the result is a one element list containing a pair of the expression and the remaining unparsed string.

`readAnyQExpression :: String → a`

Transforms a string containing an expression in standard prefix notation with qualified constructor names into the corresponding expression. The string might contain logical variable and defined function encodings produced by showAnyQExpression.

A.3   Data Structures and Algorithms

A.3.1   Library Array

Implementation of Arrays with Braun Trees. Conceptually, Braun trees are always infinite. Consequently, there is no test on emptiness.

Exported types:

`data Array`

Exported constructors:

Exported functions:

`emptyErrorArray :: Array a`

> Creates an empty array which generates errors for non-initialized indexes.

`emptyDefaultArray :: (Int → a) → Array a`

> Creates an empty array, call given function for non-initialized indexes.

`(//) :: Array a → [(Int,a)] → Array a`

> Inserts a list of entries into an array.

`update :: Array a → Int → a → Array a`

> Inserts a new entry into an array.

`applyAt :: Array a → Int → (a → a) → Array a`

> Applies a function to an element.

`(!) :: Array a → Int → a`

> Yields the value at a given position.

`listToDefaultArray :: (Int → a) → [a] → Array a`

> Creates a default array from a list of entries.

`listToErrorArray :: [a] → Array a`

> Creates an error array from a list of entries.

`combine :: (a → b → c) → Array a → Array b → Array c`

> combine two arbitrary arrays

`combineSimilar :: (a → a → a) → Array a → Array a → Array a`

> the combination of two arrays with identical default function and a combinator which is neutral in the default can be implemented much more efficient

A.3.2 Library Dequeue

An implementation of double-ended queues supporting access at both ends in constant amortized time.

Exported types:

`data Queue`

> The datatype of a queue.

Exported constructors:

Exported functions:

`empty :: Queue a`

The empty queue.

`cons :: a → Queue a → Queue a`

Inserts an element at the front of the queue.

`snoc :: a → Queue a → Queue a`

Inserts an element at the end of the queue.

`isEmpty :: Queue a → Bool`

Is the queue empty?

`deqLength :: Queue a → Int`

Returns the number of elements in the queue.

`deqHead :: Queue a → a`

The first element of the queue.

`deqTail :: Queue a → Queue a`

Removes an element at the front of the queue.

`deqLast :: Queue a → a`

The last element of the queue.

`deqInit :: Queue a → Queue a`

Removes an element at the end of the queue.

`deqReverse :: Queue a → Queue a`

Reverses a double ended queue.

`rotate :: Queue a → Queue a`

Moves the first element to the end of the queue.

`matchHead :: Queue a → Maybe (a,Queue a)`

Matches the front of a queue. `matchHead q` is equivalent to `if isEmpty q then Nothing else Just (deqHead q, deqTail q)` but more efficient.

`matchLast :: Queue a → Maybe (a,Queue a)`

Matches the end of a queue. `matchLast q` is equivalent to `if isEmpty q then Nothing else Just (deqLast q,deqInit q)` but more efficient.

`listToDeq :: [a] → Queue a`

Transforms a list to a double ended queue.

`deqToList :: Queue a → [a]`

Transforms a double ended queue to a list.

A.3.3 Library FiniteMap

A finite map is an efficient purely functional data structure to store a mapping from keys to values. In order to store the mapping efficiently, an irreflexive(!) order predicate has to be given, i.e., the order predicate `le` should not satisfy (`le x x`) for some key `x`.

Example: To store a mapping from `Int -> String`, the finite map needs a Boolean predicate like (`<`). This version was ported from a corresponding Haskell library

Exported types:

```
data FM
```

Exported constructors:

Exported functions:

emptyFM :: (a → a → Bool) → FM a b

> The empty finite map.

unitFM :: (a → a → Bool) → a → b → FM a b

> Construct a finite map with only a single element.

listToFM :: (a → a → Bool) → [(a,b)] → FM a b

> Builts a finite map from given list of tuples (key,element). For multiple occurences of key, the last corresponding element of the list is taken.

addToFM :: FM a b → a → b → FM a b

> Throws away any previous binding and stores the new one given.

addListToFM :: FM a b → [(a,b)] → FM a b

> Throws away any previous bindings and stores the new ones given. The items are added starting with the first one in the list

addToFM_C :: (a → a → a) → FM b a → b → a → FM b a

> Instead of throwing away the old binding, addToFM_C combines the new element with the old one.

addListToFM_C :: (a → a → a) → FM b a → [(b,a)] → FM b a

> Combine with a list of tuples (key,element), cf. addToFM_C

delFromFM :: FM a b → a → FM a b

> Deletes key from finite map. Deletion doesn't complain if you try to delete something which isn't there

```
delListFromFM :: FM a b → [a] → FM a b
```

Deletes a list of keys from finite map. Deletion doesn't complain if you try to delete something which isn't there

```
updFM :: FM a b → a → (b → b) → FM a b
```

Applies a function to element bound to given key.

```
splitFM :: FM a b → a → Maybe (FM a b,(a,b))
```

Combines delFrom and lookup.

```
plusFM :: FM a b → FM a b → FM a b
```

Efficiently add key/element mappings of two maps into a single one. Bindings in right argument shadow those in the left

```
plusFM_C :: (a → a → a) → FM b a → FM b a → FM b a
```

Efficiently combine key/element mappings of two maps into a single one, cf. addToFM_C

```
minusFM :: FM a b → FM a b → FM a b
```

(minusFM a1 a2) deletes from a1 any bindings which are bound in a2

```
intersectFM :: FM a b → FM a b → FM a b
```

Filters only those keys that are bound in both of the given maps. The elements will be taken from the second map.

```
intersectFM_C :: (a → b → c) → FM d a → FM d b → FM d c
```

Filters only those keys that are bound in both of the given maps and combines the elements as in addToFM_C.

```
foldFM :: (a → b → c → c) → c → FM a b → c
```

Folds finite map by given function.

```
mapFM :: (a → b → c) → FM a b → FM a c
```

Applies a given function on every element in the map.

```
filterFM :: (a → b → Bool) → FM a b → FM a b
```

Yields a new finite map with only those key/element pairs matching the given predicate.

```
sizeFM :: FM a b → Int
```

How many elements does given map contain?

```
eqFM :: FM a b → FM a b → Bool
```

Do two given maps contain the same key/element pairs?

`isEmptyFM :: FM a b → Bool`

Is the given finite map empty?

`elemFM :: a → FM a b → Bool`

Does given map contain given key?

`lookupFM :: FM a b → a → Maybe b`

Retrieves element bound to given key

`lookupWithDefaultFM :: FM a b → b → a → b`

Retrieves element bound to given key. If the element is not contained in map, return default value.

`keyOrder :: FM a b → a → a → Bool`

Retrieves the ordering on which the given finite map is built.

`minFM :: FM a b → Maybe (a,b)`

Retrieves the smallest key/element pair in the finite map according to the basic key ordering.

`maxFM :: FM a b → Maybe (a,b)`

Retrieves the greatest key/element pair in the finite map according to the basic key ordering.

`fmToList :: FM a b → [(a,b)]`

Builds a list of key/element pairs. The list is ordered by the initially given irreflexive order predicate on keys.

`keysFM :: FM a b → [a]`

Retrieves a list of keys contained in finite map. The list is ordered by the initially given irreflexive order predicate on keys.

`eltsFM :: FM a b → [b]`

Retrieves a list of elements contained in finite map. The list is ordered by the initially given irreflexive order predicate on keys.

`fmToListPreOrder :: FM a b → [(a,b)]`

Retrieves list of key/element pairs in preorder of the internal tree. Useful for lists that will be retransformed into a tree or to match any elements regardless of basic order.

`fmSortBy :: (a → a → Bool) → [a] → [a]`

Sorts a given list by inserting and retrieving from finite map. Duplicates are deleted.

```
showFM :: FM a b → String
```

> Transforms a finite map into a string. For efficiency reasons, the tree structure is shown which is valid for reading only if one uses the same ordering predicate.

```
readFM :: (a → a → Bool) → String → FM a b
```

> Transforms a string representation of a finite map into a finite map. One has two provide the same ordering predicate as used in the original finite map.

A.3.4   Library GraphInductive

Library for inductive graphs (port of a Haskell library by Martin Erwig).
In this library, graphs are composed and decomposed in an inductive way.
The key idea is as follows:
A graph is either *empty* or it consists of *node context* and a *graph g'* which are put together by a constructor (:&).
This constructor (:&), however, is not a constructor in the sense of abstract data type, but more basically a defined constructing funtion.
A *context* is a node together withe the edges to and from this node into the nodes in the graph g'.
For examples of how to use this library, cf. the module `GraphAlgorithms`.

Exported types:

```
type Node = Int
```

> Nodes and edges themselves (in contrast to their labels) are coded as integers.

> For both of them, there are variants as labeled, unlabelwd and quasi unlabeled (labeled with ()).

> Unlabeled node

```
type LNode a = (Int,a)
```

> Labeled node

```
type UNode = (Int,())
```

> Quasi-unlabeled node

```
type Edge = (Int,Int)
```

> Unlabeled edge

```
type LEdge a = (Int,Int,a)
```

> Labeled edge

```
type UEdge = (Int,Int,())
```

> Quasi-unlabeled edge

```
type Context a b = ([(b,Int)],Int,a,[(b,Int)])
```

> The context of a node is the node itself (along with label) and its adjacent nodes. Thus, a context is a quadrupel, for node n it is of the form (edges to n,node n,n's label,edges from n)

```
type MContext a b = Maybe ([(b,Int)],Int,a,[(b,Int)])
```

> maybe context

```
type Context' a b = ([(b,Int)],a,[(b,Int)])
```

> context with edges and node label only, without the node identifier itself

```
type UContext = ([Int],Int,[Int])
```

> Unlabeled context.

```
type GDecomp a b = (([(b,Int)],Int,a,[(b,Int)]),Graph a b)
```

> A graph decompostion is a context for a node n and the remaining graph without that node.

```
type Decomp a b = (Maybe ([(b,Int)],Int,a,[(b,Int)]),Graph a b)
```

> a decomposition with a maybe context

```
type UDecomp a = (Maybe ([Int],Int,[Int]),a)
```

> Unlabeled decomposition.

```
type Path = [Int]
```

> Unlabeled path

```
type LPath a = [(Int,a)]
```

> Labeled path

```
type UPath = [(Int,())]
```

> Quasi-unlabeled path

```
type UGr = Graph () ()
```

> a graph without any labels

```
data Graph
```

> The type variables of Graph are *nodeLabel* and *edgeLabel*. The internal representation of Graph is hidden.

Exported constructors:

Exported functions:

`(:&) :: ([(a,Int)],Int,b,[(a,Int)]) → Graph b a → Graph b a`

> (:&) takes a node-context and a Graph and yields a new graph.
>
> The according key idea is detailed at the beginning.
>
> nl is the type of the node labels and el the edge labels.
>
> Note that it is an error to induce a context for a node already contained in the graph.

`matchAny :: Graph a b → (([(b,Int)],Int,a,[(b,Int)]),Graph a b)`

> decompose a graph into the `Context` for an arbitrarily-chosen `Node` and the remaining `Graph`.
>
> In order to use graphs as abstract data structures, we also need means to decompose a graph. This decompostion should work as much like pattern matching as possible. The normal matching is done by the function matchAny, which takes a graph and yields a graph decompostion.
>
> According to the main idea, matchAny . (:&) should be an identity.

`empty :: Graph a b`

> An empty `Graph`.

`mkGraph :: [(Int,a)] → [(Int,Int,b)] → Graph a b`

> Create a `Graph` from the list of `LNode`s and `LEdge`s.

`buildGr :: [([(a,Int)],Int,b,[(a,Int)])] → Graph b a`

> Build a `Graph` from a list of `Context`s.

`mkUGraph :: [Int] → [(Int,Int)] → Graph () ()`

> Build a quasi-unlabeled `Graph` from the list of `Node`s and `Edge`s.

`insNode :: (Int,a) → Graph a b → Graph a b`

> Insert a `LNode` into the `Graph`.

`insEdge :: (Int,Int,a) → Graph b a → Graph b a`

> Insert a `LEdge` into the `Graph`.

`delNode :: Int → Graph a b → Graph a b`

> Remove a `Node` from the `Graph`.

`delEdge :: (Int,Int) → Graph a b → Graph a b`

> Remove an `Edge` from the `Graph`.

`insNodes :: [(Int,a)] → Graph a b → Graph a b`

Insert multiple `LNodes` into the `Graph`.

`insEdges :: [(Int,Int,a)] → Graph b a → Graph b a`

Insert multiple `LEdges` into the `Graph`.

`delNodes :: [Int] → Graph a b → Graph a b`

Remove multiple `Nodes` from the `Graph`.

`delEdges :: [(Int,Int)] → Graph a b → Graph a b`

Remove multiple `Edges` from the `Graph`.

`isEmpty :: Graph a b → Bool`

test if the given `Graph` is empty.

`match :: Int → Graph a b → (Maybe ([(b,Int)],Int,a,[(b,Int)]),Graph a b)`

match is the complement side of (:&), decomposing a `Graph` into the `MContext` found for the given node and the remaining `Graph`.

`noNodes :: Graph a b → Int`

The number of `Nodes` in a `Graph`.

`nodeRange :: Graph a b → (Int,Int)`

The minimum and maximum `Node` in a `Graph`.

`context :: Graph a b → Int → ([(b,Int)],Int,a,[(b,Int)])`

Find the context for the given `Node`. In contrast to "match", "context" causes an error if the `Node` is not present in the `Graph`.

`lab :: Graph a b → Int → Maybe a`

Find the label for a `Node`.

`neighbors :: Graph a b → Int → [Int]`

Find the neighbors for a `Node`.

`suc :: Graph a b → Int → [Int]`

Find all `Nodes` that have a link from the given `Node`.

`pre :: Graph a b → Int → [Int]`

Find all `Nodes` that link to to the given `Node`.

`lsuc :: Graph a b → Int → [(Int,b)]`

Find all Nodes and their labels, which are linked from the given `Node`.

`lpre :: Graph a b → Int → [(Int,b)]`

    Find all `Node`s that link to the given `Node` and the label of each link.

`out :: Graph a b → Int → [(Int,Int,b)]`

    Find all outward-bound `LEdge`s for the given `Node`.

`inn :: Graph a b → Int → [(Int,Int,b)]`

    Find all inward-bound `LEdge`s for the given `Node`.

`outdeg :: Graph a b → Int → Int`

    The outward-bound degree of the `Node`.

`indeg :: Graph a b → Int → Int`

    The inward-bound degree of the `Node`.

`deg :: Graph a b → Int → Int`

    The degree of the `Node`.

`gelem :: Int → Graph a b → Bool`

    `True` if the `Node` is present in the `Graph`.

`equal :: Graph a b → Graph a b → Bool`

    graph equality

`node' :: ([(a,Int)],Int,b,[(a,Int)]) → Int`

    The `Node` in a `Context`.

`lab' :: ([(a,Int)],Int,b,[(a,Int)]) → b`

    The label in a `Context`.

`labNode' :: ([(a,Int)],Int,b,[(a,Int)]) → (Int,b)`

    The `LNode` from a `Context`.

`neighbors' :: ([(a,Int)],Int,b,[(a,Int)]) → [Int]`

    All `Node`s linked to or from in a `Context`.

`suc' :: ([(a,Int)],Int,b,[(a,Int)]) → [Int]`

    All `Node`s linked to in a `Context`.

`pre' :: ([(a,Int)],Int,b,[(a,Int)]) → [Int]`

    All `Node`s linked from in a `Context`.

`lpre' :: ([(a,Int)],Int,b,[(a,Int)]) → [(Int,a)]`

All Nodes linked from in a Context, and the label of the links.

`lsuc' :: ([(a,Int)],Int,b,[(a,Int)]) → [(Int,a)]`

All Nodes linked from in a Context, and the label of the links.

`out' :: ([(a,Int)],Int,b,[(a,Int)]) → [(Int,Int,a)]`

All outward-directed LEdges in a Context.

`inn' :: ([(a,Int)],Int,b,[(a,Int)]) → [(Int,Int,a)]`

All inward-directed LEdges in a Context.

`outdeg' :: ([(a,Int)],Int,b,[(a,Int)]) → Int`

The outward degree of a Context.

`indeg' :: ([(a,Int)],Int,b,[(a,Int)]) → Int`

The inward degree of a Context.

`deg' :: ([(a,Int)],Int,b,[(a,Int)]) → Int`

The degree of a Context.

`labNodes :: Graph a b → [(Int,a)]`

A list of all LNodes in the Graph.

`labEdges :: Graph a b → [(Int,Int,b)]`

A list of all LEdges in the Graph.

`nodes :: Graph a b → [Int]`

List all Nodes in the Graph.

`edges :: Graph a b → [(Int,Int)]`

List all Edges in the Graph.

`newNodes :: Int → Graph a b → [Int]`

List N available Nodes, ie Nodes that are not used in the Graph.

`ufold :: (([(a,Int)],Int,b,[(a,Int)]) → c → c) → c → Graph b a → c`

Fold a function over the graph.

`gmap :: (([(a,Int)],Int,b,[(a,Int)]) → ([(c,Int)],Int,d,[(c,Int)])) → Graph b a → Graph d c`

Map a function over the graph.

`nmap :: (a → b) → Graph a c → Graph b c`

  Map a function over the `Node` labels in a graph.

`emap :: (a → b) → Graph c a → Graph c b`

  Map a function over the `Edge` labels in a graph.

`labUEdges :: [(a,b)] → [(a,b,())]`

  add label () to list of edges (node,node)

`labUNodes :: [a] → [(a,())]`

  add label () to list of nodes

`showGraph :: Graph a b → String`

  Represent Graph as String

A.3.5   Library Random

Library for pseudo-random number generation in Curry.

This library provides operations for generating pseudo-random number sequences. For any given seed, the sequences generated by the operations in this module should be **identical** to the sequences generated by the `java.util.Random package`.

The algorithm is a linear congruential pseudo-random number generator described in Donald E. Knuth, *The Art of Computer Programming*, Volume 2: *Seminumerical Algorithms*, section 3.2.1.

Exported functions:

`nextInt :: Int → [Int]`

  Returns a sequence of pseudorandom, uniformly distributed 32-bits integer values. All 2^{32} possible integer values are produced with (approximately) equal probability.

`nextIntRange :: Int → Int → [Int]`

  Returns a pseudorandom, uniformly distributed sequence of values between 0 (inclusive) and the specified value (exclusive). Each value is a 32-bits positive integer. All `n` possible values are produced with (approximately) equal probability.

`nextBoolean :: Int → [Bool]`

  Returns a pseudorandom, uniformly distributed sequence of boolean values. The values `True` and `False` are produced with (approximately) equal probability.

`getRandomSeed :: IO Int`

  Returns a time-dependent integer number as a seed for really random numbers. Should only be used as a seed for pseudorandom number sequence and not as a random number since the precision is limited to milliseconds

A.3.6 Library RedBlackTree

Library with an implementation of red-black trees:
Serves as the base for both TableRBT and SetRBT All the operations on trees are generic, i.e., one has to provide two explicit order predicates ("`lessThan`" and "`eq`"below) on elements.

Exported types:

`data RedBlackTree`

> A red-black tree consists of a tree structure and three order predicates. These predicates generalize the red black tree. They define 1) equality when inserting into the tree
>
> eg for a set eqInsert is (==), for a multiset it is (-> False) for a lookUp-table it is ((==) . fst) 2) equality for looking up values eg for a set eqLookUp is (==), for a multiset it is (==) for a lookUp-table it is ((==) . fst) 3) the (less than) relation for the binary search tree

> *Exported constructors:*

Exported functions:

`empty :: (a → a → Bool) → (a → a → Bool) → (a → a → Bool) → RedBlackTree a`

> The three relations are inserted into the structure by function empty. Returns an empty tree, i.e., an empty red-black tree augmented with the order predicates.

`isEmpty :: RedBlackTree a → Bool`

> Test on emptyness

`newTreeLike :: RedBlackTree a → RedBlackTree a`

> Creates a new empty red black tree from with the same ordering as a give one.

`lookup :: a → RedBlackTree a → Maybe a`

> Returns an element if it is contained in a red-black tree.

`update :: a → RedBlackTree a → RedBlackTree a`

> Updates/inserts an element into a RedBlackTree.

`delete :: a → RedBlackTree a → RedBlackTree a`

> Deletes entry from red black tree.

`tree2list :: RedBlackTree a → [a]`

> Transforms a red-black tree into an ordered list of its elements.

`sort :: (a → a → Bool) → [a] → [a]`

> Generic sort based on insertion into red-black trees. The first argument is the order for the elements.

`setInsertEquivalence :: (a → a → Bool) → RedBlackTree a → RedBlackTree a`

> For compatibility with old version only

A.3.7 Library SetRBT

Library with an implementation of sets as red-black trees.
All the operations on sets are generic, i.e., one has to provide an explicit order predicate ($<$) (less-than) on elements.

Exported types:

```
type SetRBT a = RedBlackTree a
```

Exported functions:

emptySetRBT :: (a → a → Bool) → RedBlackTree a

    Returns an empty set, i.e., an empty red-black tree augmented with an order predicate.

isEmptySetRBT :: RedBlackTree a → Bool

    Test for an empty set.

elemRBT :: a → RedBlackTree a → Bool

    Returns true if an element is contained in a (red-black tree) set.

insertRBT :: a → RedBlackTree a → RedBlackTree a

    Inserts an element into a set if it is not already there.

insertMultiRBT :: a → RedBlackTree a → RedBlackTree a

    Inserts an element into a multiset. Thus, the same element can have several occurrences in the multiset.

deleteRBT :: a → RedBlackTree a → RedBlackTree a

    delete an element from a set. Deletes only a single element from a multi set

setRBT2list :: RedBlackTree a → [a]

    Transforms a (red-black tree) set into an ordered list of its elements.

unionRBT :: RedBlackTree a → RedBlackTree a → RedBlackTree a

    Computes the union of two (red-black tree) sets. This is done by inserting all elements of the first set into the second set.

intersectRBT :: RedBlackTree a → RedBlackTree a → RedBlackTree a

    Computes the intersection of two (red-black tree) sets. This is done by inserting all elements of the first set contained in the second set into a new set, which order is taken from the first set.

sortRBT :: (a → a → Bool) → [a] → [a]

    Generic sort based on insertion into red-black trees. The first argument is the order for the elements.

A.3.8 Library Sort

A collection of useful functions for sorting and comparing characters, strings, and lists.

