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## 1 Module Ast\_util : util over untyped AST (for comprehensions)

```
val setcomp_bindings : (Name.t -> bool) -> Ast.exp -> Set.Make(Name).t
```

Infer the comprehension variables for a set comprehension without explicitly listed comprehension variables. The first argument should return true for variables that are currently bound in the enclosing environment (such variables cannot become comprehension variables)

```
val get_imported_modules : Ast.defs * Ast.lex_skips -> (Path.t * Ast.l) list
```

`get_imported_modules ast` returns a list of the modules imported by the given definitions. These are modules that are explicitly imported via an `import` statement. The resulting list may contain duplicates and is not sorted in any way.

## 2 Module Backend : generate code for various backends

```
val gen_extra_level : int Pervasives.ref
```

The level of extra information to generate

```
module Make :
```

```
  functor (C : sig
```

```
    val avoid : Typed_ast.var_avoid_f
```

```
    val env : Typed_ast.env
```

```
    val dir : string
```

the directory the output will be stored. This is important for setting relative paths to import other modules

```
  end ) -> sig
```

```
    val ident_defs : Typed_ast.def list * Ast.lex_skips -> Ulib.Text.t
```

```
    val lem_defs : Typed_ast.def list * Ast.lex_skips -> Ulib.Text.t
```

```
    val hol_defs :
```

```
      Typed_ast.def list * Ast.lex_skips -> Ulib.Text.t * Ulib.Text.t option
```

```
    val ocaml_defs :
```

```
      Typed_ast.def list * Ast.lex_skips -> Ulib.Text.t * Ulib.Text.t option
```

```
    val isa_defs :
```

```
      Typed_ast.def list * Ast.lex_skips -> Ulib.Text.t * Ulib.Text.t option
```

```
    val isa_header_defs : Typed_ast.def list * Ast.lex_skips -> Ulib.Text.t
```

```
    val coq_defs :
```

```
      Typed_ast.def list * Ast.lex_skips -> Ulib.Text.t * Ulib.Text.t
```

```
    val tex_defs : Typed_ast.def list * Ast.lex_skips -> Ulib.Text.t
```

```
    val tex_inc_defs :
```

```
      Typed_ast.def list * Ast.lex_skips -> Ulib.Text.t * Ulib.Text.t
```

```
    val html_defs : Typed_ast.def list * Ast.lex_skips -> Ulib.Text.t
```

```
    val ident_exp : Typed_ast.exp -> Ulib.Text.t
```

```
    val ident_pat : Typed_ast.pat -> Ulib.Text.t
```

```
    val ident_src_t : Types.src_t -> Ulib.Text.t
```

```
    val ident_typ : Types.t -> Ulib.Text.t
```

```
    val ident_def : Typed_ast.def -> Ulib.Text.t
```

end

The various backends that generate text from typed asts

### 3 Module Backend\_common : Functions used by multiple backends

```
val def_add_location_comment_flag : bool Pervasives.ref
    def_add_location_comment_flag controls whether def_add_location_comment.

val def_add_location_comment : Typed_ast.def -> Output.t * Typed_ast.def_aux
    If def_add_location_comment_flag is set, def_add_location_comment d adds a comment
    with location information before definition d. This may require changing the initial
    whitespace before the definition. Therefore, the def_aux of d with changed whitespace as
    well as the output that should be added before d is returned.

val inline_exp_macro :
    Target.non_ident_target ->
    Typed_ast.env ->
    Macro_expander.macro_context -> Typed_ast.exp -> Typed_ast.exp option
    inline_exp_macro target env does the inlining of target specific constant definitions

val inline_pat_macro :
    Target.non_ident_target ->
    Typed_ast.env -> 'a -> 'b -> Typed_ast.pat -> Typed_ast.pat option
    inline_pat_macro target env does the inlining of target specific constant definitions

val component_to_output : Ast.component -> Output.t
    component_to_output c formats component c as an output

val get_module_name :
    Typed_ast.env -> Target.target -> Name.t list -> Name.t -> Name.t
    get_module_name env targ mod_path mod_name looks up the name of module
    mod_path.mod_name in environment env for target targ.

val get_module_open_string :
    Typed_ast.env -> Target.target -> string -> Path.t -> string
    get_module_open_string l env targ dir mod_path looks up how to represent this
    module in import / open statements.

val get_imported_target_modules :
    Typed_ast.def list * Ast.lex_skips -> Typed_ast.imported_modules list
```