Exported functions:

quickSort :: (a → a → Bool) → [a] → [a]

    Quicksort.

mergeSort :: (a → a → Bool) → [a] → [a]

    Bottom-up mergesort.

leqList :: (a → a → Bool) → [a] → [a] → Bool

    Less-or-equal on lists.

cmpList :: (a → a → Ordering) → [a] → [a] → Ordering

    Comparison of lists.

leqChar :: Char → Char → Bool

    Less-or-equal on characters (deprecated, use Prelude.<=</code></=</code>).

cmpChar :: Char → Char → Ordering

    Comparison of characters (deprecated, use `Prelude.compare`).

leqCharIgnoreCase :: Char → Char → Bool

    Less-or-equal on characters ignoring case considerations.

leqString :: String → String → Bool

    Less-or-equal on strings (deprecated, use Prelude.<=</code></=</code>).

cmpString :: String → String → Ordering

    Comparison of strings (deprecated, use `Prelude.compare`).

leqStringIgnoreCase :: String → String → Bool

    Less-or-equal on strings ignoring case considerations.

leqLexGerman :: String → String → Bool

    Lexicographical ordering on German strings. Thus, upper/lowercase are not distinguished and Umlauts are sorted as vocals.

A.3.9 Library TableRBT

Library with an implementation of tables as red-black trees:
A table is a finite mapping from keys to values. All the operations on tables are generic, i.e., one has to provide an explicit order predicate ("`cmp`" below) on elements. Each inner node in the red-black tree contains a key-value association.

Exported types:

```
type TableRBT a b = RedBlackTree (a,b)
```

Exported functions:

emptyTableRBT :: (a → a → Bool) → RedBlackTree (a,b)

> Returns an empty table, i.e., an empty red-black tree.

isEmptyTable :: RedBlackTree (a,b) → Bool

> tests whether a given table is empty

lookupRBT :: a → RedBlackTree (a,b) → Maybe b

> Looks up an entry in a table.

updateRBT :: a → b → RedBlackTree (a,b) → RedBlackTree (a,b)

> Inserts or updates an element in a table.

tableRBT2list :: RedBlackTree (a,b) → [(a,b)]

> Transforms the nodes of red-black tree into a list.

deleteRBT :: a → RedBlackTree (a,b) → RedBlackTree (a,b)

A.3.10   Library Traversal

Library to support lightweight generic traversals through tree-structured data. See here[11] for a description of the library.

Exported types:

type Traversable a b = a → ([b],[b] → a)

> A datatype is `Traversable` if it defines a function that can decompose a value into a list of children of the same type and recombine new children to a new value of the original type.

---

[11]http://www-ps.informatik.uni-kiel.de/~sebf/projects/traversal.html

Exported functions:

`noChildren :: a → ([b],[b] → a)`

    Traversal function for constructors without children.

`children :: (a → ([b],[b] → a)) → a → [b]`

    Yields the children of a value.

`replaceChildren :: (a → ([b],[b] → a)) → a → [b] → a`

    Replaces the children of a value.

`mapChildren :: (a → ([b],[b] → a)) → (b → b) → a → a`

    Applies the given function to each child of a value.

`family :: (a → ([a],[a] → a)) → a → [a]`

    Computes a list of the given value, its children, those children, etc.

`childFamilies :: (a → ([b],[b] → a)) → (b → ([b],[b] → b)) → a → [b]`

    Computes a list of family members of the children of a value. The value and its children can have different types.

`mapFamily :: (a → ([a],[a] → a)) → (a → a) → a → a`

    Applies the given function to each member of the family of a value. Proceeds bottom-up.

`mapChildFamilies :: (a → ([b],[b] → a)) → (b → ([b],[b] → b)) → (b → b) → a → a`

    Applies the given function to each member of the families of the children of a value. The value and its children can have different types. Proceeds bottom-up.

`evalFamily :: (a → ([a],[a] → a)) → (a → Maybe a) → a → a`

    Applies the given function to each member of the family of a value as long as possible. On each member of the family of the result the given function will yield `Nothing`. Proceeds bottom-up.

`evalChildFamilies :: (a → ([b],[b] → a)) → (b → ([b],[b] → b)) → (b → Maybe b) → a → a`

    Applies the given function to each member of the families of the children of a value as long as possible. Similar to `evalFamily`.

`fold :: (a → ([a],[a] → a)) → (a → [b] → b) → a → b`

    Implements a traversal similar to a fold with possible default cases.

```
foldChildren :: (a → ([b],[b] → a)) → (b → ([b],[b] → b)) → (a → [c] → d)
→ (b → [c] → c) → a → d
```

Fold the children and combine the results.

```
replaceChildrenIO :: (a → ([b],[b] → a)) → a → IO [b] → IO a
```

IO version of replaceChildren

```
mapChildrenIO :: (a → ([b],[b] → a)) → (b → IO b) → a → IO a
```

IO version of mapChildren

```
mapFamilyIO :: (a → ([a],[a] → a)) → (a → IO a) → a → IO a
```

IO version of mapFamily

```
mapChildFamiliesIO :: (a → ([b],[b] → a)) → (b → ([b],[b] → b)) → (b → IO
b) → a → IO a
```

IO version of mapChildFamilies

```
evalFamilyIO :: (a → ([a],[a] → a)) → (a → IO (Maybe a)) → a → IO a
```

IO version of evalFamily

```
evalChildFamiliesIO :: (a → ([b],[b] → a)) → (b → ([b],[b] → b)) → (b → IO
(Maybe b)) → a → IO a
```

IO version of evalChildFamilies

A.4   Libraries for Web Applications

A.4.1   Library CategorizedHtmlList

This library provides functions to categorize a list of entities into a HTML page with an index
access (e.g., "A-Z") to these entities.

Exported functions:

```
list2CategorizedHtml :: [(a,[HtmlExp])] → [(b,String)] → (a → b → Bool) →
[HtmlExp]
```

General categorization of a list of entries.

The item will occur in every category for which the boolean function categoryFun yields
True.

```
categorizeByItemKey :: [(String,[HtmlExp])] → [HtmlExp]
```

Categorize a list of entries with respect to the inial keys.

The categories are named as all initial characters of the keys of the items.

```
stringList2ItemList :: [String] → [(String,[HtmlExp])]
```

Convert a string list into an key-item list The strings are used as keys and for the simple
text layout.

A.4.2 Library HTML

Library for HTML and CGI programming. This paper contains a description of the basic ideas behind this library.

The installation of a cgi script written with this library can be done by the command

```
makecurrycgi -m initialForm -o /home/joe/public_html/prog.cgi prog
```

where **prog** is the name of the Curry program with the cgi script, **/home/joe/public_html/prog.cgi** is the desired location of the compiled cgi script, and **initialForm** is the Curry expression (of type IO HtmlForm) computing the HTML form (where makecurrycgi is a shell script stored in *pakcshome*/bin).

Exported types:

```
type CgiEnv = CgiRef → String
```

> The type for representing cgi environments (i.e., mappings from cgi references to the corresponding values of the input elements).

```
type HtmlHandler = (CgiRef → String) → IO HtmlForm
```

> The type of event handlers in HTML forms.

```
data CgiRef
```

> The (abstract) data type for representing references to input elements in HTML forms.

> *Exported constructors:*

```
data HtmlExp
```

> The data type for representing HTML expressions.

> *Exported constructors:*

> - `HtmlText :: String → HtmlExp`
>
>   `HtmlText s`
>
>   – a text string without any further structure
>
> - `HtmlStruct :: String → [(String,String)] → [HtmlExp] → HtmlExp`
>
>   `HtmlStruct t as hs`
>
>   – a structure with a tag, attributes, and HTML expressions inside the structure
>
> - `HtmlCRef :: HtmlExp → CgiRef → HtmlExp`
>
>   `HtmlCRef h ref`
>
>   – an input element (described by the first argument) with a cgi reference

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- HtmlEvent :: HtmlExp → ((CgiRef → String) → IO HtmlForm) → HtmlExp

  HtmlEvent h hdlr

  – an input element (first arg) with an associated event handler (tpyically, a submit button)

data HtmlForm

The data type for representing HTML forms (active web pages) and return values of HTML forms.

Exported constructors:

- HtmlForm :: String → [FormParam] → [HtmlExp] → HtmlForm

  HtmlForm t ps hs

  – an HTML form with title t, optional parameters (e.g., cookies) ps, and contents hs

- HtmlAnswer :: String → String → HtmlForm

  HtmlAnswer t c

  – an answer in an arbitrary format where t is the content type (e.g., "text/plain") and c is the contents

data FormParam

The possible parameters of an HTML form. The parameters of a cookie (FormCookie) are its name and value and optional parameters (expiration date, domain, path (e.g., the path "/" makes the cookie valid for all documents on the server), security) which are collected in a list.

Exported constructors:

- FormCookie :: String → String → [CookieParam] → FormParam

  FormCookie name value params

  – a cookie to be sent to the client's browser

- FormCSS :: String → FormParam

  FormCSS s

  – a URL for a CSS file for this form

- FormJScript :: String → FormParam

  FormJScript s

  – a URL for a Javascript file for this form

- FormOnSubmit :: String → FormParam

  FormOnSubmit s

– a JavaScript statement to be executed when the form is submitted (i.e., <form ... onsubmit="s">)

- **FormTarget :: String → FormParam**

  FormTarget s

  – a name of a target frame where the output of the script should be represented (should only be used for scripts running in a frame)

- **FormEnc :: String → FormParam**

  FormEnc

  – the encoding scheme of this form

- **FormMeta :: [(String,String)] → FormParam**

  FormMeta as

  – meta information (in form of attributes) for this form

- **HeadInclude :: HtmlExp → FormParam**

  HeadInclude he

  – HTML expression to be included in form header

- **MultipleHandlers :: FormParam**

  MultipleHandlers

  – indicates that the event handlers of the form can be multiply used (i.e., are not deleted if the form is submitted so that they are still available when going back in the browser; but then there is a higher risk that the web server process might overflow with unused events); the default is a single use of event handlers, i.e., one cannot use the back button in the browser and submit the same form again (which is usually a reasonable behavior to avoid double submissions of data).

- **BodyAttr :: (String,String) → FormParam**

  BodyAttr ps

  – optional attribute for the body element (more than one occurrence is allowed)

data CookieParam

The possible parameters of a cookie.

Exported constructors:

- **CookieExpire :: ClockTime → CookieParam**

- **CookieDomain :: String → CookieParam**

- CookiePath :: String → CookieParam

- CookieSecure :: CookieParam

data HtmlPage

The data type for representing HTML pages. The constructor arguments are the title, the parameters, and the contents (body) of the web page.

Exported constructors:

- HtmlPage :: String → [PageParam] → [HtmlExp] → HtmlPage

data PageParam

The possible parameters of an HTML page.

Exported constructors:

- PageEnc :: String → PageParam

  PageEnc

    – the encoding scheme of this page

- PageCSS :: String → PageParam

  PageCSS s

    – a URL for a CSS file for this page

- PageJScript :: String → PageParam

  PageJScript s

    – a URL for a Javascript file for this page

- PageMeta :: [(String,String)] → PageParam

  PageMeta as

    – meta information (in form of attributes) for this page

- PageLink :: [(String,String)] → PageParam

  PageLink as

    – link information (in form of attributes) for this page

- PageBodyAttr :: (String,String) → PageParam

  PageBodyAttr attr

    – optional attribute for the body element of the page (more than one occurrence is allowed)

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Exported functions:

`defaultEncoding :: String`

> The default encoding used in generated web pages.

`idOfCgiRef :: CgiRef → String`

> Internal identifier of a CgiRef (intended only for internal use in other libraries!).

`formEnc :: String → FormParam`

> An encoding scheme for a HTML form.

`formCSS :: String → FormParam`

> A URL for a CSS file for a HTML form.

`formMetaInfo :: [(String,String)] → FormParam`

> Meta information for a HTML form. The argument is a list of attributes included in the meta-tag in the header for this form.

`formBodyAttr :: (String,String) → FormParam`

> Optional attribute for the body element of the HTML form. More than one occurrence is allowed, i.e., all such attributes are collected.

`form :: String → [HtmlExp] → HtmlForm`

> A basic HTML form for active web pages with the default encoding and a default background.

`standardForm :: String → [HtmlExp] → HtmlForm`

> A standard HTML form for active web pages where the title is included in the body as the first header.

`cookieForm :: String → [(String,String)] → [HtmlExp] → HtmlForm`

> An HTML form with simple cookies. The cookies are sent to the client's browser together with this form.

`addCookies :: [(String,String)] → HtmlForm → HtmlForm`

> Add simple cookie to HTML form. The cookies are sent to the client's browser together with this form.

`answerText :: String → HtmlForm`

> A textual result instead of an HTML form as a result for active web pages.

`answerEncText :: String → String → HtmlForm`

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A textual result instead of an HTML form as a result for active web pages where the encoding is given as the first parameter.

`addFormParam :: HtmlForm → FormParam → HtmlForm`

Adds a parameter to an HTML form.

`redirect :: Int → String → HtmlForm → HtmlForm`

Adds redirection to given HTML form.

`expires :: Int → HtmlForm → HtmlForm`

Adds expire time to given HTML form.

`addSound :: String → Bool → HtmlForm → HtmlForm`

Adds sound to given HTML form. The functions adds two different declarations for sound, one invented by Microsoft for the internet explorer, one introduced for netscape. As neither is an official part of HTML, addsound might not work on all systems and browsers. The greatest chance is by using sound files in MID-format.

`pageEnc :: String → PageParam`

An encoding scheme for a HTML page.

`pageCSS :: String → PageParam`

A URL for a CSS file for a HTML page.

`pageMetaInfo :: [(String,String)] → PageParam`

Meta information for a HTML page. The argument is a list of attributes included in the `meta`-tag in the header for this page.

`pageLinkInfo :: [(String,String)] → PageParam`

Link information for a HTML page. The argument is a list of attributes included in the `link`-tag in the header for this page.

`pageBodyAttr :: (String,String) → PageParam`

Optional attribute for the body element of the web page. More than one occurrence is allowed, i.e., all such attributes are collected.

`page :: String → [HtmlExp] → HtmlPage`

A basic HTML web page with the default encoding.

`standardPage :: String → [HtmlExp] → HtmlPage`

A standard HTML web page where the title is included in the body as the first header.

`addPageParam :: HtmlPage → PageParam → HtmlPage`

Adds a parameter to an HTML page.

`htxt :: String → HtmlExp`

Basic text as HTML expression. The text may contain special HTML chars (like
$<,>,\&,"$) which will be quoted so that they appear as in the parameter string.

`htxts :: [String] → [HtmlExp]`

A list of strings represented as a list of HTML expressions. The strings may contain
special HTML chars that will be quoted.

`hempty :: HtmlExp`

An empty HTML expression.

`nbsp :: HtmlExp`

Non breaking Space

`h1 :: [HtmlExp] → HtmlExp`

Header 1

`h2 :: [HtmlExp] → HtmlExp`

Header 2

`h3 :: [HtmlExp] → HtmlExp`

Header 3

`h4 :: [HtmlExp] → HtmlExp`

Header 4

`h5 :: [HtmlExp] → HtmlExp`

Header 5

`par :: [HtmlExp] → HtmlExp`

Paragraph

`section :: [HtmlExp] → HtmlExp`

Section

`header :: [HtmlExp] → HtmlExp`

Header

`footer :: [HtmlExp] → HtmlExp`

Footer

`emphasize :: [HtmlExp]` → `HtmlExp`

> Emphasize

`strong :: [HtmlExp]` → `HtmlExp`

> Strong (more emphasized) text.

`bold :: [HtmlExp]` → `HtmlExp`

> Boldface

`italic :: [HtmlExp]` → `HtmlExp`

> Italic

`nav :: [HtmlExp]` → `HtmlExp`

> Navigation

`code :: [HtmlExp]` → `HtmlExp`

> Program code

`center :: [HtmlExp]` → `HtmlExp`

> Centered text

`blink :: [HtmlExp]` → `HtmlExp`

> Blinking text

`teletype :: [HtmlExp]` → `HtmlExp`

> Teletype font

`pre :: [HtmlExp]` → `HtmlExp`

> Unformatted input, i.e., keep spaces and line breaks and don't quote special characters.

`verbatim :: String` → `HtmlExp`

> Verbatim (unformatted), special characters ($<$,$>$,&,") are quoted.

`address :: [HtmlExp]` → `HtmlExp`

> Address

`href :: String` → `[HtmlExp]` → `HtmlExp`

> Hypertext reference

`anchor :: String` → `[HtmlExp]` → `HtmlExp`

> An anchored text with a hypertext reference inside a document.

`ulist :: [[HtmlExp]]` → `HtmlExp`

    Unordered list

`olist :: [[HtmlExp]]` → `HtmlExp`

    Ordered list

`litem :: [HtmlExp]` → `HtmlExp`

    A single list item (usually not explicitly used)

`dlist :: [([HtmlExp],[HtmlExp])]` → `HtmlExp`

    Description list

`table :: [[[HtmlExp]]]` → `HtmlExp`

    Table with a matrix of items where each item is a list of HTML expressions.

`headedTable :: [[[HtmlExp]]]` → `HtmlExp`

    Similar to `table` but introduces header tags for the first row.

`addHeadings :: HtmlExp` → `[[HtmlExp]]` → `HtmlExp`

    Add a row of items (where each item is a list of HTML expressions) as headings to a table. If the first argument is not a table, the headings are ignored.

`hrule :: HtmlExp`

    Horizontal rule

`breakline :: HtmlExp`

    Break a line

`image :: String` → `String` → `HtmlExp`

    Image

`styleSheet :: String` → `HtmlExp`

    Defines a style sheet to be used in this HTML document.

`style :: String` → `[HtmlExp]` → `HtmlExp`

    Provides a style for HTML elements. The style argument is the name of a style class defined in a style definition (see `styleSheet`) or in an external style sheet (see form and page parameters `FormCSS` and `PageCSS`).

`textstyle :: String` → `String` → `HtmlExp`

    Provides a style for a basic text. The style argument is the name of a style class defined in an external style sheet.

`blockstyle :: String → [HtmlExp] → HtmlExp`

> Provides a style for a block of HTML elements. The style argument is the name of a style class defined in an external style sheet. This element is used (in contrast to "style") for larger blocks of HTML elements since a line break is placed before and after these elements.

`inline :: [HtmlExp] → HtmlExp`

> Joins a list of HTML elements into a single HTML element. Although this construction has no rendering, it is sometimes useful for programming when several HTML elements must be put together.

`block :: [HtmlExp] → HtmlExp`

> Joins a list of HTML elements into a block. A line break is placed before and after these elements.

`button :: String → ((CgiRef → String) → IO HtmlForm) → HtmlExp`

> Submit button with a label string and an event handler

`resetbutton :: String → HtmlExp`

> Reset button with a label string

`imageButton :: String → ((CgiRef → String) → IO HtmlForm) → HtmlExp`

> Submit button in form of an imag.

`textfield :: CgiRef → String → HtmlExp`

> Input text field with a reference and an initial contents

`password :: CgiRef → HtmlExp`

> Input text field (where the entered text is obscured) with a reference

`textarea :: CgiRef → (Int,Int) → String → HtmlExp`

> Input text area with a reference, height/width, and initial contents

`checkbox :: CgiRef → String → HtmlExp`

> A checkbox with a reference and a value. The value is returned if checkbox is on, otherwise "" is returned.

`checkedbox :: CgiRef → String → HtmlExp`

> A checkbox that is initially checked with a reference and a value. The value is returned if checkbox is on, otherwise "" is returned.

`radio_main :: CgiRef → String → HtmlExp`

A main button of a radio (initially "on") with a reference and a value. The value is returned of this button is on. A complete radio button suite always consists of a main button (radio*main) and some further buttons (radio*others) with the same reference. Initially, the main button is selected (or nothing is selected if one uses radio*main*off instead of radio_main). The user can select another button but always at most one button of the radio can be selected. The value corresponding to the selected button is returned in the environment for this radio reference.

radio_main_off :: CgiRef → String → HtmlExp

A main button of a radio (initially "off") with a reference and a value. The value is returned of this button is on.

radio_other :: CgiRef → String → HtmlExp

A further button of a radio (initially "off") with a reference (identical to the main button of this radio) and a value. The value is returned of this button is on.

selection :: CgiRef → [(String,String)] → HtmlExp

A selection button with a reference and a list of name/value pairs. The names are shown in the selection and the value is returned for the selected name.

selectionInitial :: CgiRef → [(String,String)] → Int → HtmlExp

A selection button with a reference, a list of name/value pairs, and a preselected item in this list. The names are shown in the selection and the value is returned for the selected name.

multipleSelection :: CgiRef → [(String,String,Bool)] → HtmlExp

A selection button with a reference and a list of name/value/flag pairs. The names are shown in the selection and the value is returned if the corresponding name is selected. If flag is True, the corresonding name is initially selected. If more than one name has been selected, all values are returned in one string where the values are separated by newline (<code>\n</code>) characters.

hiddenfield :: String → String → HtmlExp

A hidden field to pass a value referenced by a fixed name. This function should be used with care since it may cause conflicts with the CGI-based implementation of this library.

htmlQuote :: String → String

Quotes special characters ($<$,$>$,&,", umlauts) in a string as HTML special characters.

htmlIsoUmlauts :: String → String

Translates umlauts in iso-8859-1 encoding into HTML special characters.

`addAttr :: HtmlExp → (String,String) → HtmlExp`

Adds an attribute (name/value pair) to an HTML element.

`addAttrs :: HtmlExp → [(String,String)] → HtmlExp`

Adds a list of attributes (name/value pair) to an HTML element.

`addClass :: HtmlExp → String → HtmlExp`

Adds a class attribute to an HTML element.

`showHtmlExps :: [HtmlExp] → String`

Transforms a list of HTML expressions into string representation.

`showHtmlExp :: HtmlExp → String`

Transforms a single HTML expression into string representation.

`showHtmlPage :: HtmlPage → String`

Transforms HTML page into string representation.

`getUrlParameter :: IO String`

Gets the parameter attached to the URL of the script. For instance, if the script is called with URL "http://.../script.cgi?parameter", then "parameter" is returned by this I/O action. Note that an URL parameter should be "URL encoded" to avoid the appearance of characters with a special meaning. Use the functions "urlencoded2string" and "string2urlencoded" to decode and encode such parameters, respectively.

`urlencoded2string :: String → String`

Translates urlencoded string into equivalent ASCII string.

`string2urlencoded :: String → String`

Translates arbitrary strings into equivalent urlencoded string.

`getCookies :: IO [(String,String)]`

Gets the cookies sent from the browser for the current CGI script. The cookies are represented in the form of name/value pairs since no other components are important here.

`coordinates :: (CgiRef → String) → Maybe (Int,Int)`

For image buttons: retrieve the coordinates where the user clicked within the image.

`runFormServerWithKey :: String → String → IO HtmlForm → IO ()`

The server implementing an HTML form (possibly containing input fields). It receives a message containing the environment of the client's web browser, translates the HTML form w.r.t. this environment into a string representation of the complete HTML document and sends the string representation back to the client's browser by binding the corresponding message argument.

`runFormServerWithKeyAndFormParams :: String → String → [FormParam] → IO HtmlForm → IO ()`

The server implementing an HTML form (possibly containing input fields). It receives a message containing the environment of the client's web browser, translates the HTML form w.r.t. this environment into a string representation of the complete HTML document and sends the string representation back to the client's browser by binding the corresponding message argument.

`showLatexExps :: [HtmlExp] → String`

Transforms HTML expressions into LaTeX string representation.

`showLatexExp :: HtmlExp → String`

Transforms an HTML expression into LaTeX string representation.

`htmlSpecialChars2tex :: String → String`

Convert special HTML characters into their LaTeX representation, if necessary.

`showLatexDoc :: [HtmlExp] → String`

Transforms HTML expressions into a string representation of a complete LaTeX document.

`showLatexDocWithPackages :: [HtmlExp] → [String] → String`

Transforms HTML expressions into a string representation of a complete LaTeX document. The variable "packages" holds the packages to add to the latex document e.g. "ngerman"

`showLatexDocs :: [[HtmlExp]] → String`

Transforms a list of HTML expressions into a string representation of a complete LaTeX document where each list entry appears on a separate page.

`showLatexDocsWithPackages :: [[HtmlExp]] → [String] → String`

Transforms a list of HTML expressions into a string representation of a complete LaTeX document where each list entry appears on a separate page. The variable "packages" holds the packages to add to the latex document (e.g., "ngerman").

`germanLatexDoc :: [HtmlExp] → String`

show german latex document

```
intForm :: IO HtmlForm → IO ()
```

Execute an HTML form in "interactive" mode.

```
intFormMain :: String → String → String → String → Bool → String → IO
HtmlForm → IO ()
```

Execute an HTML form in "interactive" mode with various parameters.

A.4.3 Library HtmlCgi

Library to support CGI programming in the HTML library. It is only intended as an auxiliary library to implement dynamic web pages according to the HTML library. It contains a simple script that is installed for a dynamic web page and which sends the user input to the real application server implementing the application.

Exported types:

```
data CgiServerMsg
```

The messages to comunicate between the cgi script and the server program. CgiSubmit env cgienv nextpage - pass the environment and show next page, where env are the values of the environment variables of the web script (e.g., QUERY$STRING$, REMOTE$HOST$, REMOTE_ADDR), cgienv are the values in the current form submitted by the client, and nextpage is the answer text to be shown in the next web page

Exported constructors:

- `CgiSubmit :: [(String,String)] → [(String,String)] → CgiServerMsg`

- `GetLoad :: CgiServerMsg`

  `GetLoad`

  – get info about the current load of the server process

- `SketchStatus :: CgiServerMsg`

  `SketchStatus`

  – get a sketch of the status of the server

- `SketchHandlers :: CgiServerMsg`

  `SketchHandlers`

  – get a sketch of all event handlers of the server

- `ShowStatus :: CgiServerMsg`

  `ShowStatus`

  – show the status of the server with all event handlers

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- CleanServer :: CgiServerMsg

  CleanServer

  – clean up the server (with possible termination)

- StopCgiServer :: CgiServerMsg

  StopCgiServer

  – stop the server

Exported functions:

readCgiServerMsg :: Handle → IO (Maybe CgiServerMsg)

    Reads a line from a handle and check whether it is a syntactically correct cgi server message.

submitForm :: IO ()

runCgiServerCmd :: String → CgiServerMsg → IO ()

    Executes a specific command for a cgi server.

noHandlerPage :: String → String → String

cgiServerRegistry :: String

    The name of the file to register all cgi servers.

registerCgiServer :: String → String → IO ()

unregisterCgiServer :: String → IO ()

A.4.4 Library HtmlParser

This module contains a very simple parser for HTML documents.

Exported functions:

readHtmlFile :: String → IO [HtmlExp]

    Reads a file with HTML text and returns the corresponding HTML expressions.

parseHtmlString :: String → [HtmlExp]

    Transforms an HTML string into a list of HTML expressions. If the HTML string is a well structured document, the list of HTML expressions should contain exactly one element.

A.4.5 Library Mail

This library contains functions for sending emails. The implementation might need to be adapted to the local environment.

Exported types:

`data MailOption`

>   Options for sending emails.

> *Exported constructors:*

> - `CC :: String → MailOption`

>   `CC`

>   > – recipient of a carbon copy

> - `BCC :: String → MailOption`

>   `BCC`

>   > – recipient of a blind carbon copy

> - `TO :: String → MailOption`

>   `TO`

>   > – recipient of the email

Exported functions:

`sendMail :: String → String → String → String → IO ()`

>   Sends an email via mailx command.

`sendMailWithOptions :: String → String → [MailOption] → String → IO ()`

>   Sends an email via mailx command and various options. Note that multiple options are allowed, e.g., more than one CC option for multiple recipient of carbon copies.

>   Important note: The implementation of this operation is based on the command "mailx" and must be adapted according to your local environment!

A.4.6 Library Markdown

Library to translate markdown documents into HTML or LaTeX. The slightly restricted subset of the markdown syntax recognized by this implementation is documented in this page.

Exported types:

```
type MarkdownDoc = [MarkdownElem]
```

A markdown document is a list of markdown elements.

```
data MarkdownElem
```

The data type for representing the different elements occurring in a markdown document.

Exported constructors:

- `Text :: String → MarkdownElem`

  `Text s`

    – a simple text in a markdown document

- `Emph :: String → MarkdownElem`

  `Emph s`

    – an emphasized text in a markdown document

- `Strong :: String → MarkdownElem`

  `Strong s`

    – a strongly emphaszed text in a markdown document

- `Code :: String → MarkdownElem`

  `Code s`

    – a code string in a markdown document

- `HRef :: String → String → MarkdownElem`

  `HRef s u`

    – a reference to URL `u` with text `s` in a markdown document

- `Par :: [MarkdownElem] → MarkdownElem`

  `Par md`

    – a paragraph in a markdown document

- `CodeBlock :: String → MarkdownElem`

  `CodeBlock s`

    – a code block in a markdown document

- `UList :: [[MarkdownElem]] → MarkdownElem`

  `UList mds`

- an unordered list in a markdown document

- OList :: [[MarkdownElem]] → MarkdownElem

  OList mds

  - an ordered list in a markdown document

- Quote :: [MarkdownElem] → MarkdownElem

  Quote md

  - a quoted paragraph in a markdown document

- HRule :: MarkdownElem

  HRule

  - a hoirzontal rule in a markdown document

- Header :: Int → String → MarkdownElem

  Header l s

  - a level `l` header with title `s` in a markdown document

Exported functions:

fromMarkdownText :: String → [MarkdownElem]

Parse markdown document from its textual representation.

removeEscapes :: String → String

Remove the backlash of escaped markdown characters in a string.

markdownEscapeChars :: String

Escape characters supported by markdown.

markdownText2HTML :: String → [HtmlExp]

Translate a markdown text into a (partial) HTML document.

markdownText2CompleteHTML :: String → String → String

Translate a markdown text into a complete HTML text that can be viewed as a standalone document by a browser. The first argument is the title of the document.

markdownText2LaTeX :: String → String

Translate a markdown text into a (partial) LaTeX document. All characters with a special meaning in LaTeX, like dollar or ampersand signs, are quoted.

markdownText2LaTeXWithFormat :: (String → String) → String → String

Translate a markdown text into a (partial) LaTeX document where the first argument is a function to translate the basic text occurring in markdown elements to a LaTeX string. For instance, one can use a translation operation that supports passing mathematical formulas in LaTeX style instead of quoting all special characters.

`markdownText2CompleteLaTeX :: String → String`

Translate a markdown text into a complete LaTeX document that can be formatted as a standalone document.

`formatMarkdownInputAsPDF :: IO ()`

Format the standard input (containing markdown text) as PDF.

`formatMarkdownFileAsPDF :: String → IO ()`

Format a file containing markdown text as PDF.

A.4.7 Library URL

Library for dealing with URLs (Uniform Resource Locators).

Exported functions:

`getContentsOfUrl :: String → IO String`

Reads the contents of a document located by a URL. This action requires that the program "wget" is in your path, otherwise the implementation must be adapted to the local installation.

A.4.8 Library WUI

A library to support the type-oriented construction of Web User Interfaces (WUIs).
The ideas behind the application and implementation of WUIs are described in a paper that is available via this web page.

Exported types:

`type Rendering = [HtmlExp] → HtmlExp`

A rendering is a function that combines the visualization of components of a data structure into some HTML expression.

`data WuiHandler`

A handler for a WUI is an event handler for HTML forms possibly with some specific code attached (for future extensions).

Exported constructors:

`data WuiSpec`

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The type of WUI specifications. The first component are parameters specifying the behavior of this WUI type (rendering, error message, and constraints on inputs). The second component is a "show" function returning an HTML expression for the edit fields and a WUI state containing the CgiRefs to extract the values from the edit fields. The third component is "read" function to extract the values from the edit fields for a given cgi environment (returned as (Just v)). If the value is not legal, Nothing is returned. The second component of the result contains an HTML edit expression together with a WUI state to edit the value again.

Exported constructors:

`data WTree`

A simple tree structure to demonstrate the construction of WUIs for tree types.

Exported constructors:

- `WLeaf :: a → WTree a`

- `WNode :: [WTree a] → WTree a`

Exported functions:

`wuiHandler2button :: String → WuiHandler → HtmlExp`

Transform a WUI handler into a submit button with a given label string.

`withRendering :: WuiSpec a → ([HtmlExp] → HtmlExp) → WuiSpec a`

Puts a new rendering function into a WUI specification.

`withError :: WuiSpec a → String → WuiSpec a`

Puts a new error message into a WUI specification.

`withCondition :: WuiSpec a → (a → Bool) → WuiSpec a`

Puts a new condition into a WUI specification.

`transformWSpec :: (a → b,b → a) → WuiSpec a → WuiSpec b`

Transforms a WUI specification from one type to another.

`adaptWSpec :: (a → b) → WuiSpec a → WuiSpec b`

Adapt a WUI specification to a new type. For this purpose, the first argument must be a transformation mapping values from the old type to the new type. This function must be bijective and operationally invertible (i.e., the inverse must be computable by narrowing). Otherwise, use `transformWSpec`!

`wHidden :: WuiSpec a`

A hidden widget for a value that is not shown in the WUI. Usually, this is used in components of larger structures, e.g., internal identifiers, data base keys.

wConstant :: (a → HtmlExp) → WuiSpec a

A widget for values that are shown but cannot be modified. The first argument is a mapping of the value into a HTML expression to show this value.

wInt :: WuiSpec Int

A widget for editing integer values.

wString :: WuiSpec String

A widget for editing string values.

wStringSize :: Int → WuiSpec String

A widget for editing string values with a size attribute.

wRequiredString :: WuiSpec String

A widget for editing string values that are required to be non-empty.

wRequiredStringSize :: Int → WuiSpec String

A widget with a size attribute for editing string values that are required to be non-empty.

wTextArea :: (Int,Int) → WuiSpec String

A widget for editing string values in a text area. The argument specifies the height and width of the text area.

wSelect :: (a → String) → [a] → WuiSpec a

A widget to select a value from a given list of values. The current value should be contained in the value list and is preselected. The first argument is a mapping from values into strings to be shown in the selection widget.

wSelectInt :: [Int] → WuiSpec Int

A widget to select a value from a given list of integers (provided as the argument). The current value should be contained in the value list and is preselected.

wSelectBool :: String → String → WuiSpec Bool

A widget to select a Boolean value via a selection box. The arguments are the strings that are shown for the values True and False in the selection box, respectively.

wCheckBool :: [HtmlExp] → WuiSpec Bool

A widget to select a Boolean value via a check box. The first argument are HTML expressions that are shown after the check box. The result is True if the box is checked.

```
wMultiCheckSelect :: (a → [HtmlExp]) → [a] → WuiSpec [a]
```

A widget to select a list of values from a given list of values via check boxes. The current values should be contained in the value list and are preselected. The first argument is a mapping from values into HTML expressions that are shown for each item after the check box.

```
wRadioSelect :: (a → [HtmlExp]) → [a] → WuiSpec a
```

A widget to select a value from a given list of values via a radio button. The current value should be contained in the value list and is preselected. The first argument is a mapping from values into HTML expressions that are shown for each item after the radio button.

```
wRadioBool :: [HtmlExp] → [HtmlExp] → WuiSpec Bool
```

A widget to select a Boolean value via a radio button. The arguments are the lists of HTML expressions that are shown after the True and False radio buttons, respectively.

```
wPair :: WuiSpec a → WuiSpec b → WuiSpec (a,b)
```

WUI combinator for pairs.

```
wCons2 :: (a → b → c) → WuiSpec a → WuiSpec b → WuiSpec c
```

WUI combinator for constructors of arity 2. The first argument is the binary constructor. The second and third arguments are the WUI specifications for the argument types.

```
wTriple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec (a,b,c)
```

WUI combinator for triples.

```
wCons3 :: (a → b → c → d) → WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d
```

WUI combinator for constructors of arity 3. The first argument is the ternary constructor. The further arguments are the WUI specifications for the argument types.

```
w4Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec (a,b,c,d)
```

WUI combinator for tuples of arity 4.

```
wCons4 :: (a → b → c → d → e) → WuiSpec a → WuiSpec b → WuiSpec c →
WuiSpec d → WuiSpec e
```

WUI combinator for constructors of arity 4. The first argument is the ternary constructor. The further arguments are the WUI specifications for the argument types.

```
w5Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec (a,b,c,d,e)
```

WUI combinator for tuples of arity 5.

```
wCons5 :: (a → b → c → d → e → f) → WuiSpec a → WuiSpec b → WuiSpec c →
WuiSpec d → WuiSpec e → WuiSpec f
```

WUI combinator for constructors of arity 5. The first argument is the ternary construc-
tor. The further arguments are the WUI specifications for the argument types.

```
w6Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec f → WuiSpec (a,b,c,d,e,f)
```

WUI combinator for tuples of arity 6.

```
wCons6 :: (a → b → c → d → e → f → g) → WuiSpec a → WuiSpec b → WuiSpec c
→ WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g
```

WUI combinator for constructors of arity 6. The first argument is the ternary construc-
tor. The further arguments are the WUI specifications for the argument types.

```
w7Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec f → WuiSpec g → WuiSpec (a,b,c,d,e,f,g)
```

WUI combinator for tuples of arity 7.

```
wCons7 :: (a → b → c → d → e → f → g → h) → WuiSpec a → WuiSpec b →
WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g → WuiSpec h
```

WUI combinator for constructors of arity 7. The first argument is the ternary construc-
tor. The further arguments are the WUI specifications for the argument types.

```
w8Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec (a,b,c,d,e,f,g,h)
```

WUI combinator for tuples of arity 8.

```
wCons8 :: (a → b → c → d → e → f → g → h → i) → WuiSpec a → WuiSpec b
→ WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g → WuiSpec h →
WuiSpec i
```

WUI combinator for constructors of arity 8. The first argument is the ternary construc-
tor. The further arguments are the WUI specifications for the argument types.

```
w9Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec (a,b,c,d,e,f,g,h,i)
```

WUI combinator for tuples of arity 9.

```
wCons9 :: (a → b → c → d → e → f → g → h → i → j) → WuiSpec a → WuiSpec
b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g → WuiSpec h →
WuiSpec i → WuiSpec j
```

WUI combinator for constructors of arity 9. The first argument is the ternary construc-
tor. The further arguments are the WUI specifications for the argument types.

`w10Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e`
`→ WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec`
`(a,b,c,d,e,f,g,h,i,j)`

WUI combinator for tuples of arity 10.

`wCons10 :: (a → b → c → d → e → f → g → h → i → j → k) → WuiSpec a →`
`WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g →`
`WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k`

WUI combinator for constructors of arity 10. The first argument is the ternary con-structor. The further arguments are the WUI specifications for the argument types.

`w11Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →`
`WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k →`
`WuiSpec (a,b,c,d,e,f,g,h,i,j,k)`

WUI combinator for tuples of arity 11.

`wCons11 :: (a → b → c → d → e → f → g → h → i → j → k → l) → WuiSpec a`
`→ WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g →`
`WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k → WuiSpec l`

WUI combinator for constructors of arity 11. The first argument is the ternary con-structor. The further arguments are the WUI specifications for the argument types.

`w12Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →`
`WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k →`
`WuiSpec l → WuiSpec (a,b,c,d,e,f,g,h,i,j,k,l)`

WUI combinator for tuples of arity 12.

`wCons12 :: (a → b → c → d → e → f → g → h → i → j → k → l → m) →`
`WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f →`
`WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k → WuiSpec l →`
`WuiSpec m`

WUI combinator for constructors of arity 12. The first argument is the ternary con-structor. The further arguments are the WUI specifications for the argument types.

`wJoinTuple :: WuiSpec a → WuiSpec b → WuiSpec (a,b)`

WUI combinator to combine two tuples into a joint tuple. It is similar to wPair but renders both components as a single tuple provided that the components are already rendered as tuples, i.e., by the rendering function `renderTuple`. This combinator is useful to define combinators for large tuples.

`wList :: WuiSpec a → WuiSpec [a]`

WUI combinator for list structures where the list elements are vertically aligned in a table.

`wListWithHeadings :: [String]` $\rightarrow$ `WuiSpec a` $\rightarrow$ `WuiSpec [a]`

Add headings to a standard WUI for list structures:

`wHList :: WuiSpec a` $\rightarrow$ `WuiSpec [a]`

WUI combinator for list structures where the list elements are horizontally aligned in a table.

`wMatrix :: WuiSpec a` $\rightarrow$ `WuiSpec [[a]]`

WUI for matrices, i.e., list of list of elements visualized as a matrix.

`wMaybe :: WuiSpec Bool` $\rightarrow$ `WuiSpec a` $\rightarrow$ `a` $\rightarrow$ `WuiSpec (Maybe a)`

WUI for Maybe values. It is constructed from a WUI for Booleans and a WUI for the potential values. Nothing corresponds to a selection of False in the Boolean WUI. The value WUI is shown after the Boolean WUI.

`wCheckMaybe :: WuiSpec a` $\rightarrow$ `[HtmlExp]` $\rightarrow$ `a` $\rightarrow$ `WuiSpec (Maybe a)`

A WUI for Maybe values where a check box is used to select Just. The value WUI is shown after the check box.

`wRadioMaybe :: WuiSpec a` $\rightarrow$ `[HtmlExp]` $\rightarrow$ `[HtmlExp]` $\rightarrow$ `a` $\rightarrow$ `WuiSpec (Maybe a)`

A WUI for Maybe values where radio buttons are used to switch between Nothing and Just. The value WUI is shown after the radio button WUI.

`wEither :: WuiSpec a` $\rightarrow$ `WuiSpec b` $\rightarrow$ `WuiSpec (Either a b)`

WUI for union types. Here we provide only the implementation for Either types since other types with more alternatives can be easily reduced to this case.

`wTree :: WuiSpec a` $\rightarrow$ `WuiSpec (WTree a)`

WUI for tree types. The rendering specifies the rendering of inner nodes. Leaves are shown with their default rendering.

`renderTuple :: [HtmlExp]` $\rightarrow$ `HtmlExp`

Standard rendering of tuples as a table with a single row. Thus, the elements are horizontally aligned.

`renderTaggedTuple :: [String]` $\rightarrow$ `[HtmlExp]` $\rightarrow$ `HtmlExp`

Standard rendering of tuples with a tag for each element. Thus, each is preceded by a tag, that is set in bold, and all elements are vertically aligned.

`renderList :: [HtmlExp]` $\rightarrow$ `HtmlExp`

Standard rendering of lists as a table with a row for each item: Thus, the elements are vertically aligned.

```
mainWUI :: WuiSpec a → a → (a → IO HtmlForm) → IO HtmlForm
```

> Generates an HTML form from a WUI data specification, an initial value and an update form.

```
wui2html :: WuiSpec a → a → (a → IO HtmlForm) → (HtmlExp,WuiHandler)
```

> Generates HTML editors and a handler from a WUI data specification, an initial value and an update form.

```
wuiInForm :: WuiSpec a → a → (a → IO HtmlForm) → (HtmlExp → WuiHandler → IO
HtmlForm) → IO HtmlForm
```

> Puts a WUI into a HTML form containing "holes" for the WUI and the handler.

```
wuiWithErrorForm :: WuiSpec a → a → (a → IO HtmlForm) → (HtmlExp → WuiHandler
→ IO HtmlForm) → (HtmlExp,WuiHandler)
```

> Generates HTML editors and a handler from a WUI data specification, an initial value and an update form. In addition to wui2html, we can provide a skeleton form used to show illegal inputs.

A.4.9 Library WUIjs

A library to support the type-oriented construction of Web User Interfaces (WUIs).
The ideas behind the application and implementation of WUIs are described in a paper that is available via this web page.
In addition to the original library, this version provides also support for JavaScript.

Exported types:

```
type Rendering = [HtmlExp] → HtmlExp
```

> A rendering is a function that combines the visualization of components of a data structure into some HTML expression.

```
data WuiHandler
```

> A handler for a WUI is an event handler for HTML forms possibly with some specific JavaScript code attached.

Exported constructors:

```
data WuiSpec
```

> The type of WUI specifications. The first component are parameters specifying the behavior of this WUI type (rendering, error message, and constraints on inputs). The second component is a "show" function returning an HTML expression for the edit fields and a WUI state containing the CgiRefs to extract the values from the edit fields. The third component is "read" function to extract the values from the edit fields for a given cgi environment (returned as (Just v)). If the value is not legal, Nothing is returned. The second component of the result contains an HTML edit expression together with a WUI state to edit the value again.

Exported constructors:

```
data WTree
```

A simple tree structure to demonstrate the construction of WUIs for tree types.

Exported constructors:

- `WLeaf :: a → WTree a`

- `WNode :: [WTree a] → WTree a`

Exported functions:

`wuiHandler2button :: String → WuiHandler → HtmlExp`

Transform a WUI handler into a submit button with a given label string.

`withRendering :: WuiSpec a → ([HtmlExp] → HtmlExp) → WuiSpec a`

Puts a new rendering function into a WUI specification.

`withError :: WuiSpec a → String → WuiSpec a`

Puts a new error message into a WUI specification.

`withCondition :: WuiSpec a → (a → Bool) → WuiSpec a`

Puts a new condition into a WUI specification.

`withConditionJS :: WuiSpec a → (a → Bool) → WuiSpec a`

Puts a new JavaScript implementation of the condition into a WUI specification.

`withConditionJSName :: WuiSpec a → (a → Bool,String) → WuiSpec a`

Puts a new JavaScript implementation of the condition into a WUI specification.

`transformWSpec :: (a → b,b → a) → WuiSpec a → WuiSpec b`

Transforms a WUI specification from one type to another.

`adaptWSpec :: (a → b) → WuiSpec a → WuiSpec b`

Adapt a WUI specification to a new type. For this purpose, the first argument must be a transformation mapping values from the old type to the new type. This function must be bijective and operationally invertible (i.e., the inverse must be computable by narrowing). Otherwise, use `transformWSpec`!

`wHidden :: WuiSpec a`

A hidden widget for a value that is not shown in the WUI. Usually, this is used in components of larger structures, e.g., internal identifiers, data base keys.

`wConstant :: (a → HtmlExp) → WuiSpec a`

> A widget for values that are shown but cannot be modified. The first argument is a mapping of the value into a HTML expression to show this value.

`wInt :: WuiSpec Int`

> A widget for editing integer values.