`get_imported_target_modules env targ defs` extracts a list of module that should be imported. The exact names of these modules depend on the environment and the target. Therefore, they get extracted in an abstract form and converted (after possible changes to the environment) by `imported_modules_to_strings`.

```
val imported_modules_to_strings :
  Typed_ast.env ->
  Target.target -> string -> Typed_ast.imported_modules list -> string list
  imported_modules_to_strings env targ dir imported_mods is used together with
  get_imported_target_modules. Please see there.
```

module Make :

```
  functor (A : sig

    val env : Typed_ast.env
    val target : Target.target
    val dir : string
    val id_format_args :
      (bool -> Output.id_annot -> Ulib.Text.t -> Output.t) * Ulib.Text.t

  end) -> sig

  val open_to_open_target :
    Path.t Types.id list -> (Typed_ast.lskips * string) list * Typed_ast.lskips
  val function_application_to_output :
    Ast.l ->
    (Typed_ast.exp -> Output.t) ->
    bool ->
    Typed_ast.exp ->
    Types.const_descr_ref Types.id -> Typed_ast.exp list -> bool -> Output.t list

    function_application_to_output l exp inf full_exp c_id args tries to format a
    function application as output. It gets an expression full_ex of the form c arg1 ...
    argn. The id c_id corresponds to constant c. The arguments arg1, ... argn are
    handed over as args. The description corresponding to c is looked up in A.env.
    Depending on this description and the backend-specific formats therein, the function
    and its arguments are formatted as output. In the simplest case the representation is an
    identifier (Ident.t), which is formatted using A.id_format_args and the information,
    whether it the whole expression is an infix one inf. In more complicated cases,
    forming of expressions is needed, which is done via the callback exp. In particular if
    some arguments are not needed by the forming of the function application, the
    function exp is called on these remaining arguments. The original expression full_exp
    is needed, if not enough parameters are present to format the definition correctly. In
    this case, eta-expansion is applied and the resulting expression formatting via exp.
    ascii_alternative denotes whether an ascii alternative representation for this
    function name is required.
```

```

val pattern_application_to_output :
  Ast.l ->
  (Typed_ast.pat -> Output.t) ->
  Types.const_descr_ref Types.id -> Typed_ast.pat list -> bool -> Output.t list

  pattern_application_to_output l pat c_id args tries to format a function
  application in a pattern as output. It does otherwise the same as
  function_application_to_output. However, since there are no infix patterns, the
  parameter inf is always set to false.

val const_id_to_ident : Types.const_descr_ref Types.id -> bool -> Ident.t

  const_id_to_ident c_id use_ascii tries to format a constant, constructor or field
  c_id as an identifier for target A.target using the rules stored in environment A.env.
  If the flag use_ascii is set, the ascii representation of the constant should be used, if
  there is one. Depending on the formatting rules for the constant, const_id_to_ident
  might raise an exception.

val const_ref_to_name :
  Name.lskips_t -> bool -> Types.const_descr_ref -> Name.lskips_t

  const_ref_to_name n use_ascii c tries to format a constant c for target A.target
  using the rules stored in environment A.env. If use_ascii is set, the
  ascii-representation is returned. const_ref_to_name always returns a name n'. If
  special formatting rules are installed, this name might not be the one used by
  function_application_to_output, though. The argument n is the name used in the
  original input. It's whitespace is used to format n'.

val type_path_to_name : Name.lskips_t -> Path.t -> Name.lskips_t

  type_path_to_name n p tries to format a type-path p for target A.target using the
  rules stored in environment A.env. It always returns a name n'. If special formatting
  rules are installed, this name might not be the one used by
  function_application_to_output, though. The argument n is the name used in the
  original input. It's whitespace is used to format n'.

val type_id_to_ident : Path.t Types.id -> Ident.t

  type_id_to_ident ty_id tries to format a type ty_id as an identifier for target
  A.target using the rules stored in environment A.env.

val type_id_to_output : Path.t Types.id -> Output.t

  type_id_to_output ty_id tries to format a type ty_id as an identifier for target
  A.target using the rules stored in environment A.env.

val type_id_to_ident_no_modify : Path.t Types.id -> Ident.t