`wString :: WuiSpec String`

> A widget for editing string values.

`wStringSize :: Int → WuiSpec String`

> A widget for editing string values with a size attribute.

`wRequiredString :: WuiSpec String`

> A widget for editing string values that are required to be non-empty.

`wRequiredStringSize :: Int → WuiSpec String`

> A widget with a size attribute for editing string values that are required to be non-empty.

`wTextArea :: (Int,Int) → WuiSpec String`

> A widget for editing string values in a text area. The argument specifies the height and width of the text area.

`wSelect :: (a → String) → [a] → WuiSpec a`

> A widget to select a value from a given list of values. The current value should be contained in the value list and is preselected. The first argument is a mapping from values into strings to be shown in the selection widget.

`wSelectInt :: [Int] → WuiSpec Int`

> A widget to select a value from a given list of integers (provided as the argument). The current value should be contained in the value list and is preselected.

`wSelectBool :: String → String → WuiSpec Bool`

> A widget to select a Boolean value via a selection box. The arguments are the strings that are shown for the values True and False in the selection box, respectively.

`wCheckBool :: [HtmlExp] → WuiSpec Bool`

> A widget to select a Boolean value via a check box. The first argument are HTML expressions that are shown after the check box. The result is True if the box is checked.

`wMultiCheckSelect :: (a → [HtmlExp]) → [a] → WuiSpec [a]`

A widget to select a list of values from a given list of values via check boxes. The current values should be contained in the value list and are preselected. The first argument is a mapping from values into HTML expressions that are shown for each item after the check box.

`wRadioSelect :: (a → [HtmlExp]) → [a] → WuiSpec a`

A widget to select a value from a given list of values via a radio button. The current value should be contained in the value list and is preselected. The first argument is a mapping from values into HTML expressions that are shown for each item after the radio button.

`wRadioBool :: [HtmlExp] → [HtmlExp] → WuiSpec Bool`

A widget to select a Boolean value via a radio button. The arguments are the lists of HTML expressions that are shown after the True and False radio buttons, respectively.

`wJoinTuple :: WuiSpec a → WuiSpec b → WuiSpec (a,b)`

WUI combinator to combine two tuples into a joint tuple. It is similar to wPair but renders both components as a single tuple provided that the components are already rendered as tuples, i.e., by the rendering function `renderTuple`. This combinator is useful to define combinators for large tuples.

`wPair :: WuiSpec a → WuiSpec b → WuiSpec (a,b)`

WUI combinator for pairs.

`wCons2 :: (a → b → c) → WuiSpec a → WuiSpec b → WuiSpec c`

WUI combinator for constructors of arity 2. The first argument is the binary constructor. The second and third arguments are the WUI specifications for the argument types.

`wCons2JS :: Maybe ([JSExp] → JSExp) → (a → b → c) → WuiSpec a → WuiSpec b → WuiSpec c`

`wTriple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec (a,b,c)`

WUI combinator for triples.

`wCons3 :: (a → b → c → d) → WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d`

WUI combinator for constructors of arity 3. The first argument is the ternary constructor. The further arguments are the WUI specifications for the argument types.

`wCons3JS :: Maybe ([JSExp] → JSExp) → (a → b → c → d) → WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d`

```
w4Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec (a,b,c,d)
```

WUI combinator for tuples of arity 4.

```
wCons4 :: (a → b → c → d → e) → WuiSpec a → WuiSpec b → WuiSpec c →
WuiSpec d → WuiSpec e
```

WUI combinator for constructors of arity 4. The first argument is the ternary constructor. The further arguments are the WUI specifications for the argument types.

```
wCons4JS :: Maybe ([JSExp] → JSExp) → (a → b → c → d → e) → WuiSpec a →
WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e
```

```
w5Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec (a,b,c,d,e)
```

WUI combinator for tuples of arity 5.

```
wCons5 :: (a → b → c → d → e → f) → WuiSpec a → WuiSpec b → WuiSpec c →
WuiSpec d → WuiSpec e → WuiSpec f
```

WUI combinator for constructors of arity 5. The first argument is the ternary constructor. The further arguments are the WUI specifications for the argument types.

```
wCons5JS :: Maybe ([JSExp] → JSExp) → (a → b → c → d → e → f) → WuiSpec a
→ WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f
```

```
w6Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec f → WuiSpec (a,b,c,d,e,f)
```

WUI combinator for tuples of arity 6.

```
wCons6 :: (a → b → c → d → e → f → g) → WuiSpec a → WuiSpec b → WuiSpec c
→ WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g
```

WUI combinator for constructors of arity 6. The first argument is the ternary constructor. The further arguments are the WUI specifications for the argument types.

```
wCons6JS :: Maybe ([JSExp] → JSExp) → (a → b → c → d → e → f → g) →
WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f →
WuiSpec g
```

```
w7Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec f → WuiSpec g → WuiSpec (a,b,c,d,e,f,g)
```

WUI combinator for tuples of arity 7.

```
wCons7 :: (a → b → c → d → e → f → g → h) → WuiSpec a → WuiSpec b →
WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g → WuiSpec h
```

WUI combinator for constructors of arity 7. The first argument is the ternary construc-
tor. The further arguments are the WUI specifications for the argument types.

```
wCons7JS :: Maybe ([JSExp] → JSExp) → (a → b → c → d → e → f → g → h)
→ WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f →
WuiSpec g → WuiSpec h
```

```
w8Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec (a,b,c,d,e,f,g,h)
```

WUI combinator for tuples of arity 8.

```
wCons8 :: (a → b → c → d → e → f → g → h → i) → WuiSpec a → WuiSpec b
→ WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g → WuiSpec h →
WuiSpec i
```

WUI combinator for constructors of arity 8. The first argument is the ternary construc-
tor. The further arguments are the WUI specifications for the argument types.

```
wCons8JS :: Maybe ([JSExp] → JSExp) → (a → b → c → d → e → f → g → h →
i) → WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f
→ WuiSpec g → WuiSpec h → WuiSpec i
```

```
w9Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec (a,b,c,d,e,f,g,h,i)
```

WUI combinator for tuples of arity 9.

```
wCons9 :: (a → b → c → d → e → f → g → h → i → j) → WuiSpec a → WuiSpec
b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g → WuiSpec h →
WuiSpec i → WuiSpec j
```

WUI combinator for constructors of arity 9. The first argument is the ternary construc-
tor. The further arguments are the WUI specifications for the argument types.

```
wCons9JS :: Maybe ([JSExp] → JSExp) → (a → b → c → d → e → f → g → h → i
→ j) → WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec
f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j
```

```
w10Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e
→ WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec
(a,b,c,d,e,f,g,h,i,j)
```

WUI combinator for tuples of arity 10.

wCons10 :: (a → b → c → d → e → f → g → h → i → j → k) → WuiSpec a →
WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g →
WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k

> WUI combinator for constructors of arity 10. The first argument is the ternary con-
> structor. The further arguments are the WUI specifications for the argument types.

wCons10JS :: Maybe ([JSExp] → JSExp) → (a → b → c → d → e → f → g → h →
i → j → k) → WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k

w11Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k →
WuiSpec (a,b,c,d,e,f,g,h,i,j,k)

> WUI combinator for tuples of arity 11.

wCons11 :: (a → b → c → d → e → f → g → h → i → j → k → l) → WuiSpec a
→ WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f → WuiSpec g →
WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k → WuiSpec l

> WUI combinator for constructors of arity 11. The first argument is the ternary con-
> structor. The further arguments are the WUI specifications for the argument types.

wCons11JS :: Maybe ([JSExp] → JSExp) → (a → b → c → d → e → f → g → h →
i → j → k → l) → WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e
→ WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k →
WuiSpec l

w12Tuple :: WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e →
WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k →
WuiSpec l → WuiSpec (a,b,c,d,e,f,g,h,i,j,k,l)

> WUI combinator for tuples of arity 12.

wCons12 :: (a → b → c → d → e → f → g → h → i → j → k → l → m) →
WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d → WuiSpec e → WuiSpec f →
WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j → WuiSpec k → WuiSpec l →
WuiSpec m

> WUI combinator for constructors of arity 12. The first argument is the ternary con-
> structor. The further arguments are the WUI specifications for the argument types.

wCons12JS :: Maybe ([JSExp] → JSExp) → (a → b → c → d → e → f → g → h
→ i → j → k → l → m) → WuiSpec a → WuiSpec b → WuiSpec c → WuiSpec d →
WuiSpec e → WuiSpec f → WuiSpec g → WuiSpec h → WuiSpec i → WuiSpec j →
WuiSpec k → WuiSpec l → WuiSpec m

wList :: WuiSpec a → WuiSpec [a]

> WUI combinator for list structures where the list elements are vertically aligned in a
> table.

wListWithHeadings :: [String] → WuiSpec a → WuiSpec [a]

> Add headings to a standard WUI for list structures:

wHList :: WuiSpec a → WuiSpec [a]

> WUI combinator for list structures where the list elements are horizontally aligned in
> a table.

wMatrix :: WuiSpec a → WuiSpec [[a]]

> WUI for matrices, i.e., list of list of elements visualized as a matrix.

wMaybe :: WuiSpec Bool → WuiSpec a → a → WuiSpec (Maybe a)

> WUI for Maybe values. It is constructed from a WUI for Booleans and a WUI for the
> potential values. Nothing corresponds to a selection of False in the Boolean WUI. The
> value WUI is shown after the Boolean WUI.

wCheckMaybe :: WuiSpec a → [HtmlExp] → a → WuiSpec (Maybe a)

> A WUI for Maybe values where a check box is used to select Just. The value WUI is
> shown after the check box.

wRadioMaybe :: WuiSpec a → [HtmlExp] → [HtmlExp] → a → WuiSpec (Maybe a)

> A WUI for Maybe values where radio buttons are used to switch between Nothing and
> Just. The value WUI is shown after the radio button WUI.

wEither :: WuiSpec a → WuiSpec b → WuiSpec (Either a b)

> WUI for union types. Here we provide only the implementation for Either types since
> other types with more alternatives can be easily reduced to this case.

wTree :: WuiSpec a → WuiSpec (WTree a)

> WUI for tree types. The rendering specifies the rendering of inner nodes. Leaves are
> shown with their default rendering.

renderTuple :: [HtmlExp] → HtmlExp

Standard rendering of tuples as a table with a single row. Thus, the elements are horizontally aligned.

renderTaggedTuple :: [String] → [HtmlExp] → HtmlExp

Standard rendering of tuples with a tag for each element. Thus, each is preceded by a tag, that is set in bold, and all elements are vertically aligned.

renderList :: [HtmlExp] → HtmlExp

Standard rendering of lists as a table with a row for each item: Thus, the elements are vertically aligned.

mainWUI :: WuiSpec a → a → (a → IO HtmlForm) → IO HtmlForm

Generates an HTML form from a WUI data specification, an initial value and an update form.

wui2html :: WuiSpec a → a → (a → IO HtmlForm) → (HtmlExp,WuiHandler)

Generates HTML editors and a handler from a WUI data specification, an initial value and an update form.

wuiInForm :: WuiSpec a → a → (a → IO HtmlForm) → (HtmlExp → WuiHandler → IO HtmlForm) → IO HtmlForm

Puts a WUI into a HTML form containing "holes" for the WUI and the handler.

wuiWithErrorForm :: WuiSpec a → a → (a → IO HtmlForm) → (HtmlExp → WuiHandler → IO HtmlForm) → (HtmlExp,WuiHandler)

Generates HTML editors and a handler from a WUI data specification, an initial value and an update form. In addition to wui2html, we can provide a skeleton form used to show illegal inputs.

A.4.10 Library XML

Library for processing XML data.
Warning: the structure of this library is not stable and might be changed in the future!

Exported types:

data XmlExp

The data type for representing XML expressions.

Exported constructors:

- XText :: String → XmlExp

  XText

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– a text string (PCDATA)

- XElem :: String → [(String,String)] → [XmlExp] → XmlExp

  XElem

  – an XML element with tag field, attributes, and a list of XML elements as contents

data Encoding

The data type for encodings used in the XML document.

Exported constructors:

- StandardEnc :: Encoding

- Iso88591Enc :: Encoding

data XmlDocParams

The data type for XML document parameters.

Exported constructors:

- Enc :: Encoding → XmlDocParams

  Enc

  – the encoding for a document

- DtdUrl :: String → XmlDocParams

  DtdUrl

  – the url of the DTD for a document

Exported functions:

tagOf :: XmlExp → String

Returns the tag of an XML element (or empty for a textual element).

elemsOf :: XmlExp → [XmlExp]

Returns the child elements an XML element.

textOf :: [XmlExp] → String

Extracts the textual contents of a list of XML expressions. Useful auxiliary function when transforming XML expressions into other data structures.

For instance, textOf [XText ”xy”, XElem ”a” [] [], XText "bc"] == "xy bc"

textOfXml :: [XmlExp] → String

Included for backward compatibility, better use `textOf`!

`xtxt :: String → XmlExp`

> Basic text (maybe containing special XML chars).

`xml :: String → [XmlExp] → XmlExp`

> XML element without attributes.

`writeXmlFile :: String → XmlExp → IO ()`

> Writes a file with a given XML document.

`writeXmlFileWithParams :: String → [XmlDocParams] → XmlExp → IO ()`

> Writes a file with a given XML document and XML parameters.

`showXmlDoc :: XmlExp → String`

> Show an XML document in indented format as a string.

`showXmlDocWithParams :: [XmlDocParams] → XmlExp → String`

`readXmlFile :: String → IO XmlExp`

> Reads a file with an XML document and returns the corresponding XML expression.

`readUnsafeXmlFile :: String → IO (Maybe XmlExp)`

> Tries to read a file with an XML document and returns the corresponding XML expression, if possible. If file or parse errors occur, Nothing is returned.

`readFileWithXmlDocs :: String → IO [XmlExp]`

> Reads a file with an arbitrary sequence of XML documents and returns the list of corresponding XML expressions.

`parseXmlString :: String → [XmlExp]`

> Transforms an XML string into a list of XML expressions. If the XML string is a well structured document, the list of XML expressions should contain exactly one element.

`updateXmlFile :: (XmlExp → XmlExp) → String → IO ()`

> An action that updates the contents of an XML file by some transformation on the XML document.

A.4.11   Library XmlConv

Provides type-based combinators to construct XML converters. Arbitrary XML data can be represented as algebraic datatypes and vice versa. See here[12] for a description of this library.

---

[12]`http://www-ps.informatik.uni-kiel.de/~sebf/projects/xmlconv/`

Exported types:

`type XmlReads a = ([(String,String)],[XmlExp]) → (a,([(String,String)],[XmlExp]))`

    Type of functions that consume some XML data to compute a result

`type XmlShows a = a → ([(String,String)],[XmlExp]) → ([(String,String)],[XmlExp])`

    Type of functions that extend XML data corresponding to a given value

`type XElemConv a = XmlConv Repeatable Elem a`

    Type of converters for XML elements

`type XAttrConv a = XmlConv NotRepeatable NoElem a`

    Type of converters for attributes

`type XPrimConv a = XmlConv NotRepeatable NoElem a`

    Type of converters for primitive values

`type XOptConv a = XmlConv NotRepeatable NoElem a`

    Type of converters for optional values

`type XRepConv a = XmlConv NotRepeatable NoElem a`

    Type of converters for repetitions

Exported functions:

`xmlReads :: XmlConv a b c → ([(String,String)],[XmlExp]) →`
`(c,([(String,String)],[XmlExp]))`

    Takes an XML converter and returns a function that consumes XML data and returns
    the remaining data along with the result.

`xmlShows :: XmlConv a b c → c → ([(String,String)],[XmlExp]) →`
`([(String,String)],[XmlExp])`

    Takes an XML converter and returns a function that extends XML data with the
    representation of a given value.

`xmlRead :: XmlConv a Elem b → XmlExp → b`

    Takes an XML converter and an XML expression and returns a corresponding Curry
    value.

`xmlShow :: XmlConv a Elem b → b → XmlExp`

    Takes an XML converter and a value and returns a corresponding XML expression.

`int :: XmlConv NotRepeatable NoElem Int`

Creates an XML converter for integer values. Integer values must not be used in repetitions and do not represent XML elements.

`float :: XmlConv NotRepeatable NoElem Float`

Creates an XML converter for float values. Float values must not be used in repetitions and do not represent XML elements.

`char :: XmlConv NotRepeatable NoElem Char`

Creates an XML converter for character values. Character values must not be used in repetitions and do not represent XML elements.

`string :: XmlConv NotRepeatable NoElem String`

Creates an XML converter for string values. String values must not be used in repetitions and do not represent XML elements.

`(!) :: XmlConv a b c → XmlConv a b c → XmlConv a b c`

Parallel composition of XML converters.

`element :: String → XmlConv a b c → XmlConv Repeatable Elem c`

Takes an arbitrary XML converter and returns a converter representing an XML element that contains the corresponding data. XML elements may be used in repetitions.

`empty :: a → XmlConv NotRepeatable NoElem a`

Takes a value and returns an XML converter for this value which is not represented as XML data. Empty XML data must not be used in repetitions and does not represent an XML element.

`attr :: String → (String → a,a → String) → XmlConv NotRepeatable NoElem a`

Takes a name and string conversion functions and returns an XML converter that represents an attribute. Attributes must not be used in repetitions and do not represent an XML element.

`adapt :: (a → b,b → a) → XmlConv c d a → XmlConv c d b`

Converts between arbitrary XML converters for different types.

`opt :: XmlConv a b c → XmlConv NotRepeatable NoElem (Maybe c)`

Creates a converter for arbitrary optional XML data. Optional XML data must not be used in repetitions and does not represent an XML element.

`rep :: XmlConv Repeatable a b → XmlConv NotRepeatable NoElem [b]`

Takes an XML converter representing repeatable data and returns an XML converter that represents repetitions of this data. Repetitions must not be used in other repetitions and do not represent XML elements.

`aInt :: String → XmlConv NotRepeatable NoElem Int`

Creates an XML converter for integer attributes. Integer attributes must not be used in repetitions and do not represent XML elements.

`aFloat :: String → XmlConv NotRepeatable NoElem Float`

Creates an XML converter for float attributes. Float attributes must not be used in repetitions and do not represent XML elements.

`aChar :: String → XmlConv NotRepeatable NoElem Char`

Creates an XML converter for character attributes. Character attributes must not be used in repetitions and do not represent XML elements.

`aString :: String → XmlConv NotRepeatable NoElem String`

Creates an XML converter for string attributes. String attributes must not be used in repetitions and do not represent XML elements.

`aBool :: String → String → String → XmlConv NotRepeatable NoElem Bool`

Creates an XML converter for boolean attributes. Boolean attributes must not be used in repetitions and do not represent XML elements.

`eInt :: String → XmlConv Repeatable Elem Int`

Creates an XML converter for integer elements. Integer elements may be used in repetitions.

`eFloat :: String → XmlConv Repeatable Elem Float`

Creates an XML converter for float elements. Float elements may be used in repetitions.

`eChar :: String → XmlConv Repeatable Elem Char`

Creates an XML converter for character elements. Character elements may be used in repetitions.

`eString :: String → XmlConv Repeatable Elem String`

Creates an XML converter for string elements. String elements may be used in repetitions.

`eBool :: String → String → XmlConv Repeatable Elem Bool`

Creates an XML converter for boolean elements. Boolean elements may be used in repetitions.

`eEmpty :: String → a → XmlConv Repeatable Elem a`

Takes a name and a value and creates an empty XML element that represents the given value. The created element may be used in repetitions.

`eOpt :: String → XmlConv a b c → XmlConv Repeatable Elem (Maybe c)`

Creates an XML converter that represents an element containing optional XML data. The created element may be used in repetitions.

`eRep :: String → XmlConv Repeatable a b → XmlConv Repeatable Elem [b]`

Creates an XML converter that represents an element containing repeated XML data. The created element may be used in repetitions.

`seq1 :: (a → b) → XmlConv c d a → XmlConv c NoElem b`

Creates an XML converter representing a sequence of arbitrary XML data. The sequence must not be used in repetitions and does not represent an XML element.

`repSeq1 :: (a → b) → XmlConv Repeatable c a → XmlConv NotRepeatable NoElem [b]`

Creates an XML converter that represents a repetition of a sequence of repeatable XML data. The repetition may be used in other repetitions but does not represent an XML element. This combinator is provided because converters for repeatable sequences cannot be constructed by the seq combinators.

`eSeq1 :: String → (a → b) → XmlConv c d a → XmlConv Repeatable Elem b`

Creates an XML converter for compound values represented as an XML element with children that correspond to the values components. The element can be used in repetitions.

`eRepSeq1 :: String → (a → b) → XmlConv Repeatable c a → XmlConv Repeatable Elem [b]`

Creates an XML converter for repetitions of sequences represented as an XML element that can be used in repetitions.

`seq2 :: (a → b → c) → XmlConv d e a → XmlConv f g b → XmlConv NotRepeatable NoElem c`

Creates an XML converter representing a sequence of arbitrary XML data. The sequence must not be used in repetitions and does not represent an XML element.

`repSeq2 :: (a → b → c) → XmlConv Repeatable d a → XmlConv Repeatable e b → XmlConv NotRepeatable NoElem [c]`

Creates an XML converter that represents a repetition of a sequence of repeatable XML data. The repetition may be used in other repetitions and does not represent an XML element. This combinator is provided because converters for repeatable sequences cannot be constructed by the seq combinators.

`eSeq2 :: String → (a → b → c) → XmlConv d e a → XmlConv f g b → XmlConv Repeatable Elem c`

Creates an XML converter for compound values represented as an XML element with children that correspond to the values components. The element can be used in repetitions.

eRepSeq2 :: String → (a → b → c) → XmlConv Repeatable d a → XmlConv Repeatable e b → XmlConv Repeatable Elem [c]

Creates an XML converter for repetitions of sequences represented as an XML element that can be used in repetitions.

seq3 :: (a → b → c → d) → XmlConv e f a → XmlConv g h b → XmlConv i j c → XmlConv NotRepeatable NoElem d

Creates an XML converter representing a sequence of arbitrary XML data. The sequence must not be used in repetitions and does not represent an XML element.

repSeq3 :: (a → b → c → d) → XmlConv Repeatable e a → XmlConv Repeatable f b → XmlConv Repeatable g c → XmlConv NotRepeatable NoElem [d]

Creates an XML converter that represents a repetition of a sequence of repeatable XML data. The repetition may be used in other repetitions and does not represent an XML element. This combinator is provided because converters for repeatable sequences cannot be constructed by the seq combinators.

eSeq3 :: String → (a → b → c → d) → XmlConv e f a → XmlConv g h b → XmlConv i j c → XmlConv Repeatable Elem d

Creates an XML converter for compound values represented as an XML element with children that correspond to the values components. The element can be used in repetitions.

eRepSeq3 :: String → (a → b → c → d) → XmlConv Repeatable e a → XmlConv Repeatable f b → XmlConv Repeatable g c → XmlConv Repeatable Elem [d]

Creates an XML converter for repetitions of sequences represented as an XML element that can be used in repetitions.

seq4 :: (a → b → c → d → e) → XmlConv f g a → XmlConv h i b → XmlConv j k c → XmlConv l m d → XmlConv NotRepeatable NoElem e

Creates an XML converter representing a sequence of arbitrary XML data. The sequence must not be used in repetitions and does not represent an XML element.

repSeq4 :: (a → b → c → d → e) → XmlConv Repeatable f a → XmlConv Repeatable g b → XmlConv Repeatable h c → XmlConv Repeatable i d → XmlConv NotRepeatable NoElem [e]

Creates an XML converter that represents a repetition of a sequence of repeatable XML data. The repetition may be used in other repetitions and does not represent an XML element. This combinator is provided because converters for repeatable sequences cannot be constructed by the seq combinators.

eSeq4 :: String → (a → b → c → d → e) → XmlConv f g a → XmlConv h i b →
XmlConv j k c → XmlConv l m d → XmlConv Repeatable Elem e

> Creates an XML converter for compound values represented as an XML element with
> children that correspond to the values components. The element can be used in repe-
> titions.

eRepSeq4 :: String → (a → b → c → d → e) → XmlConv Repeatable f a → XmlConv
Repeatable g b → XmlConv Repeatable h c → XmlConv Repeatable i d → XmlConv
Repeatable Elem [e]

> Creates an XML converter for repetitions of sequences represented as an XML element
> that can be used in repetitions.

seq5 :: (a → b → c → d → e → f) → XmlConv g h a → XmlConv i j b → XmlConv
k l c → XmlConv m n d → XmlConv o p e → XmlConv NotRepeatable NoElem f

> Creates an XML converter representing a sequence of arbitrary XML data. The se-
> quence must not be used in repetitions and does not represent an XML element.

repSeq5 :: (a → b → c → d → e → f) → XmlConv Repeatable g a → XmlConv
Repeatable h b → XmlConv Repeatable i c → XmlConv Repeatable j d → XmlConv
Repeatable k e → XmlConv NotRepeatable NoElem [f]

> Creates an XML converter that represents a repetition of a sequence of repeatable
> XML data. The repetition may be used in other repetitions and does not represent an
> XML element. This combinator is provided because converters for repeatable sequences
> cannot be constructed by the seq combinators.

eSeq5 :: String → (a → b → c → d → e → f) → XmlConv g h a → XmlConv i j b
→ XmlConv k l c → XmlConv m n d → XmlConv o p e → XmlConv Repeatable Elem f

> Creates an XML converter for compound values represented as an XML element with
> children that correspond to the values components. The element can be used in repe-
> titions.

eRepSeq5 :: String → (a → b → c → d → e → f) → XmlConv Repeatable g a →
XmlConv Repeatable h b → XmlConv Repeatable i c → XmlConv Repeatable j d →
XmlConv Repeatable k e → XmlConv Repeatable Elem [f]

> Creates an XML converter for repetitions of sequences represented as an XML element
> that can be used in repetitions.

seq6 :: (a → b → c → d → e → f → g) → XmlConv h i a → XmlConv j k b →
XmlConv l m c → XmlConv n o d → XmlConv p q e → XmlConv r s f → XmlConv
NotRepeatable NoElem g

> Creates an XML converter representing a sequence of arbitrary XML data. The se-
> quence must not be used in repetitions and does not represent an XML element.

repSeq6 :: (a → b → c → d → e → f → g) → XmlConv Repeatable h a → XmlConv
Repeatable i b → XmlConv Repeatable j c → XmlConv Repeatable k d → XmlConv
Repeatable l e → XmlConv Repeatable m f → XmlConv NotRepeatable NoElem [g]

> Creates an XML converter that represents a repetition of a sequence of repeatable
> XML data. The repetition may be used in other repetitions and does not represent an
> XML element. This combinator is provided because converters for repeatable sequences
> cannot be constructed by the seq combinators.

eSeq6 :: String → (a → b → c → d → e → f → g) → XmlConv h i a → XmlConv j
k b → XmlConv l m c → XmlConv n o d → XmlConv p q e → XmlConv r s f → XmlConv
Repeatable Elem g

> Creates an XML converter for compound values represented as an XML element with
> children that correspond to the values components. The element can be used in repe-
> titions.

eRepSeq6 :: String → (a → b → c → d → e → f → g) → XmlConv Repeatable h a
→ XmlConv Repeatable i b → XmlConv Repeatable j c → XmlConv Repeatable k d →
XmlConv Repeatable l e → XmlConv Repeatable m f → XmlConv Repeatable Elem [g]

> Creates an XML converter for repetitions of sequences represented as an XML element
> that can be used in repetitions.

A.5 Libraries for Meta-Programming

A.5.1 Library AbstractCurry.Types

This library contains a definition for representing Curry programs in Curry and an I/O action to
read Curry programs and transform them into this abstract representation.
Note this defines a slightly new format for AbstractCurry in comparison to the first proposal of
2003.
Assumption: an abstract Curry program is stored in file with extension .acy

Exported types:

type MName = String

> A module name.

type QName = (String,String)

> The data type for representing qualified names. In AbstractCurry all names are qual-
> ified to avoid name clashes. The first component is the module name and the second
> component the unqualified name as it occurs in the source program. An exception are
> locally defined names where the module name is the empty string (to avoid name clashes
> with a globally defined name).

type CTVarIName = (Int,String)

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The type for representing type variables. They are represented by (i,n) where i is a type variable index which is unique inside a function and n is a name (if possible, the name written in the source program).

```
type CField a = ((String,String),a)
```

Labeled record fields

```
type Arity = Int
```

Function arity

```
type CVarIName = (Int,String)
```

Data types for representing object variables. Object variables occurring in expressions are represented by (Var i) where i is a variable index.

```
data CVisibility
```

Data type to specify the visibility of various entities.

Exported constructors:

- `Public :: CVisibility`

- `Private :: CVisibility`

```
data CurryProg
```

Data type for representing a Curry module in the intermediate form. A value of this data type has the form

```
(CProg modname imports typedecls functions opdecls)
```

where modname: name of this module, imports: list of modules names that are imported, typedecls: Type declarations functions: Function declarations opdecls: Operator precedence declarations

Exported constructors:

- `CurryProg :: String → [String] → [CTypeDecl] → [CFuncDecl] → [COpDecl] → CurryProg`

```
data CTypeDecl
```

Data type for representing definitions of algebraic data types and type synonyms.

A data type definition of the form

```
data t x1...xn = ...| c t1....tkc |...
```

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is represented by the Curry term

```
(CType t v [i1,...,in] [...(CCons c kc v [t1,...,tkc])...])
```

where each `ij` is the index of the type variable `xj`.

Note: the type variable indices are unique inside each type declaration and are usually numbered from 0

Thus, a data type declaration consists of the name of the data type, a list of type parameters and a list of constructor declarations.

Exported constructors:

- `CType :: (String,String) → CVisibility → [(Int,String)] → [CConsDecl] →` `CTypeDecl`

- `CTypeSyn :: (String,String) → CVisibility → [(Int,String)] → CTypeExpr →` `CTypeDecl`

- `CNewType :: (String,String) → CVisibility → [(Int,String)] → CConsDecl →` `CTypeDecl`

data CConsDecl

A constructor declaration consists of the name of the constructor and a list of the argument types of the constructor. The arity equals the number of types.

Exported constructors:

- `CCons :: (String,String) → CVisibility → [CTypeExpr] → CConsDecl`

- `CRecord :: (String,String) → CVisibility → [CFieldDecl] → CConsDecl`

data CFieldDecl

A record field declaration consists of the name of the the label, the visibility and its corresponding type.

Exported constructors:

- `CField :: (String,String) → CVisibility → CTypeExpr → CFieldDecl`

data CTypeExpr

Type expression. A type expression is either a type variable, a function type, or a type constructor application.

Note: the names of the predefined type constructors are "Int", "Float", "Bool", "Char", "IO", "Success", "()" (unit type), "(,...,)" (tuple types), "[]" (list type)

Exported constructors:

- CTVar :: (Int,String) → CTypeExpr

- CFuncType :: CTypeExpr → CTypeExpr → CTypeExpr

- CTCons :: (String,String) → [CTypeExpr] → CTypeExpr

data COpDecl

Data type for operator declarations. An operator declaration "fix p n" in Curry corresponds to the AbstractCurry term (COp n fix p).

Exported constructors:

- COp :: (String,String) → CFixity → Int → COpDecl

data CFixity

Data type for operator associativity

Exported constructors:

- CInfixOp :: CFixity

- CInfixlOp :: CFixity

- CInfixrOp :: CFixity

data CFuncDecl

Data type for representing function declarations.

A function declaration in AbstractCurry is a term of the form

(CFunc name arity visibility type (CRules eval [CRule rule1,...,rulek]))

and represents the function **name** defined by the rules **rule1,...,rulek**.

Note: the variable indices are unique inside each rule

Thus, a function declaration consists of the name, arity, type, and a list of rules.

A function declaration with the constructor CmtFunc is similarly to CFunc but has a comment as an additional first argument. This comment could be used by pretty printers that generate a readable Curry program containing documentation comments.

Exported constructors:

- CFunc :: (String,String) → Int → CVisibility → CTypeExpr → [CRule] → CFuncDecl

- CmtFunc :: String → (String,String) → Int → CVisibility → CTypeExpr → [CRule] → CFuncDecl

```
data CRule
```

The general form of a function rule. It consists of a list of patterns (left-hand side) and the right-hand side for these patterns.

Exported constructors:

- `CRule :: [CPattern] → CRhs → CRule`

```
data CRhs
```

Right-hand-side of a `CRule` or a `case` expression. It is either a simple unconditional right-hand side or a list of guards with their corresponding right-hand sides, and a list of local declarations.

Exported constructors:

- `CSimpleRhs :: CExpr → [CLocalDecl] → CRhs`

- `CGuardedRhs :: [(CExpr,CExpr)] → [CLocalDecl] → CRhs`

```
data CLocalDecl
```

Data type for representing local (let/where) declarations

Exported constructors:

- `CLocalFunc :: CFuncDecl → CLocalDecl`

- `CLocalPat :: CPattern → CRhs → CLocalDecl`

- `CLocalVars :: [(Int,String)] → CLocalDecl`

```
data CPattern
```

Data type for representing pattern expressions.

Exported constructors:

- `CPVar :: (Int,String) → CPattern`

- `CPLit :: CLiteral → CPattern`

- `CPComb :: (String,String) → [CPattern] → CPattern`

- `CPAs :: (Int,String) → CPattern → CPattern`

- `CPFuncComb :: (String,String) → [CPattern] → CPattern`

- `CPLazy :: CPattern → CPattern`

- `CPRecord :: (String,String) → [((String,String),CPattern)] → CPattern`

```
data CExpr
```

Data type for representing Curry expressions.

Exported constructors:

- CVar :: (Int,String) → CExpr

- CLit :: CLiteral → CExpr

- CSymbol :: (String,String) → CExpr

- CApply :: CExpr → CExpr → CExpr

- CLambda :: [CPattern] → CExpr → CExpr

- CLetDecl :: [CLocalDecl] → CExpr → CExpr

- CDoExpr :: [CStatement] → CExpr

- CListComp :: CExpr → [CStatement] → CExpr

- CCase :: CCaseType → CExpr → [(CPattern,CRhs)] → CExpr

- CTyped :: CExpr → CTypeExpr → CExpr

- CRecConstr :: (String,String) → [((String,String),CExpr)] → CExpr

- CRecUpdate :: CExpr → [((String,String),CExpr)] → CExpr

```
data CLiteral
```

Data type for representing literals occurring in an expression. It is either an integer, a float, or a character constant.

Exported constructors:

- CIntc :: Int → CLiteral

- CFloatc :: Float → CLiteral

- CCharc :: Char → CLiteral

- CStringc :: String → CLiteral

```
data CStatement
```

Data type for representing statements in do expressions and list comprehensions.

Exported constructors:

- CSExpr :: CExpr → CStatement

- CSPat :: CPattern → CExpr → CStatement

- CSLet :: [CLocalDecl] → CStatement

data CCaseType

Type of case expressions

Exported constructors:

- CRigid :: CCaseType

- CFlex :: CCaseType

Exported functions:

version :: String

Current version of AbstractCurry

pre :: String → (String,String)

Converts a string into a qualified name of the Prelude.

A.5.2 Library AbstractCurry.Files

This library defines various I/O actions to read Curry programs and transform them into the AbstractCurry representation and to write AbstractCurry files.
Assumption: an abstract Curry program is stored in file with extension .acy in the subdirectory .curry

Exported functions:

readCurry :: String → IO CurryProg

I/O action which parses a Curry program and returns the corresponding typed Abstract Curry program. Thus, the argument is the file name without suffix ".curry" or ".lcurry") and the result is a Curry term representing this program.

readUntypedCurry :: String → IO CurryProg

I/O action which parses a Curry program and returns the corresponding untyped Abstract Curry program. Thus, the argument is the file name without suffix ".curry" or ".lcurry") and the result is a Curry term representing this program.

readCurryWithParseOptions :: String → FrontendParams → IO CurryProg

I/O action which reads a typed Curry program from a file (with extension ".acy") with respect to some parser options. This I/O action is used by the standard action readCurry. It is currently predefined only in Curry2Prolog.

readUntypedCurryWithParseOptions :: String → FrontendParams → IO CurryProg

I/O action which reads an untyped Curry program from a file (with extension
".uacy") with respect to some parser options. For more details see function
`readCurryWithParseOptions`

`abstractCurryFileName :: String → String`

Transforms a name of a Curry program (with or without suffix ".curry" or ".lcurry")
into the name of the file containing the corresponding AbstractCurry program.

`untypedAbstractCurryFileName :: String → String`

Transforms a name of a Curry program (with or without suffix ".curry" or ".lcurry")
into the name of the file containing the corresponding untyped AbstractCurry program.

`readAbstractCurryFile :: String → IO CurryProg`

I/O action which reads an AbstractCurry program from a file in ".acy" format. In
contrast to `readCurry`, this action does not parse a source program. Thus, the argument
must be the name of an existing file (with suffix ".acy") containing an AbstractCurry
program in ".acy" format and the result is a Curry term representing this program. It
is currently predefined only in Curry2Prolog.

`tryReadACYFile :: String → IO (Maybe CurryProg)`

Tries to read an AbstractCurry file and returns

- Left err , where err specifies the error occurred
- Right prog, where prog is the AbstractCurry program

`writeAbstractCurryFile :: String → CurryProg → IO ()`

Writes an AbstractCurry program into a file in ".acy" format. The first argument must
be the name of the target file (with suffix ".acy").

A.5.3 Library AbstractCurry.Select

This library provides some useful operations to select components in AbstractCurry programs, i.e.,
it provides a collection of selector functions for AbstractCurry.

Exported functions:

`typeName :: CTypeDecl → (String,String)`

Returns the name of a given type declaration

`typeVis :: CTypeDecl → CVisibility`

Returns the visibility of a given type declaration

`typeCons :: CTypeDecl → [CConsDecl]`

Returns the constructors of a given type declaration

`consName :: CConsDecl → (String,String)`

 Returns the name of a given constructor declaration

`consVis :: CConsDecl → CVisibility`

 Returns the visibility of a given constructor declaration

`isBaseType :: CTypeExpr → Bool`

 Returns true if the type expression is a base type.

`isPolyType :: CTypeExpr → Bool`

 Returns true if the type expression contains type variables.

`isFunctionalType :: CTypeExpr → Bool`

 Returns true if the type expression is a functional type.

`isIOType :: CTypeExpr → Bool`

 Returns true if the type expression is (IO t).

`isIOReturnType :: CTypeExpr → Bool`

 Returns true if the type expression is (IO t) with t/=() and t is not functional

`argTypes :: CTypeExpr → [CTypeExpr]`

 Returns all argument types from a functional type

`resultType :: CTypeExpr → CTypeExpr`

 Return the result type from a (nested) functional type

`tvarsOfType :: CTypeExpr → [(Int,String)]`

 Returns all type variables occurring in a type expression.

`modsOfType :: CTypeExpr → [String]`

 Returns all modules used in the given type.

`funcName :: CFuncDecl → (String,String)`

 Returns the name of a given function declaration

`funcVis :: CFuncDecl → CVisibility`

 Returns the visibility of a given function declaration

`varsOfPat :: CPattern → [(Int,String)]`

Returns list of all variables occurring in a pattern. Each occurrence corresponds to one element, i.e., the list might contain multiple elements.

varsOfExp :: CExpr → [(Int,String)]

Returns list of all variables occurring in an expression. Each occurrence corresponds to one element, i.e., the list might contain multiple elements.

varsOfRhs :: CRhs → [(Int,String)]

Returns list of all variables occurring in a right-hand side. Each occurrence corresponds to one element, i.e., the list might contain multiple elements.

varsOfStat :: CStatement → [(Int,String)]

Returns list of all variables occurring in a statement. Each occurrence corresponds to one element, i.e., the list might contain multiple elements.

varsOfLDecl :: CLocalDecl → [(Int,String)]

Returns list of all variables occurring in a local declaration. Each occurrence corresponds to one element, i.e., the list might contain multiple elements.

varsOfFDecl :: CFuncDecl → [(Int,String)]

Returns list of all variables occurring in a function declaration. Each occurrence corresponds to one element, i.e., the list might contain multiple elements.

varsOfRule :: CRule → [(Int,String)]

Returns list of all variables occurring in a rule. Each occurrence corresponds to one element, i.e., the list might contain multiple elements.

isPrelude :: String → Bool

Tests whether a module name is the prelude.

A.5.4 Library AbstractCurry.Build

This library provides some useful operations to write programs that generate AbstractCurry programs in a more compact and readable way.

Exported functions:

(~>) :: CTypeExpr → CTypeExpr → CTypeExpr

A function type.

baseType :: (String,String) → CTypeExpr

A base type.

listType :: CTypeExpr → CTypeExpr

Constructs a list type from an element type.

`tupleType :: [CTypeExpr] → CTypeExpr`

Constructs a tuple type from list of component types.

`ioType :: CTypeExpr → CTypeExpr`

Constructs an IO type from a type.

`maybeType :: CTypeExpr → CTypeExpr`

Constructs a Maybe type from element type.

`stringType :: CTypeExpr`

The type expression of the String type.

`intType :: CTypeExpr`

The type expression of the Int type.

`floatType :: CTypeExpr`

The type expression of the Float type.

`boolType :: CTypeExpr`

The type expression of the Bool type.

`unitType :: CTypeExpr`

The type expression of the unit type.

`dateType :: CTypeExpr`

The type expression of the Time.CalendarTime type.

`cfunc :: (String,String) → Int → CVisibility → CTypeExpr → [CRule] →`
`CFuncDecl`

Constructs a function declaration from a given qualified function name, arity, visibility, type expression and list of defining rules.

`cmtfunc :: String → (String,String) → Int → CVisibility → CTypeExpr → [CRule]`
`→ CFuncDecl`

Constructs a function declaration from a given comment, qualified function name, arity, visibility, type expression and list of defining rules.

`simpleRule :: [CPattern] → CExpr → CRule`

Constructs a simple rule with a pattern list and an unconditional right-hand side.

`guardedRule :: [CPattern] → [(CExpr,CExpr)] → [CLocalDecl] → CRule`

Constructs a rule with a possibly guarded right-hand side and local declarations. A simple right-hand side is constructed if there is only one `success` condition.

noGuard :: CExpr → (CExpr,CExpr)

Constructs a guarded expression with the trivial guard.

applyF :: (String,String) → [CExpr] → CExpr

An application of a qualified function name to a list of arguments.

applyE :: CExpr → [CExpr] → CExpr

An application of an expression to a list of arguments.

constF :: (String,String) → CExpr

A constant, i.e., an application without arguments.

applyV :: (Int,String) → [CExpr] → CExpr

An application of a variable to a list of arguments.

applyJust :: CExpr → CExpr

applyMaybe :: CExpr → CExpr → CExpr → CExpr

tupleExpr :: [CExpr] → CExpr

Constructs a tuple expression from list of component expressions.

cBranch :: CPattern → CExpr → (CPattern,CRhs)

Constructs from a pattern and an expression a branch for a case expression.

tuplePattern :: [CPattern] → CPattern

Constructs a tuple pattern from list of component patterns.

pVars :: Int → [CPattern]

Constructs, for given n, a list of n PVars starting from 0.

pChar :: Char → CPattern

Converts a character into a pattern.

pNil :: CPattern

Constructs an empty list pattern.

listPattern :: [CPattern] → CPattern

Constructs a list pattern from list of component patterns.

stringPattern :: String → CPattern

Converts a string into a pattern representing this string.

list2ac :: [CExpr] → CExpr

Converts a list of AbstractCurry expressions into an AbstractCurry representation of this list.

cChar :: Char → CExpr

Converts a character into an AbstractCurry expression.

string2ac :: String → CExpr

Converts a string into an AbstractCurry represention of this string.

toVar :: Int → CExpr

Converts an index i into a variable named xi.

cvar :: String → CExpr

Converts a string into a variable with index 1.

cpvar :: String → CPattern

Converts a string into a pattern variable with index 1.

ctvar :: String → CTypeExpr

Converts a string into a type variable with index 1.

A.5.5   Library AbstractCurry.Pretty

Pretty printing of AbstractCurry.
This library provides a pretty-printer for AbstractCurry modules.

Exported types:

data Qualification

Exported constructors:

- **Full :: Qualification**

- **Imports :: Qualification**

- **None :: Qualification**

data Options

Exported constructors:

Exported functions:

`defaultOptions :: Options`

> `defaultOptions = options 78 2 Imports ""` Therefore use these options only with functions like `prettyCurryProg` or `ppCurryProg`, because they will overwrite the module name anyway.

`options :: Int → Int → Qualification → String → Options`

`setPageWith :: Int → Options → Options`

> Sets the page width of the pretty printer options.

`setIndentWith :: Int → Options → Options`

> Sets the indentation width of the pretty printer options.

`setQualification :: Qualification → Options → Options`

> Sets the qualification method to be used by the pretty printer.

`setModName :: String → Options → Options`

> Sets the name of the current module in the pretty printer options.

`showCProg :: CurryProg → String`

> Shows a pretty formatted version of an abstract Curry Program. The options for pretty printing are the `defaultOptions`.

`prettyCurryProg :: Options → CurryProg → String`

> pretty-print the document generated by `ppCurryProg`, using the page width specified by given options.

`ppCurryProg :: Options → CurryProg → Doc`

> pretty-print a CurryProg (the representation of a program, written in curry, using AbstractCurry) according to given options. This function will overwrite the module name given by options with the name encapsulated in CurryProg.

`ppMName :: String → Doc`

> pretty-print a module name (just a string).

`ppExports :: Options → [CTypeDecl] → [CFuncDecl] → Doc`

> pretty-print exports, i.e. all type and function declarations which are public. extract the type and function declarations which are public and gather their qualified names in a list.

`ppImports :: Options → [String] → Doc`

> pretty-print imports (list of module names) by prepending the word "import" to the module name.