```

`type_id_to_ident_no_modify ty_id` formats `ty_id` as an identifier. In contrast to `type_id_to_ident` neither the target `A.target` nor the rules stored in environment `A.env` are used. Instead the type is translated without any modifications. This method is intended to be used for backend types, which are already formatted.

```
val type_app_to_output :
  (Types.src_t -> Output.t) ->
  Path.t Types.id -> Types.src_t list -> Types.src_t list * Output.t
val module_id_to_ident : Path.t Types.id -> Ident.t

  module_id_to_ident m_id tries to format a module m_id as an identifier for target
  A.target using the rules stored in environment A.env.

end
```

## 4 Module Coq\_decidable\_equality

```
val generate_coq_decidable_equality :
  'a list -> Typed_ast.name_l -> Typed_ast.texp -> Output.t
```

## 5 Module Def\_trans : Infrastructure form definition macros

### 5.1 Infrastructure form definition macros

```
type def_macro = Name.t list ->
  Typed_ast.env -> Typed_ast.def -> (Typed_ast.env * Typed_ast.def list) option
```

`def_macro` is the type of definition macros. A definition macro `def_mac` gets the arguments `rev_path`, `env` and `d`. The argument `d` is the definition the macro should process. `rev_path` represents the path of the module of definition `d` as a list of names in reverse order. `env` is the local environment for the module of `d`. This means that also the definitions in the same module that follow `d` are present. If the macro does not modify the definition, it should return `None`. Otherwise, it should return a pair `Some (env', ds)`, where `env'` is a updated environment and `ds` a list of definitions that replace `d`.

```
val list_to_mac : def_macro list -> def_macro
```

`list_to_mac macro_list` collapses a list of `def_macros` into a single one. It looks for the first macro in the list that succeeds, i.e. returns not `None` and returns the result of this macro.

```
val process_defs :
  Name.t list ->
  def_macro ->
  Name.t ->
  Typed_ast.env -> Typed_ast.def list -> Typed_ast.env * Typed_ast.def list
```



`process_defs rev_path def_mac mod_name env ds` is intended to run the macro `def_mac` over all definitions in module `mod_name`. The argument `rev_path` is the path to module `mod_name` in reversed order. `env` is the environment containing module `mod_name` and `ds` is the list of definitions in this module. If `def_mac` modifies a definition `d` to a list `ds`, it is then run on all definitions in `ds`. If one of the is a module-definition, which is not modified by `ds`, then `def_macro` is run on all definitions inside this module. For this recursive call the path, module name and environment are adapted.

The result of `process_defs` is an updated environment and a new list of definitions.

## 5.2 Dictionary passing

`val class_to_record : Target.target -> def_macro`

Type classes are not supported by all backends. The `def_macro class_to_record` takes a definition of a type class and turns it into a definition of a record type. The methods of the class become field of the record. This record can then be used as the dictionary type for the dictionary passing.

`val comment_out_inline_instances_and_classes : Target.target -> def_macro`

Removes inline instances for backends that employ typeclasses.

`val instance_to_dict : bool -> Target.target -> def_macro`

`instance_to_dict do_inline targ` turns instance declarations into a definition of a dictionary record. If `do_inline` is set, this definition will be inlined (for this the target argument is needed).

`val class_constraint_to_parameter : Target.target -> def_macro`

## 5.3 Open / Include / Import

`val remove_opens : def_macro`

`remove_opens` removes all open / include and import statements

`val remove_import_include : def_macro`

`remove_import_include` removes all import and include statements. Imports are deleted and includes turned into open statements.

`val remove_import : def_macro`

`remove_import` removes all import statements.

`val remove_module_renames : def_macro`

`remove_module_renames` removes all module rename statements.