`ppCOpDecl :: Options → COpDecl → Doc`

> pretty-print operator precedence declarations.

`ppCTypeDecl :: Options → CTypeDecl → Doc`

> pretty-print type declarations, like `data ... = ...`, `type ... = ...` or `newtype ... = ...`.

`ppCFuncDecl :: Options → CFuncDecl → Doc`

> pretty-print a function declaration.

`ppCFuncDeclWithoutSig :: Options → CFuncDecl → Doc`

> pretty-print a function declaration without signature.

`ppCFuncSignature :: Options → (String,String) → CTypeExpr → Doc`

> pretty-print a function signature according to given options.

`ppCTypeExpr :: Options → CTypeExpr → Doc`

> pretty-print a type expression.

`ppCPattern :: Options → CPattern → Doc`

> pretty-print a pattern expression.

`ppCLiteral :: Options → CLiteral → Doc`

> pretty-print given literal (Int, Float, ...).

`ppCExpr :: Options → CExpr → Doc`

> pretty-print an expression.

`ppCStatement :: Options → CStatement → Doc`

`ppQName :: Options → (String,String) → Doc`

> pretty-print a QName qualified according to given options.

`ppName :: (String,String) → Doc`

> pretty-print a QName non-qualified.

A.5.6 Library AnnotatedFlatCurry

This library contains a version of FlatCurry's abstract syntax tree which can be annotated with arbitrary information due to a polymorphic type parameter. For instance, this could be used to annotate function declarations and expressions with their corresponding type.
For more information about the abstract syntax tree of `FlatCurry`, see the documentation of the respective module.

Exported types:

```
type Arity = Int
```

     Arity of a function declaration

```
data AProg
```

     Annotated FlatCurry program (corresponds to a module)

  Exported constructors:

- APeg :: String → [String] → [TypeDecl] → [AFuncDecl a] → [OpDecl] → APeg a

  APeg a

```
data AFuncDecl
```

     Annotated function declaration

  Exported constructors:

- AFunc :: (String,String) → Int → Visibility → TypeExpr → (ARule a) → AFuncDecl a

  AFuncDecl a

```
data ARule
```

     Annotated function rule

  Exported constructors:

- ARule :: a → [(Int,a)] → (AExpr a) → ARule a

- AExternal :: a → String → ARule a

```
data AExpr
```

     Annotated expression

  Exported constructors:

- AVar :: a → Int → AExpr a

- ALit :: a → Literal → AExpr a

- AComb :: a → CombType → ((String,String),a) → [AExpr a] → AExpr a

- ALet :: a → [((Int,a),AExpr a)] → (AExpr a) → AExpr a

- AFree :: a → [(Int,a)] → (AExpr a) → AExpr a

- AOr :: a → (AExpr a) → (AExpr a) → AExpr a

- ACase :: a → CaseType → (AExpr a) → [ABranchExpr a] → AExpr a

- ATyped :: a → (AExpr a) → TypeExpr → AExpr a

data ABranchExpr

    Annotated case branch

Exported constructors:

- ABranch :: (APattern a) → (AExpr a) → ABranchExpr a

data APattern

    Annotated pattern

Exported constructors:

- APattern :: a → ((String,String),a) → [(Int,a)] → APattern a

- ALPattern :: a → Literal → APattern a

A.5.7 Library AnnotatedFlatCurryGoodies

This library provides selector functions, test and update operations as well as some useful auxiliary functions for FlatCurry data terms. Most of the provided functions are based on general trans-formation functions that replace constructors with user-defined functions. For recursive datatypes the transformations are defined inductively over the term structure. This is quite usual for trans-formations on FlatCurry terms, so the provided functions can be used to implement specific trans-formations without having to explicitly state the recursion. Essentially, the tedious part of such transformations - descend in fairly complex term structures - is abstracted away, which hopefully makes the code more clear and brief.

Exported types:

type Update a b = (b → b) → a → a

Exported functions:

```
trProg :: (String → [String] → [TypeDecl] → [AFuncDecl a] → [OpDecl] → b) →
AProg a → b
```

> transform program

```
progName :: AProg a → String
```

> get name from program

```
progImports :: AProg a → [String]
```

> get imports from program

```
progTypes :: AProg a → [TypeDecl]
```

> get type declarations from program

```
progFuncs :: AProg a → [AFuncDecl a]
```

> get functions from program

```
progOps :: AProg a → [OpDecl]
```

> get infix operators from program

```
updProg :: (String → String) → ([String] → [String]) → ([TypeDecl] →
[TypeDecl]) → ([AFuncDecl a] → [AFuncDecl a]) → ([OpDecl] → [OpDecl]) → AProg
a → AProg a
```

> update program

```
updProgName :: (String → String) → AProg a → AProg a
```

> update name of program

```
updProgImports :: ([String] → [String]) → AProg a → AProg a
```

> update imports of program

```
updProgTypes :: ([TypeDecl] → [TypeDecl]) → AProg a → AProg a
```

> update type declarations of program

```
updProgFuncs :: ([AFuncDecl a] → [AFuncDecl a]) → AProg a → AProg a
```

> update functions of program

```
updProgOps :: ([OpDecl] → [OpDecl]) → AProg a → AProg a
```

> update infix operators of program

```
allVarsInProg :: AProg a → [Int]
```

get all program variables (also from patterns)

`updProgExps :: (AExpr a → AExpr a) → AProg a → AProg a`

    lift transformation on expressions to program

`rnmAllVarsInProg :: (Int → Int) → AProg a → AProg a`

    rename programs variables

`updQNamesInProg :: ((String,String) → (String,String)) → AProg a → AProg a`

    update all qualified names in program

`rnmProg :: String → AProg a → AProg a`

    rename program (update name of and all qualified names in program)

`trType :: ((String,String) → Visibility → [Int] → [ConsDecl] → a) →`
`((String,String) → Visibility → [Int] → TypeExpr → a) → TypeDecl → a`

    transform type declaration

`typeName :: TypeDecl → (String,String)`

    get name of type declaration

`typeVisibility :: TypeDecl → Visibility`

    get visibility of type declaration

`typeParams :: TypeDecl → [Int]`

    get type parameters of type declaration

`typeConsDecls :: TypeDecl → [ConsDecl]`

    get constructor declarations from type declaration

`typeSyn :: TypeDecl → TypeExpr`

    get synonym of type declaration

`isTypeSyn :: TypeDecl → Bool`

    is type declaration a type synonym?

`updType :: ((String,String) → (String,String)) → (Visibility → Visibility)`
`→ ([Int] → [Int]) → ([ConsDecl] → [ConsDecl]) → (TypeExpr → TypeExpr) →`
`TypeDecl → TypeDecl`

    update type declaration

`updTypeName :: ((String,String) → (String,String)) → TypeDecl → TypeDecl`

update name of type declaration

`updTypeVisibility :: (Visibility → Visibility) → TypeDecl → TypeDecl`

    update visibility of type declaration

`updTypeParams :: ([Int] → [Int]) → TypeDecl → TypeDecl`

    update type parameters of type declaration

`updTypeConsDecls :: ([ConsDecl] → [ConsDecl]) → TypeDecl → TypeDecl`

    update constructor declarations of type declaration

`updTypeSynonym :: (TypeExpr → TypeExpr) → TypeDecl → TypeDecl`

    update synonym of type declaration

`updQNamesInType :: ((String,String) → (String,String)) → TypeDecl → TypeDecl`

    update all qualified names in type declaration

`trCons :: ((String,String) → Int → Visibility → [TypeExpr] → a) → ConsDecl → a`

    transform constructor declaration

`consName :: ConsDecl → (String,String)`

    get name of constructor declaration

`consArity :: ConsDecl → Int`

    get arity of constructor declaration

`consVisibility :: ConsDecl → Visibility`

    get visibility of constructor declaration

`consArgs :: ConsDecl → [TypeExpr]`

    get arguments of constructor declaration

`updCons :: ((String,String) → (String,String)) → (Int → Int) → (Visibility → Visibility) → ([TypeExpr] → [TypeExpr]) → ConsDecl → ConsDecl`

    update constructor declaration

`updConsName :: ((String,String) → (String,String)) → ConsDecl → ConsDecl`

    update name of constructor declaration

`updConsArity :: (Int → Int) → ConsDecl → ConsDecl`

    update arity of constructor declaration

`updConsVisibility :: (Visibility → Visibility) → ConsDecl → ConsDecl`

> update visibility of constructor declaration

`updConsArgs :: ([TypeExpr] → [TypeExpr]) → ConsDecl → ConsDecl`

> update arguments of constructor declaration

`updQNamesInConsDecl :: ((String,String) → (String,String)) → ConsDecl → ConsDecl`

> update all qualified names in constructor declaration

`tVarIndex :: TypeExpr → Int`

> get index from type variable

`domain :: TypeExpr → TypeExpr`

> get domain from functional type

`range :: TypeExpr → TypeExpr`

> get range from functional type

`tConsName :: TypeExpr → (String,String)`

> get name from constructed type

`tConsArgs :: TypeExpr → [TypeExpr]`

> get arguments from constructed type

`trTypeExpr :: (Int → a) → ((String,String) → [a] → a) → (a → a → a) → TypeExpr → a`

`isTVar :: TypeExpr → Bool`

> is type expression a type variable?

`isTCons :: TypeExpr → Bool`

> is type declaration a constructed type?

`isFuncType :: TypeExpr → Bool`

> is type declaration a functional type?

`updTVars :: (Int → TypeExpr) → TypeExpr → TypeExpr`

> update all type variables

`updTCons :: ((String,String) → [TypeExpr] → TypeExpr) → TypeExpr → TypeExpr`

update all type constructors

`updFuncTypes :: (TypeExpr → TypeExpr → TypeExpr) → TypeExpr → TypeExpr`

update all functional types

`argTypes :: TypeExpr → [TypeExpr]`

get argument types from functional type

`resultType :: TypeExpr → TypeExpr`

get result type from (nested) functional type

`rnmAllVarsInTypeExpr :: (Int → Int) → TypeExpr → TypeExpr`

rename variables in type expression

`updQNamesInTypeExpr :: ((String,String) → (String,String)) → TypeExpr → TypeExpr`

update all qualified names in type expression

`trOp :: ((String,String) → Fixity → Int → a) → OpDecl → a`

transform operator declaration

`opName :: OpDecl → (String,String)`

get name from operator declaration

`opFixity :: OpDecl → Fixity`

get fixity of operator declaration

`opPrecedence :: OpDecl → Int`

get precedence of operator declaration

`updOp :: ((String,String) → (String,String)) → (Fixity → Fixity) → (Int → Int) → OpDecl → OpDecl`

update operator declaration

`updOpName :: ((String,String) → (String,String)) → OpDecl → OpDecl`

update name of operator declaration

`updOpFixity :: (Fixity → Fixity) → OpDecl → OpDecl`

update fixity of operator declaration

`updOpPrecedence :: (Int → Int) → OpDecl → OpDecl`

update precedence of operator declaration

```
trFunc :: ((String,String) → Int → Visibility → TypeExpr → ARule a → b) →
AFuncDecl a → b
```

transform function

```
funcName :: AFuncDecl a → (String,String)
```

get name of function

```
funcArity :: AFuncDecl a → Int
```

get arity of function

```
funcVisibility :: AFuncDecl a → Visibility
```

get visibility of function

```
funcType :: AFuncDecl a → TypeExpr
```

get type of function

```
funcRule :: AFuncDecl a → ARule a
```

get rule of function

```
updFunc :: ((String,String) → (String,String)) → (Int → Int) → (Visibility →
Visibility) → (TypeExpr → TypeExpr) → (ARule a → ARule a) → AFuncDecl a →
AFuncDecl a
```

update function

```
updFuncName :: ((String,String) → (String,String)) → AFuncDecl a → AFuncDecl a
```

update name of function

```
updFuncArity :: (Int → Int) → AFuncDecl a → AFuncDecl a
```

update arity of function

```
updFuncVisibility :: (Visibility → Visibility) → AFuncDecl a → AFuncDecl a
```

update visibility of function

```
updFuncType :: (TypeExpr → TypeExpr) → AFuncDecl a → AFuncDecl a
```

update type of function

```
updFuncRule :: (ARule a → ARule a) → AFuncDecl a → AFuncDecl a
```

update rule of function

```
isExternal :: AFuncDecl a → Bool
```

is function externally defined?

```
allVarsInFunc :: AFuncDecl a → [Int]
```

get variable names in a function declaration

```
funcArgs :: AFuncDecl a → [(Int,a)]
```

get arguments of function, if not externally defined

```
funcBody :: AFuncDecl a → AExpr a
```

get body of function, if not externally defined

```
funcRHS :: AFuncDecl a → [AExpr a]
```


```
rnmAllVarsInFunc :: (Int → Int) → AFuncDecl a → AFuncDecl a
```

rename all variables in function

```
updQNamesInFunc :: ((String,String) → (String,String)) → AFuncDecl a →
AFuncDecl a
```

update all qualified names in function

```
updFuncArgs :: ([(Int,a)] → [(Int,a)]) → AFuncDecl a → AFuncDecl a
```

update arguments of function, if not externally defined

```
updFuncBody :: (AExpr a → AExpr a) → AFuncDecl a → AFuncDecl a
```

update body of function, if not externally defined

```
trRule :: (a → [(Int,a)] → AExpr a → b) → (a → String → b) → ARule a → b
```

transform rule

```
ruleArgs :: ARule a → [(Int,a)]
```

get rules arguments if it's not external

```
ruleBody :: ARule a → AExpr a
```

get rules body if it's not external

```
ruleExtDecl :: ARule a → String
```

get rules external declaration

```
isRuleExternal :: ARule a → Bool
```

is rule external?

```
updRule :: (a → a) → ([(Int,a)] → [(Int,a)]) → (AExpr a → AExpr a) → (String
→ String) → ARule a → ARule a
```

update rule

```
updRuleArgs :: ([(Int,a)] → [(Int,a)]) → ARule a → ARule a
```

       update rules arguments

```
updRuleBody :: (AExpr a → AExpr a) → ARule a → ARule a
```

       update rules body

```
updRuleExtDecl :: (String → String) → ARule a → ARule a
```

       update rules external declaration

```
allVarsInRule :: ARule a → [Int]
```

       get variable names in a functions rule

```
rnmAllVarsInRule :: (Int → Int) → ARule a → ARule a
```

       rename all variables in rule

```
updQNamesInRule :: ((String,String) → (String,String)) → ARule a → ARule a
```

       update all qualified names in rule

```
trCombType :: a → (Int → a) → a → (Int → a) → CombType → a
```

       transform combination type

```
isCombTypeFuncCall :: CombType → Bool
```

       is type of combination FuncCall?

```
isCombTypeFuncPartCall :: CombType → Bool
```

       is type of combination FuncPartCall?

```
isCombTypeConsCall :: CombType → Bool
```

       is type of combination ConsCall?

```
isCombTypeConsPartCall :: CombType → Bool
```

       is type of combination ConsPartCall?

```
missingArgs :: CombType → Int
```

```
varNr :: AExpr a → Int
```

       get internal number of variable

```
literal :: AExpr a → Literal
```

get literal if expression is literal expression

```
combType :: AExpr a → CombType
```

get combination type of a combined expression

```
combName :: AExpr a → (String,String)
```

get name of a combined expression

```
combArgs :: AExpr a → [AExpr a]
```

get arguments of a combined expression

```
missingCombArgs :: AExpr a → Int
```

get number of missing arguments if expression is combined

```
letBinds :: AExpr a → [((Int,a),AExpr a)]
```

get indices of variables in let declaration

```
letBody :: AExpr a → AExpr a
```

get body of let declaration

```
freeVars :: AExpr a → [Int]
```

get variable indices from declaration of free variables

```
freeExpr :: AExpr a → AExpr a
```

get expression from declaration of free variables

```
orExps :: AExpr a → [AExpr a]
```

get expressions from or-expression

```
caseType :: AExpr a → CaseType
```

get case-type of case expression

```
caseExpr :: AExpr a → AExpr a
```

get scrutinee of case expression

```
caseBranches :: AExpr a → [ABranchExpr a]
```

```
isVar :: AExpr a → Bool
```

is expression a variable?

```
isLit :: AExpr a → Bool
```

is expression a literal expression?

```
isComb :: AExpr a → Bool
```

is expression combined?

```
isLet :: AExpr a → Bool
```

is expression a let expression?

```
isFree :: AExpr a → Bool
```

is expression a declaration of free variables?

```
isOr :: AExpr a → Bool
```

is expression an or-expression?

```
isCase :: AExpr a → Bool
```

is expression a case expression?

```
trExpr :: (a → Int → b) → (a → Literal → b) → (a → CombType →
((String,String),a) → [b] → b) → (a → [((Int,a),b)] → b → b) → (a →
[(Int,a)] → b → b) → (a → b → b → b) → (a → CaseType → b → [c] → b)
→ (APattern a → b → c) → (a → b → TypeExpr → b) → AExpr a → b
```

transform expression

```
updVars :: (a → Int → AExpr a) → AExpr a → AExpr a
```

update all variables in given expression

```
updLiterals :: (a → Literal → AExpr a) → AExpr a → AExpr a
```

update all literals in given expression

```
updCombs :: (a → CombType → ((String,String),a) → [AExpr a] → AExpr a) →
AExpr a → AExpr a
```

update all combined expressions in given expression

```
updLets :: (a → [((Int,a),AExpr a)] → AExpr a → AExpr a) → AExpr a → AExpr a
```

update all let expressions in given expression

```
updFrees :: (a → [(Int,a)] → AExpr a → AExpr a) → AExpr a → AExpr a
```

update all free declarations in given expression

```
updOrs :: (a → AExpr a → AExpr a → AExpr a) → AExpr a → AExpr a
```

update all or expressions in given expression

```
updCases :: (a → CaseType → AExpr a → [ABranchExpr a] → AExpr a) → AExpr a →
AExpr a
```

   update all case expressions in given expression

```
updBranches :: (APattern a → AExpr a → ABranchExpr a) → AExpr a → AExpr a
```

   update all case branches in given expression

```
updTypeds :: (a → AExpr a → TypeExpr → AExpr a) → AExpr a → AExpr a
```

   update all typed expressions in given expression

```
isFuncCall :: AExpr a → Bool
```

   is expression a call of a function where all arguments are provided?

```
isFuncPartCall :: AExpr a → Bool
```

   is expression a partial function call?

```
isConsCall :: AExpr a → Bool
```

   is expression a call of a constructor?

```
isConsPartCall :: AExpr a → Bool
```

   is expression a partial constructor call?

```
isGround :: AExpr a → Bool
```

   is expression fully evaluated?

```
allVars :: AExpr a → [Int]
```

   get all variables (also pattern variables) in expression

```
rnmAllVars :: (Int → Int) → AExpr a → AExpr a
```

   rename all variables (also in patterns) in expression

```
updQNames :: ((String,String) → (String,String)) → AExpr a → AExpr a
```

   update all qualified names in expression

```
trBranch :: (APattern a → AExpr a → b) → ABranchExpr a → b
```

   transform branch expression

```
branchPattern :: ABranchExpr a → APattern a
```

   get pattern from branch expression

```
branchExpr :: ABranchExpr a → AExpr a
```

   get expression from branch expression

`updBranch :: (APattern a → APattern a) → (AExpr a → AExpr a) → ABranchExpr a → ABranchExpr a`

      update branch expression

`updBranchPattern :: (APattern a → APattern a) → ABranchExpr a → ABranchExpr a`

      update pattern of branch expression

`updBranchExpr :: (AExpr a → AExpr a) → ABranchExpr a → ABranchExpr a`

      update expression of branch expression

`trPattern :: (a → ((String,String),a) → [(Int,a)] → b) → (a → Literal → b) → APattern a → b`

      transform pattern

`patCons :: APattern a → (String,String)`

      get name from constructor pattern

`patArgs :: APattern a → [(Int,a)]`

      get arguments from constructor pattern

`patLiteral :: APattern a → Literal`

      get literal from literal pattern

`isConsPattern :: APattern a → Bool`

      is pattern a constructor pattern?

`updPattern :: (((String,String),a) → ((String,String),a)) → ([(Int,a)] → [(Int,a)]) → (Literal → Literal) → APattern a → APattern a`

      update pattern

`updPatCons :: ((String,String) → (String,String)) → APattern a → APattern a`

      update constructors name of pattern

`updPatArgs :: ([(Int,a)] → [(Int,a)]) → APattern a → APattern a`

      update arguments of constructor pattern

`updPatLiteral :: (Literal → Literal) → APattern a → APattern a`

      update literal of pattern

`patExpr :: APattern a → AExpr a`

      build expression from pattern

```
annRule :: ARule a → a
```

```
annExpr :: AExpr a → a
```

Extract the annotation of an annotated expression.

```
annPattern :: APattern a → a
```

Extract the annotation of an annotated pattern.

```
unAnnProg :: AProg a → Prog
```

```
unAnnFuncDecl :: AFuncDecl a → FuncDecl
```

```
unAnnRule :: ARule a → Rule
```

```
unAnnExpr :: AExpr a → Expr
```

```
unAnnPattern :: APattern a → Pattern
```

A.5.8 Library CompactFlatCurry

This module contains functions to reduce the size of FlatCurry programs by combining the main
module and all imports into a single program that contains only the functions directly or indirectly
called from a set of main functions.

Exported types:

```
data Option
```

Options to guide the compactification process.

Exported constructors:

- `Verbose :: Option`

  Verbose

  – for more output

- `Main :: String → Option`

  Main

– optimize for one main (unqualified!) function supplied here

- **Exports :: Option**

  Exports

  – optimize w.r.t. the exported functions of the module only

- **InitFuncs :: [(String,String)] → Option**

  InitFuncs

  – optimize w.r.t. given list of initially required functions

- **Required :: [RequiredSpec] → Option**

  Required

  – list of functions that are implicitly required and, thus, should not be deleted if the corresponding module is imported

- **Import :: String → Option**

  Import

  – module that should always be imported (useful in combination with option InitFuncs)

data RequiredSpec

Data type to specify requirements of functions.

Exported constructors:

Exported functions:

requires :: (String,String) → (String,String) → RequiredSpec

(fun **requires** reqfun) specifies that the use of the function "fun" implies the application of function "reqfun".

alwaysRequired :: (String,String) → RequiredSpec

(alwaysRequired fun) specifies that the function "fun" should be always present if the corresponding module is loaded.

defaultRequired :: [RequiredSpec]

Functions that are implicitly required in a FlatCurry program (since they might be generated by external functions like "==" or "=:=" on the fly).

generateCompactFlatCurryFile :: [Option] → String → String → IO ()

Computes a single FlatCurry program containing all functions potentially called from a set of main functions and writes it into a FlatCurry file. This is done by merging all imported FlatCurry modules and removing the imported functions that are definitely not used.

```
computeCompactFlatCurry :: [Option] → String → IO Prog
```

> Computes a single FlatCurry program containing all functions potentially called from a
> set of main functions. This is done by merging all imported FlatCurry modules (these
> are loaded demand-driven so that modules that contains no potentially called functions
> are not loaded) and removing the imported functions that are definitely not used.

A.5.9   Library CurryStringClassifier

The Curry string classifier is a simple tool to process strings containing Curry source code. The
source string is classified into the following categories:

- moduleHead - module interface, imports, operators

- code - the part where the actual program is defined

- big comment - parts enclosed in {- ... -}

- small comment - from ”–” to the end of a line

- text - a string, i.e. text enclosed in ”...”

- letter - the given string is the representation of a character

- meta - containing information for meta programming

For an example to use the state scanner cf. addtypes, the tool to add function types to a given
program.

Exported types:

```
type Tokens = [Token]
```

```
data Token
```

> The different categories to classify the source code.

Exported constructors:

- `SmallComment :: String → Token`

- `BigComment :: String → Token`

- `Text :: String → Token`

- `Letter :: String → Token`

- `Code :: String → Token`

- `ModuleHead :: String → Token`

- `Meta :: String → Token`

Exported functions:

isSmallComment :: Token → Bool

     test for category "SmallComment"

isBigComment :: Token → Bool

     test for category "BigComment"

isComment :: Token → Bool

     test if given token is a comment (big or small)

isText :: Token → Bool

     test for category "Text" (String)

isLetter :: Token → Bool

     test for category "Letter" (Char)

isCode :: Token → Bool

     test for category "Code"

isModuleHead :: Token → Bool

     test for category "ModuleHead", ie imports and operator declarations

isMeta :: Token → Bool

     test for category "Meta", ie between {+ and +}

scan :: String → [Token]

     Divides the given string into the six categories. For applications it is important to know whether a given part of code is at the beginning of a line or in the middle. The state scanner organizes the code in such a way that every string categorized as "Code" **always** starts in the middle of a line.

plainCode :: [Token] → String

     Yields the program code without comments (but with the line breaks for small comments).

unscan :: [Token] → String

     Inverse function of scan, i.e., unscan (scan x) = x. unscan is used to yield a program after changing the list of tokens.

readScan :: String → IO [Token]

     return tokens for given filename

testScan :: String → IO ()

     test whether (unscan . scan) is identity

A.5.10   Library FlatCurry

This library supports meta-programming, i.e., the manipulation of Curry programs in Curry. For this purpose, the library contains definitions of datatypes for the representation of so-called FlatCurry programs and an I/O action to read Curry programs and transform them into this representation.

Exported types:

type QName = (String,String)

> The data type for representing qualified names. In FlatCurry all names are qualified to avoid name clashes. The first component is the module name and the second component the unqualified name as it occurs in the source program.

type TVarIndex = Int

> The data type for representing type variables. They are represented by (TVar i) where i is a type variable index.

type VarIndex = Int

> Data type for representing object variables. Object variables occurring in expressions are represented by (Var i) where i is a variable index.

data Prog

> Data type for representing a Curry module in the intermediate form. A value of this data type has the form
>
> (Prog modname imports typedecls functions opdecls)
>
> where modname is the name of this module, imports is the list of modules names that are imported, and typedecls, functions, and opdecls are the list of data type, function, and operator declarations contained in this module, respectively.

> *Exported constructors:*

> - Prog :: String → [String] → [TypeDecl] → [FuncDecl] → [OpDecl] → Prog

data Visibility

> Data type to specify the visibility of various entities.

> *Exported constructors:*

> - Public :: Visibility

> - Private :: Visibility

```
data TypeDecl
```

> Data type for representing definitions of algebraic data types and type synonyms.
>
> A data type definition of the form
>
> ```
> data t x1...xn = ...| c t1....tkc |...
> ```
>
> is represented by the FlatCurry term
>
> ```
> (Type t [i1,...,in] [...(Cons c kc [t1,...,tkc])...])
> ```
>
> where each `ij` is the index of the type variable `xj`.
>
> Note: the type variable indices are unique inside each type declaration and are usually numbered from 0
>
> Thus, a data type declaration consists of the name of the data type, a list of type parameters and a list of constructor declarations.

Exported constructors:

- Type :: (String,String) → Visibility → [Int] → [ConsDecl] → TypeDecl

- TypeSyn :: (String,String) → Visibility → [Int] → TypeExpr → TypeDecl

```
data ConsDecl
```

> A constructor declaration consists of the name and arity of the constructor and a list of the argument types of the constructor.

Exported constructors:

- Cons :: (String,String) → Int → Visibility → [TypeExpr] → ConsDecl

```
data TypeExpr
```

> Data type for type expressions. A type expression is either a type variable, a function type, or a type constructor application.
>
> Note: the names of the predefined type constructors are "Int", "Float", "Bool", "Char", "IO", "Success", "()" (unit type), "(,...,)" (tuple types), "[]" (list type)

Exported constructors:

- TVar :: Int → TypeExpr

- FuncType :: TypeExpr → TypeExpr → TypeExpr

- TCons :: (String,String) → [TypeExpr] → TypeExpr

```
data OpDecl
```

Data type for operator declarations. An operator declaration `fix p n` in Curry corresponds to the FlatCurry term (`Op n fix p`).

Exported constructors:

- `Op :: (String,String) → Fixity → Int → OpDecl`

data Fixity

Data types for the different choices for the fixity of an operator.

Exported constructors:

- `InfixOp :: Fixity`

- `InfixlOp :: Fixity`

- `InfixrOp :: Fixity`

data FuncDecl

Data type for representing function declarations.

A function declaration in FlatCurry is a term of the form

```
(Func name k type (Rule [i1,...,ik] e))
```

and represents the function `name` with definition

```
name :: type
name x1...xk = e
```

where each `ij` is the index of the variable `xj`.

Note: the variable indices are unique inside each function declaration and are usually numbered from 0

External functions are represented as

```
(Func name arity type (External s))
```

where s is the external name associated to this function.

Thus, a function declaration consists of the name, arity, type, and rule.

Exported constructors:

- `Func :: (String,String) → Int → Visibility → TypeExpr → Rule → FuncDecl`

data Rule

A rule is either a list of formal parameters together with an expression or an "External" tag.

Exported constructors:

- Rule :: [Int] → Expr → Rule

- External :: String → Rule

data CaseType

Data type for classifying case expressions. Case expressions can be either flexible or rigid in Curry.

Exported constructors:

- Rigid :: CaseType

- Flex :: CaseType

data CombType

Data type for classifying combinations (i.e., a function/constructor applied to some arguments).

Exported constructors:

- FuncCall :: CombType

  FuncCall

    – a call to a function where all arguments are provided

- ConsCall :: CombType

  ConsCall

    – a call with a constructor at the top, all arguments are provided

- FuncPartCall :: Int → CombType

  FuncPartCall

    – a partial call to a function (i.e., not all arguments are provided) where the parameter is the number of missing arguments

- ConsPartCall :: Int → CombType

  ConsPartCall

    – a partial call to a constructor (i.e., not all arguments are provided) where the parameter is the number of missing arguments

data Expr

Data type for representing expressions.

Remarks:

if-then-else expressions are represented as function calls:

```
(if e1 then e2 else e3)
```

is represented as

```
(Comb FuncCall ("Prelude","if_then_else") [e1,e2,e3])
```

Higher-order applications are represented as calls to the (external) function `apply`. For instance, the rule

```
app f x = f x
```

is represented as

```
(Rule  [0,1] (Comb FuncCall ("Prelude","apply") [Var 0, Var 1]))
```

A conditional rule is represented as a call to an external function `cond` where the first argument is the condition (a constraint). For instance, the rule

```
equal2 x | x=:=2 = success
```

is represented as

```
(Rule [0]
      (Comb FuncCall ("Prelude","cond")
              [Comb FuncCall ("Prelude","=:=") [Var 0, Lit (Intc 2)],
               Comb FuncCall ("Prelude","success") []]))
```

Exported constructors:

- `Var :: Int → Expr`

  `Var`

    – variable (represented by unique index)

- `Lit :: Literal → Expr`

  `Lit`

    – literal (Int/Float/Char constant)

- Comb :: CombType → (String,String) → [Expr] → Expr

  Comb

    – application (f e1 ... en) of function/constructor f with n<=arity(f)

- Let :: [(Int,Expr)] → Expr → Expr

  Let

    – introduction of local variables via (recursive) let declarations

- Free :: [Int] → Expr → Expr

  Free

    – introduction of free local variables

- Or :: Expr → Expr → Expr

  Or

    – disjunction of two expressions (used to translate rules with overlapping left-hand sides)

- Case :: CaseType → Expr → [BranchExpr] → Expr

  Case

    – case distinction (rigid or flex)

- Typed :: Expr → TypeExpr → Expr

  Typed

    – typed expression to represent an expression with a type declaration

data BranchExpr

Data type for representing branches in a case expression.

Branches "(m.c x1...xn) -> e" in case expressions are represented as

(Branch (Pattern (m,c) [i1,...,in]) e)

where each ij is the index of the pattern variable xj, or as

(Branch (LPattern (Intc i)) e)

for integers as branch patterns (similarly for other literals like float or character constants).

Exported constructors:

- Branch :: Pattern → Expr → BranchExpr

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`data Pattern`

Data type for representing patterns in case expressions.

Exported constructors:

- `Pattern :: (String,String) → [Int] → Pattern`

- `LPattern :: Literal → Pattern`

`data Literal`

Data type for representing literals occurring in an expression or case branch. It is either an integer, a float, or a character constant.

Exported constructors:

- `Intc :: Int → Literal`

- `Floatc :: Float → Literal`

- `Charc :: Char → Literal`

Exported functions:

`readFlatCurry :: String → IO Prog`

I/O action which parses a Curry program and returns the corresponding FlatCurry program. Thus, the argument is the module path (without suffix ".curry" or ".lcurry") and the result is a FlatCurry term representing this program.

`readFlatCurryWithParseOptions :: String → FrontendParams → IO Prog`

I/O action which parses a Curry program with respect to some parser options and returns the corresponding FlatCurry program. This I/O action is used by the standard action `readFlatCurry`.

`flatCurryFileName :: String → String`

Transforms a name of a Curry program (with or without suffix ".curry" or ".lcurry") into the name of the file containing the corresponding FlatCurry program.

`flatCurryIntName :: String → String`

Transforms a name of a Curry program (with or without suffix ".curry" or ".lcurry") into the name of the file containing the corresponding FlatCurry program.

`readFlatCurryFile :: String → IO Prog`

I/O action which reads a FlatCurry program from a file in ".fcy" format. In contrast to `readFlatCurry`, this action does not parse a source program. Thus, the argument must be the name of an existing file (with suffix ".fcy") containing a FlatCurry program in ".fcy" format and the result is a FlatCurry term representing this program.

```
readFlatCurryInt :: String → IO Prog
```

> I/O action which returns the interface of a Curry module, i.e., a FlatCurry program
> containing only "Public" entities and function definitions without rules (i.e., external
> functions). The argument is the file name without suffix ".curry" (or ".lcurry") and the
> result is a FlatCurry term representing the interface of this module.

```
writeFCY :: String → Prog → IO ()
```

> Writes a FlatCurry program into a file in ".fcy" format. The first argument must be
> the name of the target file (with suffix ".fcy").

```
showQNameInModule :: String → (String,String) → String
```

> Translates a given qualified type name into external name relative to a module. Thus,
> names not defined in this module (except for names defined in the prelude) are prefixed
> with their module name.

A.5.11   Library FlatCurryGoodies

This library provides selector functions, test and update operations as well as some useful auxiliary
functions for FlatCurry data terms. Most of the provided functions are based on general trans-
formation functions that replace constructors with user-defined functions. For recursive datatypes
the transformations are defined inductively over the term structure. This is quite usual for trans-
formations on FlatCurry terms, so the provided functions can be used to implement specific trans-
formations without having to explicitly state the recursion. Essentially, the tedious part of such
transformations - descend in fairly complex term structures - is abstracted away, which hopefully
makes the code more clear and brief.

Exported types:

```
type Update a b = (b → b) → a → a
```

Exported functions:

```
trProg :: (String → [String] → [TypeDecl] → [FuncDecl] → [OpDecl] → a) →
Prog → a
```

> transform program

```
progName :: Prog → String
```

> get name from program

```
progImports :: Prog → [String]
```

> get imports from program

```
progTypes :: Prog → [TypeDecl]
```

get type declarations from program

`progFuncs :: Prog → [FuncDecl]`

get functions from program

`progOps :: Prog → [OpDecl]`

get infix operators from program

`updProg :: (String → String) → ([String] → [String]) → ([TypeDecl] → [TypeDecl]) → ([FuncDecl] → [FuncDecl]) → ([OpDecl] → [OpDecl]) → Prog → Prog`

update program

`updProgName :: (String → String) → Prog → Prog`

update name of program

`updProgImports :: ([String] → [String]) → Prog → Prog`

update imports of program

`updProgTypes :: ([TypeDecl] → [TypeDecl]) → Prog → Prog`

update type declarations of program

`updProgFuncs :: ([FuncDecl] → [FuncDecl]) → Prog → Prog`

update functions of program

`updProgOps :: ([OpDecl] → [OpDecl]) → Prog → Prog`

update infix operators of program

`allVarsInProg :: Prog → [Int]`

get all program variables (also from patterns)

`updProgExps :: (Expr → Expr) → Prog → Prog`

lift transformation on expressions to program

`rnmAllVarsInProg :: (Int → Int) → Prog → Prog`

rename programs variables

`updQNamesInProg :: ((String,String) → (String,String)) → Prog → Prog`

update all qualified names in program

`rnmProg :: String → Prog → Prog`

rename program (update name of and all qualified names in program)

trType :: ((String,String) → Visibility → [Int] → [ConsDecl] → a) →
((String,String) → Visibility → [Int] → TypeExpr → a) → TypeDecl → a

>   transform type declaration

typeName :: TypeDecl → (String,String)

>   get name of type declaration

typeVisibility :: TypeDecl → Visibility

>   get visibility of type declaration

typeParams :: TypeDecl → [Int]

>   get type parameters of type declaration

typeConsDecls :: TypeDecl → [ConsDecl]

>   get constructor declarations from type declaration

typeSyn :: TypeDecl → TypeExpr

>   get synonym of type declaration

isTypeSyn :: TypeDecl → Bool

>   is type declaration a type synonym?

updType :: ((String,String) → (String,String)) → (Visibility → Visibility)
→ ([Int] → [Int]) → ([ConsDecl] → [ConsDecl]) → (TypeExpr → TypeExpr) →
TypeDecl → TypeDecl

>   update type declaration

updTypeName :: ((String,String) → (String,String)) → TypeDecl → TypeDecl

>   update name of type declaration

updTypeVisibility :: (Visibility → Visibility) → TypeDecl → TypeDecl

>   update visibility of type declaration

updTypeParams :: ([Int] → [Int]) → TypeDecl → TypeDecl

>   update type parameters of type declaration

updTypeConsDecls :: ([ConsDecl] → [ConsDecl]) → TypeDecl → TypeDecl

>   update constructor declarations of type declaration

updTypeSynonym :: (TypeExpr → TypeExpr) → TypeDecl → TypeDecl

>   update synonym of type declaration

`updQNamesInType :: ((String,String) → (String,String)) → TypeDecl → TypeDecl`

    update all qualified names in type declaration

`trCons :: ((String,String) → Int → Visibility → [TypeExpr] → a) → ConsDecl → a`

    transform constructor declaration

`consName :: ConsDecl → (String,String)`

    get name of constructor declaration

`consArity :: ConsDecl → Int`

    get arity of constructor declaration

`consVisibility :: ConsDecl → Visibility`

    get visibility of constructor declaration

`consArgs :: ConsDecl → [TypeExpr]`

    get arguments of constructor declaration

`updCons :: ((String,String) → (String,String)) → (Int → Int) → (Visibility → Visibility) → ([TypeExpr] → [TypeExpr]) → ConsDecl → ConsDecl`

    update constructor declaration

`updConsName :: ((String,String) → (String,String)) → ConsDecl → ConsDecl`

    update name of constructor declaration

`updConsArity :: (Int → Int) → ConsDecl → ConsDecl`

    update arity of constructor declaration

`updConsVisibility :: (Visibility → Visibility) → ConsDecl → ConsDecl`

    update visibility of constructor declaration

`updConsArgs :: ([TypeExpr] → [TypeExpr]) → ConsDecl → ConsDecl`

    update arguments of constructor declaration

`updQNamesInConsDecl :: ((String,String) → (String,String)) → ConsDecl → ConsDecl`

    update all qualified names in constructor declaration

`tVarIndex :: TypeExpr → Int`

    get index from type variable

```
domain :: TypeExpr → TypeExpr
```

   get domain from functional type

```
range :: TypeExpr → TypeExpr
```

   get range from functional type

```
tConsName :: TypeExpr → (String,String)
```

   get name from constructed type

```
tConsArgs :: TypeExpr → [TypeExpr]
```

   get arguments from constructed type

```
trTypeExpr :: (Int → a) → ((String,String) → [a] → a) → (a → a → a) →
TypeExpr → a
```

   transform type expression

```
isTVar :: TypeExpr → Bool
```

   is type expression a type variable?

```
isTCons :: TypeExpr → Bool
```

   is type declaration a constructed type?

```
isFuncType :: TypeExpr → Bool
```

   is type declaration a functional type?

```
updTVars :: (Int → TypeExpr) → TypeExpr → TypeExpr
```

   update all type variables

```
updTCons :: ((String,String) → [TypeExpr] → TypeExpr) → TypeExpr → TypeExpr
```

   update all type constructors

```
updFuncTypes :: (TypeExpr → TypeExpr → TypeExpr) → TypeExpr → TypeExpr
```

   update all functional types

```
argTypes :: TypeExpr → [TypeExpr]
```

   get argument types from functional type

```
resultType :: TypeExpr → TypeExpr
```

   get result type from (nested) functional type

```
rnmAllVarsInTypeExpr :: (Int → Int) → TypeExpr → TypeExpr
```

   rename variables in type expression

`updQNamesInTypeExpr :: ((String,String) → (String,String)) → TypeExpr → TypeExpr`

      update all qualified names in type expression

`trOp :: ((String,String) → Fixity → Int → a) → OpDecl → a`

      transform operator declaration

`opName :: OpDecl → (String,String)`

      get name from operator declaration

`opFixity :: OpDecl → Fixity`

      get fixity of operator declaration

`opPrecedence :: OpDecl → Int`

      get precedence of operator declaration

`updOp :: ((String,String) → (String,String)) → (Fixity → Fixity) → (Int → Int) → OpDecl → OpDecl`

      update operator declaration

`updOpName :: ((String,String) → (String,String)) → OpDecl → OpDecl`

      update name of operator declaration

`updOpFixity :: (Fixity → Fixity) → OpDecl → OpDecl`

      update fixity of operator declaration

`updOpPrecedence :: (Int → Int) → OpDecl → OpDecl`

      update precedence of operator declaration

`trFunc :: ((String,String) → Int → Visibility → TypeExpr → Rule → a) → FuncDecl → a`

      transform function

`funcName :: FuncDecl → (String,String)`

      get name of function

`funcArity :: FuncDecl → Int`

      get arity of function

`funcVisibility :: FuncDecl → Visibility`

      get visibility of function

```
funcType :: FuncDecl → TypeExpr
```

   get type of function

```
funcRule :: FuncDecl → Rule
```

   get rule of function

```
updFunc :: ((String,String) → (String,String)) → (Int → Int) → (Visibility →
Visibility) → (TypeExpr → TypeExpr) → (Rule → Rule) → FuncDecl → FuncDecl
```

   update function

```
updFuncName :: ((String,String) → (String,String)) → FuncDecl → FuncDecl
```

   update name of function

```
updFuncArity :: (Int → Int) → FuncDecl → FuncDecl
```

   update arity of function

```
updFuncVisibility :: (Visibility → Visibility) → FuncDecl → FuncDecl
```

   update visibility of function

```
updFuncType :: (TypeExpr → TypeExpr) → FuncDecl → FuncDecl
```

   update type of function

```
updFuncRule :: (Rule → Rule) → FuncDecl → FuncDecl
```

   update rule of function

```
isExternal :: FuncDecl → Bool
```

   is function externally defined?

```
allVarsInFunc :: FuncDecl → [Int]
```

   get variable names in a function declaration

```
funcArgs :: FuncDecl → [Int]
```

   get arguments of function, if not externally defined

```
funcBody :: FuncDecl → Expr
```

   get body of function, if not externally defined

```
funcRHS :: FuncDecl → [Expr]
```


```
rnmAllVarsInFunc :: (Int → Int) → FuncDecl → FuncDecl
```

   rename all variables in function

`updQNamesInFunc :: ((String,String) → (String,String)) → FuncDecl → FuncDecl`

> update all qualified names in function

`updFuncArgs :: ([Int] → [Int]) → FuncDecl → FuncDecl`

> update arguments of function, if not externally defined

`updFuncBody :: (Expr → Expr) → FuncDecl → FuncDecl`

> update body of function, if not externally defined

`trRule :: ([Int] → Expr → a) → (String → a) → Rule → a`

> transform rule

`ruleArgs :: Rule → [Int]`

> get rules arguments if it's not external

`ruleBody :: Rule → Expr`

> get rules body if it's not external

`ruleExtDecl :: Rule → String`

> get rules external declaration

`isRuleExternal :: Rule → Bool`

> is rule external?

`updRule :: ([Int] → [Int]) → (Expr → Expr) → (String → String) → Rule →
Rule`

> update rule

`updRuleArgs :: ([Int] → [Int]) → Rule → Rule`

> update rules arguments

`updRuleBody :: (Expr → Expr) → Rule → Rule`

> update rules body

`updRuleExtDecl :: (String → String) → Rule → Rule`

> update rules external declaration

`allVarsInRule :: Rule → [Int]`

> get variable names in a functions rule

`rnmAllVarsInRule :: (Int → Int) → Rule → Rule`

> rename all variables in rule

```
updQNamesInRule :: ((String,String) → (String,String)) → Rule → Rule
```

   update all qualified names in rule

```
trCombType :: a → (Int → a) → a → (Int → a) → CombType → a
```

   transform combination type

```
isCombTypeFuncCall :: CombType → Bool
```

   is type of combination FuncCall?

```
isCombTypeFuncPartCall :: CombType → Bool
```

   is type of combination FuncPartCall?

```
isCombTypeConsCall :: CombType → Bool
```

   is type of combination ConsCall?

```
isCombTypeConsPartCall :: CombType → Bool
```

   is type of combination ConsPartCall?

```
missingArgs :: CombType → Int
```


```
varNr :: Expr → Int
```

   get internal number of variable

```
literal :: Expr → Literal
```

   get literal if expression is literal expression

```
combType :: Expr → CombType
```

   get combination type of a combined expression

```
combName :: Expr → (String,String)
```

   get name of a combined expression

```
combArgs :: Expr → [Expr]
```

   get arguments of a combined expression

```
missingCombArgs :: Expr → Int
```

   get number of missing arguments if expression is combined

```
letBinds :: Expr → [(Int,Expr)]
```

   get indices of variables in let declaration

`letBody :: Expr → Expr`

> get body of let declaration

`freeVars :: Expr → [Int]`

> get variable indices from declaration of free variables

`freeExpr :: Expr → Expr`

> get expression from declaration of free variables

`orExps :: Expr → [Expr]`

> get expressions from or-expression

`caseType :: Expr → CaseType`

> get case-type of case expression

`caseExpr :: Expr → Expr`

> get scrutinee of case expression

`caseBranches :: Expr → [BranchExpr]`

> get branch expressions from case expression

`isVar :: Expr → Bool`

> is expression a variable?