## 5.4 Misc

```
val remove_types_with_target_rep : Target.target -> def_macro
```

If a target representation for a type is given, the original type definition is commented out.  
Notice that target-specific renamings are not target representations.

```
val defs_with_target_rep_to_lemma :  
  Typed_ast.env -> Target.target -> def_macro
```

If a target representation for a constant is given, the original definition is not needed.  
However, turn this definition into a lemma to ensure that the target representation is sensible.

```
val remove_vals : def_macro  
val remove_indrelns : def_macro  
val remove_indrelns_true_lhs : def_macro  
val remove_classes : def_macro  
val type_annotate_definitions : def_macro  
val nvar_to_parameter : def_macro  
val prune_target_bindings :  
  Target.non_ident_target -> Typed_ast.def list -> Typed_ast.def list
```

## 6 Module Finite\_map : finite map library

```
module type Fmap =  
  sig  
    type k  
    module S :  
      Set.S with type elt = k  
      type 'a t  
      val empty : 'a t  
      val is_empty : 'a t -> bool  
      val from_list : (k * 'a) list -> 'a t  
      val from_list2 : k list -> 'a list -> 'a t  
      val insert : 'a t -> k * 'a -> 'a t  
      val union : 'a t -> 'a t -> 'a t  
      val big_union : 'a t list -> 'a t  
      val merge :  
        (k -> 'a option -> 'b option -> 'c option) ->  
        'a t -> 'b t -> 'c t  
      val apply : 'a t -> k -> 'a option
```

```

val in_dom : k -> 'a t -> bool
val map : (k -> 'a -> 'b) ->
  'a t -> 'b t
val domains_overlap : 'a t -> 'b t -> k option
val domains_disjoint : 'a t list -> bool
val iter : (k -> 'a -> unit) -> 'a t -> unit
val fold : ('a -> k -> 'b -> 'a) -> 'a -> 'b t -> 'a
val filter : (k -> 'a -> bool) ->
  'a t -> 'a t
val remove : 'a t -> k -> 'a t
val pp_map :
  (Format.formatter -> k -> unit) ->
  (Format.formatter -> 'a -> unit) ->
  Format.formatter -> 'a t -> unit
val domain : 'a t -> S.t
end

module Fmap_map :
  functor (Key : Set.OrderedType) -> sig

    type k = Key.t
    module S :
      Set.Make(Key)
      type 'a t = 'a M.t
      val empty : 'a M.t
      val is_empty : 'a M.t -> bool
      val from_list : (M.key * 'a) list -> 'a M.t
      val from_list2 : M.key list -> 'a list -> 'a M.t
      val insert : 'a M.t ->
        M.key * 'a -> 'a M.t
      val union : 'a M.t ->
        'a M.t -> 'a M.t
      val merge :
        (M.key -> 'a option -> 'b option -> 'c option) ->
        'a M.t ->
        'b M.t -> 'c M.t
      val apply : 'a M.t -> M.key -> 'a option
      val in_dom : M.key -> 'a M.t -> bool
      val map : (M.key -> 'a -> 'b) ->
        'a M.t -> 'b M.t
      val domains_overlap : 'a M.t ->

```

```

    'b M.t -> M.key option
val iter : (M.key -> 'a -> unit) ->
    'a M.t -> unit
val fold : ('a -> M.key -> 'b -> 'a) ->
    'a -> 'b M.t -> 'a
val filter : (M.key -> 'a -> bool) ->
    'a M.t -> 'a M.t
val remove : 'a M.t ->
    M.key -> 'a M.t
val pp_map :
    (Format.formatter -> M.key -> unit) ->
    (Format.formatter -> 'a -> unit) ->
    Format.formatter -> 'a M.t -> unit
val big_union : 'a M.t list -> 'a M.t
val domains_disjoint : 'a M.t list -> bool
val domain : 'a M.t -> S.t
end

module type Dmap =
sig
    type k
    type 'a t
    val empty : 'a t
    val set_default : 'a t -> 'a option -> 'a t
    val insert : 'a t -> k * 'a -> 'a t
    val insert_opt : 'a t -> k option * 'a -> 'a t
    val apply : 'a t -> k -> 'a option
    val apply_opt : 'a t -> k option -> 'a option
    val remove : 'a t -> k -> 'a t
    val in_dom : k -> 'a t -> bool
end

module Dmap_map :
functor (Key : Set.OrderedType) -> sig
    type k = Key.t
    type 'a t = 'a M.t * S.t * 'a option
    val empty : 'a M.t * S.t * 'b option
    val set_default : 'a * 'b * 'c -> 'd -> 'a * 'b * 'd
    val apply : 'a M.t * S.t * 'a option ->
        M.key -> 'a option