`isLit :: Expr → Bool`

> is expression a literal expression?

`isComb :: Expr → Bool`

> is expression combined?

`isLet :: Expr → Bool`

> is expression a let expression?

`isFree :: Expr → Bool`

> is expression a declaration of free variables?

`isOr :: Expr → Bool`

> is expression an or-expression?

`isCase :: Expr → Bool`

> is expression a case expression?

```
trExpr :: (Int → a) → (Literal → a) → (CombType → (String,String) → [a] →
a) → ([(Int,a)] → a → a) → ([Int] → a → a) → (a → a → a) → (CaseType →
a → [b] → a) → (Pattern → a → b) → (a → TypeExpr → a) → Expr → a
```

    transform expression

```
updVars :: (Int → Expr) → Expr → Expr
```

    update all variables in given expression

```
updLiterals :: (Literal → Expr) → Expr → Expr
```

    update all literals in given expression

```
updCombs :: (CombType → (String,String) → [Expr] → Expr) → Expr → Expr
```

    update all combined expressions in given expression

```
updLets :: ([(Int,Expr)] → Expr → Expr) → Expr → Expr
```

    update all let expressions in given expression

```
updFrees :: ([Int] → Expr → Expr) → Expr → Expr
```

    update all free declarations in given expression

```
updOrs :: (Expr → Expr → Expr) → Expr → Expr
```

    update all or expressions in given expression

```
updCases :: (CaseType → Expr → [BranchExpr] → Expr) → Expr → Expr
```

    update all case expressions in given expression

```
updBranches :: (Pattern → Expr → BranchExpr) → Expr → Expr
```

    update all case branches in given expression

```
updTypeds :: (Expr → TypeExpr → Expr) → Expr → Expr
```

    update all typed expressions in given expression

```
isFuncCall :: Expr → Bool
```

    is expression a call of a function where all arguments are provided?

```
isFuncPartCall :: Expr → Bool
```

    is expression a partial function call?

```
isConsCall :: Expr → Bool
```

    is expression a call of a constructor?

```
isConsPartCall :: Expr → Bool
```

is expression a partial constructor call?

`isGround :: Expr → Bool`

is expression fully evaluated?

`allVars :: Expr → [Int]`

get all variables (also pattern variables) in expression

`rnmAllVars :: (Int → Int) → Expr → Expr`

rename all variables (also in patterns) in expression

`updQNames :: ((String,String) → (String,String)) → Expr → Expr`

update all qualified names in expression

`trBranch :: (Pattern → Expr → a) → BranchExpr → a`

transform branch expression

`branchPattern :: BranchExpr → Pattern`

get pattern from branch expression

`branchExpr :: BranchExpr → Expr`

get expression from branch expression

`updBranch :: (Pattern → Pattern) → (Expr → Expr) → BranchExpr → BranchExpr`

update branch expression

`updBranchPattern :: (Pattern → Pattern) → BranchExpr → BranchExpr`

update pattern of branch expression

`updBranchExpr :: (Expr → Expr) → BranchExpr → BranchExpr`

update expression of branch expression

`trPattern :: ((String,String) → [Int] → a) → (Literal → a) → Pattern → a`

transform pattern

`patCons :: Pattern → (String,String)`

get name from constructor pattern

`patArgs :: Pattern → [Int]`

get arguments from constructor pattern

`patLiteral :: Pattern → Literal`

get literal from literal pattern

`isConsPattern :: Pattern → Bool`

is pattern a constructor pattern?

`updPattern :: ((String,String) → (String,String)) → ([Int] → [Int]) → (Literal → Literal) → Pattern → Pattern`

update pattern

`updPatCons :: ((String,String) → (String,String)) → Pattern → Pattern`

update constructors name of pattern

`updPatArgs :: ([Int] → [Int]) → Pattern → Pattern`

update arguments of constructor pattern

`updPatLiteral :: (Literal → Literal) → Pattern → Pattern`

update literal of pattern

`patExpr :: Pattern → Expr`

build expression from pattern

A.5.12 Library FlatCurryRead

This library defines operations to read a FlatCurry programs or interfaces together with all its imported modules in the current load path.

Exported functions:

`readFlatCurryWithImports :: String → IO [Prog]`

Reads a FlatCurry program together with all its imported modules. The argument is the name of the main module, possibly with a directory prefix.

`readFlatCurryWithImportsInPath :: [String] → String → IO [Prog]`

Reads a FlatCurry program together with all its imported modules in a given load path. The arguments are a load path and the name of the main module.

`readFlatCurryIntWithImports :: String → IO [Prog]`

Reads a FlatCurry interface together with all its imported module interfaces. The argument is the name of the main module, possibly with a directory prefix. If there is no interface file but a FlatCurry file (suffix ".fcy"), the FlatCurry file is read instead of the interface.

`readFlatCurryIntWithImportsInPath :: [String] → String → IO [Prog]`

Reads a FlatCurry interface together with all its imported module interfaces in a given load path. The arguments are a load path and the name of the main module. If there is no interface file but a FlatCurry file (suffix ".fcy"), the FlatCurry file is read instead of the interface.

A.5.13 Library FlatCurryShow

This library contains operations to transform FlatCurry programs into string representations, either in a FlatCurry format or in a Curry-like syntax.
This library contains

- show functions for a string representation of FlatCurry programs (`showFlatProg`, `showFlatType`, `showFlatFunc`)

- functions for showing FlatCurry (type) expressions in (almost) Curry syntax (`showCurryType`, `showCurryExpr`,...).

Exported functions:

`showFlatProg :: Prog → String`

    Shows a FlatCurry program term as a string (with some pretty printing).

`showFlatType :: TypeDecl → String`

`showFlatFunc :: FuncDecl → String`

`showCurryType :: ((String,String) → String) → Bool → TypeExpr → String`

    Shows a FlatCurry type in Curry syntax.

`showCurryExpr :: ((String,String) → String) → Bool → Int → Expr → String`

    Shows a FlatCurry expressions in (almost) Curry syntax.

`showCurryVar :: a → String`

`showCurryId :: String → String`

    Shows an identifier in Curry form. Thus, operators are enclosed in brackets.

A.5.14 Library FlatCurryXML

This library contains functions to convert FlatCurry programs into corresponding XML expressions and vice versa. This can be used to store Curry programs in a way independent of a Curry system or to use a Curry system, like PAKCS, as back end by other functional logic programming systems.

Exported functions:

`flatCurry2XmlFile :: Prog → String → IO ()`

> Transforms a FlatCurry program term into a corresponding XML file.

`flatCurry2Xml :: Prog → XmlExp`

> Transforms a FlatCurry program term into a corresponding XML expression.

`xmlFile2FlatCurry :: String → IO Prog`

> Reads an XML file with a FlatCurry program and returns the FlatCurry program.

`xml2FlatCurry :: XmlExp → Prog`

> Transforms an XML term into a FlatCurry program.

A.5.15 Library FlexRigid

This library provides a function to compute the rigid/flex status of a FlatCurry expression (right-hand side of a function definition).

Exported types:

`data FlexRigidResult`

> Datatype for representing a flex/rigid status of an expression.

> *Exported constructors:*

> - `UnknownFR :: FlexRigidResult`

> - `ConflictFR :: FlexRigidResult`

> - `KnownFlex :: FlexRigidResult`

> - `KnownRigid :: FlexRigidResult`

Exported functions:

`getFlexRigid :: Expr → FlexRigidResult`

> Computes the rigid/flex status of a FlatCurry expression. This function checks all cases in this expression. If the expression has rigid as well as flex cases (which cannot be the case for source level programs but might occur after some program transformations), the result ConflictFR is returned.

B Markdown Syntax

This document describes the syntax of texts containing markdown elements. The markdown syntax is intended to simplify the writing of texts whose source is readable and can be easily formatted, e.g., as part of a web document. It is a subset of the original markdown syntax (basically, only internal links and pictures are missing) supported by the Curry library Markdown.

B.1 Paragraphs and Basic Formatting

Paragraphs are separated by at least one line which is empty or does contain only blanks.

Inside a paragraph, one can *emphasize* text or also **strongly emphasize** text. This is done by wrapping it with one or two _ or * characters:

```
_emphasize_
*emphasize*
__strong__
**strong**
```

Furthermore, one can also mark `program code` text by backtick quotes (`):

```
The function `fib` computes Fibonacci numbers.
```

Web links can be put in angle brackets, like in the link http://www.google.com:

```
<http://www.google.com>
```

Currently, only links starting with 'http' are recognized (so that one can also use HTML markup). If one wants to put a link under a text, one can put the text in square brackets directly followed by the link in round brackets, as in Google:

```
[Google](http://www.google.com)
```

If one wants to put a character that has a specific meaning in the syntax of Markdown, like * or _, in the output document, it should be escaped with a backslash, i.e., a backslash followed by a special character in the source text is translated into the given character (this also holds for program code, see below). For instance, the input text

```
\_word\_
```

produces the output "_word_". The following backslash escapes are recognized:

```
\    backslash
`    backtick
*    asterisk
_    underscore
{}   curly braces
[]   square brackets
```

```
()   parentheses
#    hash symbol
+    plus symbol
-    minus symbol (dash)
.    dot
     blank
!    exclamation mark
```

B.2   Lists and Block Formatting

An **unordered list** (i.e., without numbering) is introduced by putting a star in front of the list elements (where the star can be preceded by blanks). The individual list elements must contain the same indentation, as in

```
* First list element
  with two lines

* Next list element.

  It contains two paragraphs.

* Final list element.
```

This is formatted as follows:

- First list element with two lines

- Next list element.

  It contains two paragraphs.

- Final list element.

Instead of a star, one can also put dashes or plus to mark unordered list items. Furthermore, one could nest lists. Thus, the input text

```
- Color:
  + Yellow
  + Read
  + Blue
- BW:
  + Black
  + White
```

is formatted as

- Color:

– Yellow

 – Read

 – Blue

- BW:

 – Black

 – White

Similarly, **ordered lists** (i.e., with numbering each item) are introduced by a number followed by a dot and at least one blank. All following lines belonging to the same numbered item must have the same indent as the first line. The actual value of the number is not important. Thus, the input

```
1. First element

99. Second
    element
```

is formatted as

1. First element

2. Second element

A quotation block is marked by putting a right angle followed by a blank in front of each line:

```
> This is
> a quotation.
```

It will be formatted as a quote element:

> This is a quotation.

A block containing **program code** starts with a blank line and is marked by intending each input line by *at least four spaces* where all following lines must have at least the same indentation as the first non-blank character of the first line:

```
f x y = let z = (x,y)
            in (z,z)
```

The indentation is removed in the output:

```
f x y = let z = (x,y)
          in (z,z)
```

To visualize the structure of a document, one can also put a line containing only blanks and at least three dashes (stars would also work) in the source text:

```
--------------------------------------------------
```

This is formatted as a horizontal line:

B.3 Headers

The are two forms to mark headers. In the first form, one can "underline" the main header in the source text by equal signs and the second-level header by dashes:

```
First-level header
==================

Second-level header
-------------------
```

Alternatively (and for more levels), one can prefix the header line by up to six hash characters, where the number of characters corresponds to the header level (where level 1 is the main header):

```
# Main header

## Level 2 header

### Level 3

#### Level 4

##### Level 5

###### Level 6
```

C   Overview of the PAKCS Distribution

A schematic overview of the various components contained in the distribution of PAKCS and the translation process of programs inside PAKCS is shown in Figure 3 on page 288. In this figure, boxes denote different components of PAKCS and names in boldface denote files containing various intermediate representations during the translation process (see Section D below). The PAKCS distribution contains a front end for reading (parsing and type checking) Curry programs that can be also used by other Curry implementations. The back end (formerly known as "Curry2Prolog") compiles Curry programs into Prolog programs. It also support constraint solvers for arithmetic constraints over real numbers and finite domain constraints, and further libraries for GUI programming, meta-programming etc. Currently, it does not implement encapsulated search in full generality (only a strict version of `findall` is supported), and concurrent threads are not executed in a fair manner.
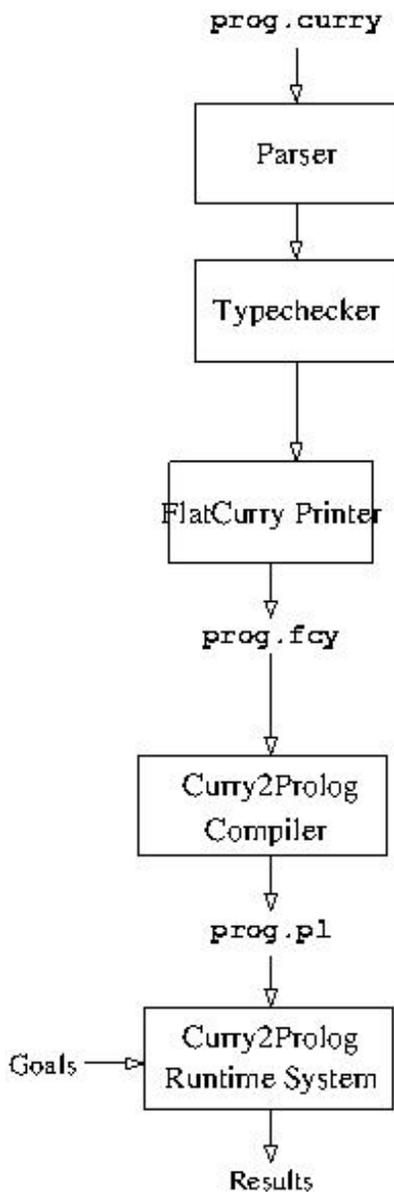
Figure 3: Overview of PAKCS

D   Auxiliary Files

During the translation and execution of a Curry program with PAKCS, various intermediate representations of the source program are created and stored in different files which are shortly explained in this section. If you use PAKCS, it is not necessary to know about these auxiliary files because they are automatically generated and updated. You should only remember the command for deleting all auxiliary files ("`cleancurry`", see Section 1.1) to clean up your directories.

The various components of PAKCS create the following auxiliary files.

`prog.fcy:` This file contains the Curry program in the so-called "FlatCurry" representation where all functions are global (i.e., lambda lifting has been performed) and pattern matching is translated into explicit case/or expressions (compare Appendix A.1.4). This representation might be useful for other back ends and compilers for Curry and is the basis doing meta-programming in Curry. This file is implicitly generated when a program is read by PAKCS. It can be also explicitly generated by the Curry front end

> `cymake --flat -i`*pakcshome*`/lib -i`*pakcshome*`/lib/meta prog`

The FlatCurry representation of a Curry program is usually generated by the front-end after parsing, type checking and eliminating local declarations.

If the Curry module M is stored in the directory dir, the corresponding FlatCurry program is stored in the directory "dir`/.curry`". This is also the case for hierarchical module names: if the module $D1.D2.M$ is stored in the directory dir (i.e., the module is actually stored in $dir/D1/D2/M.curry$), then the corresponding FlatCurry program is stored in "dir`/.curry/D1/D2/M.fcy`".

`prog.fint:` This file contains the interface of the program in the so-called "FlatCurry" representation, i.e., it is similar to `prog.fcy` but contains only exported entities and the bodies of all functions omitted (i.e., "external"). This representation is useful for providing a fast access to module interfaces. It can be also implicitly generated by the Curry front end

> `cymake --flat -i`*pakcshome*`/lib -i`*pakcshome*`/lib/meta prog`

and stored in the same directory as `prog.fcy`.

`prog.pl:` This file contains a Prolog program as the result of translating the Curry program with PAKCS.

If the Curry module M is stored in the directory dir, the corresponding Prolog program is stored in the directory "dir`/.curry/pakcs`". This is also the case for hierarchical module names: if the module $D1.D2.M$ is stored in the directory dir (i.e., the module is actually stored in $dir/D1/D2/M.curry$), then the corresponding Prolog program is stored in "dir`/.curry/pakcs/D1/D2/prog.pl`".

`prog.po:` This file contains the Prolog program `prog.pl` in an intermediate format for faster loading. This file is stored in the same directory as `prog.pl`.

`prog:` This file contains the executable after compiling and saving a program with PAKCS (see Section 2.2).

E   External Functions

Currently, PAKCS has no general interface to external functions. Therefore, if a new external function should be added to the system, this function must be declared as `external` in the Curry source code and then an implementation for this external function must be inserted in the corresponding back end. An external function is defined as follows in the Curry source code:

1. Add a type declaration for the external function somewhere in the body of the appropriate file (usually, the prelude or some system module).

2. For external functions it is not allowed to define any rule since their semantics is determined by an external implementation. Instead of the defining rules, you have to write

   ```
   f external
   ```

   somewhere in the file containing the type declaration for the external function `f`.

For instance, the addition on integers can be declared as an external function as follows:

```
(+) :: Int → Int → Int
(+) external
```

The further modifications to be done for an inclusion of an external function has to be done in the back end. A new external function is added to the back end of PAKCS by informing the compiler about the existence of an external function and adding an implementation of this function in the run-time system. Therefore, the following items must be added in the PAKCS compiler system:

1. If the Curry module `Mod` contains external functions, there must be a file named `Mod.prim_c2p` containing the specification of these external functions. The contents of this file is in XML format and has the following general structure:[13]

   ```
   <primitives>
     specification of external function f₁
     ...
     specification of external function fₙ
   </primitives>
   ```

   The specification of an external function f with arity n has the form

   ```
   <primitive name="f" arity="n">
     <library>lib</library>
     <entry>pred</entry>
   </primitive>
   ```

   where `lib` is the Prolog library (stored in the directory of the Curry module or in the global directory *pakcshome*/`curry2prolog/lib_src`) containing the code implementing this function and `pred` is a predicate name in this library implementing this function. Note that the function f must be declared in module `Mod`: either as an external function or defined in

---

[13] http://www.informatik.uni-kiel.de/~pakcs/primitives.dtd contains a DTD describing the exact structure of these files.

Curry by equations. In the latter case, the Curry definition is not translated but calls to this function are redirected to the Prolog code specified above.

Furthermore, the list of specifications can also contain entries of the form

```
<ignore name="f" arity="n" />
```

for functions f with arity n that are declared in module `Mod` but should be ignored for code generation, e.g., since they are never called w.r.t. to the current implementation of external functions. For instance, this is useful when functions that can be defined in Curry should be (usually more efficiently) are implemented as external functions.

Note that the arguments are passed in their current (possibly unevaluated) form. Thus, if the external function requires the arguments to be evaluated in a particular form, this must be done before calling the external function. For instance, the external function for adding two integers requires that both arguments must be evaluated to non-variable head normal form (which is identical to the ground constructor normal form). Therefore, the function "+" is specified in the prelude by

```
(+)   :: Int  →  Int  →  Int
x + y = (prim_Int_plus $# y) $# x

prim_Int_plus :: Int  →  Int  →  Int
prim_Int_plus external
```

where `prim_Int_plus` is the actual external function implementing the addition on integers. Consequently, the specification file `Prelude.prim_c2p` has an entry of the form

```
<primitive name="prim_Int_plus" arity="2">
  <library>prim_standard</library>
  <entry>prim_Int_plus</entry>
</primitive>
```

where the Prolog library `prim_standard.pl` contains the Prolog code implementing this function.

2. For most external functions, a *standard interface* is generated by the compiler so that an n-ary function can be implemented by an $(n + 1)$-ary predicate where the last argument must be instantiated to the result of evaluating the function. The standard interface can be used if all arguments are ensured to be fully evaluated (e.g., see definition of (+) above) and no suspension control is necessary, i.e., it is ensured that the external function call does not suspend for all arguments. Otherwise, the raw interface (see below) must be used. For instance, the Prolog code implementing `prim_Int_plus` contained in the Prolog library `prim_standard.pl` is as follows (note that the arguments of (+) are passed in reverse order to `prim_Int_plus` in order to ensure a left-to-right evaluation of the original arguments by the calls to (`$#`)):

```
prim_Int_plus(Y,X,R) :- R is X+Y.
```

3. The *standard interface for I/O actions*, i.e., external functions with result type `IO a`, assumes

that the I/O action is implemented as a predicate (with a possible side effect) that instantiates the last argument to the returned value of type "a". For instance, the primitive predicate `prim_getChar` implementing prelude I/O action `getChar` can be implemented by the Prolog code

```
prim_getChar(C) :- get_code(N), char_int(C,N).
```

where `char_int` is a predicate relating the internal Curry representation of a character with its ASCII value.

4. If some arguments passed to the external functions are not fully evaluated or the external function might suspend, the implementation must follow the structure of the PAKCS run-time system by using the *raw interface*. In this case, the name of the external entry must be suffixed by "[raw]" in the `prim_c2p` file. For instance, if we want to use the raw interface for the external function `prim_Int_plus`, the specification file `Prelude.prim_c2p` must have an entry of the form

```
<primitive name="prim_Int_plus" arity="2">
  <library>prim_standard</library>
  <entry>prim_Int_plus[raw]</entry>
</primitive>
```

In the raw interface, the actual implementation of an n-ary external function consists of the definition of an $(n + 3)$-ary predicate *pred*. The first n arguments are the corresponding actual arguments. The $(n + 1)$-th argument is a free variable which must be instantiated to the result of the function call after successful execution. The last two arguments control the suspension behavior of the function (see [5] for more details): The code for the predicate *pred* should only be executed when the $(n + 2)$-th argument is not free, i.e., this predicate has always the SICStus-Prolog block declaration

```
?- block pred(?,...,?,-,?).
```

In addition, typical external functions should suspend until the actual arguments are instantiated. This can be ensured by a call to `ensureNotFree` or (`$#`) before calling the external function. Finally, the last argument (which is a free variable at call time) must be unified with the $(n + 2)$-th argument after the function call is successfully evaluated (and does not suspend). Additionally, the actual (evaluated) arguments must be dereferenced before they are accessed. Thus, an implementation of the external function for adding integers is as follows in the raw interface:

```
?- block prim_Int_plus(?,?,?,-,?).
prim_Int_plus(RY,RX,Result,E0,E) :-
     deref(RX,X), deref(RY,Y), Result is X+Y, E0=E.
```

Here, `deref` is a predefined predicate for dereferencing the actual argument into a constant (and `derefAll` for dereferencing complex structures).

The Prolog code implementing the external functions must be accessible to the run-time system of PAKCS by putting it into the directory containing the corresponding Curry module or into the

system directory *pakcshome*/curry2prolog/lib_src. Then it will be automatically loaded into the run-time environment of each compiled Curry program.

Note that arbitrary functions implemented in C or Java can be connected to PAKCS by using the corresponding interfaces of the underlying Prolog system.

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