```

```

val apply_opt : 'a M.t * S.t * 'a option ->
  M.key option -> 'a option
val in_dom : M.key ->
  'a M.t * S.t * 'b option -> bool
val insert : 'a M.t * S.t * 'b ->
  M.key * 'a ->
  'a M.t * S.t * 'b
val insert_opt :
  'a M.t * S.t * 'a option ->
  M.key option * 'a ->
  'a M.t * S.t * 'a option
val remove : 'a M.t * S.t * 'b ->
  M.key ->
  'a M.t * S.t * 'b
end

```

## 7 Module Ident : source-file long identifiers

```

type t
  t is the type of dot separated lists of names (with preceding lexical spacing), e.g. (*Foo*) M
  . x

val pp : Format.formatter -> t -> unit
  Pretty print

val to_string : t -> string
  to_string i formats i using pp.

val from_id : Ast.id -> t
val from_name : Name.lskips_t -> t
val get_name : t -> Name.lskips_t
  Return the last name in the ident, e.g., M.Y.x gives x

val mk_ident : Ast.lex_skips -> Name.t list -> Name.t -> t
  mk_ident sk ms n creates an identifier n with module prefix ms and leading whitespace sk.

val mk_ident_ast :
  (Name.lskips_t * Ast.lex_skips) list -> Name.lskips_t -> Ast.l -> t
  mk_ident_ast nsl ns l generates a new identifiers during type-checking. Whitespace is
  prohibited in all Name.lskips_t except the very first one and all Ast.lex_skips has to be
  empty. Otherwise, this operation may fail and uses the location l for the error message.

```

```

val mk_ident_strings : string list -> string -> t
    mk_ident_strings is a version of mk_ident that uses strings as input and uses empty
    whitespace.

val to_output_format :
    (Output.id_annot -> Ulib.Text.t -> Output.t) ->
    Output.id_annot -> Ulib.Text.t -> t -> Output.t
val to_output : Output.id_annot -> Ulib.Text.t -> t -> Output.t
val get_lskip : t -> Ast.lex_skips
val replace_lskip : t -> Ast.lex_skips -> t
val to_name_list : t -> Name.t list * Name.t
val has_empty_path_prefix : t -> bool
    has_empty_path_prefix i check whether the identifier i consists of just a single name
    without any prefix describing its module path

val strip_path : Name.t -> t -> t
    Remove the name from the identifier if it occurs at the first

val rename : t -> Name.t -> t
    rename i n' renames the last name component of identifier i to n'.

val drop_path : t -> t
    drop_path i drops the path of an identifier. This means an identifier of the form
    M1.M2...Mn.name is converted to name. White-space is preserved.

```

## 8 Module Initial\_env : The initial environment.

It is empty except bindings for predefined things like `bool`

```

val initial_env : Typed_ast.env
val read_target_constants : string -> Target.target -> Typed_ast.NameSet.t
    read_target_constants lib_path target reads the list of constants that should be avoided
    for target target. These constants are read from a file lib_path/{target}_constants. If
    this file does not exist, the empty set is returned.

```

## 9 Module Macro\_expander

```

type level =
| Top_level
| Nested

```

```

type pat_pos =
  | Bind
  | Param

type macro_context =
  | Ctxt_theorem
  | Ctxt_other

type pat_position = level * pat_pos

module Expander :
  functor (C : Typed_ast.Exp_context) -> sig

    val expand_defs :
      Typed_ast.def list ->
      (Macro_expander.macro_context -> Typed_ast.exp -> Typed_ast.exp option) *
      (Types.t -> Types.t) * (Types.src_t -> Types.src_t) *
      (Macro_expander.pat_position ->
        Macro_expander.macro_context -> Typed_ast.pat -> Typed_ast.pat option) ->
      Typed_ast.def list

    val expand_pat :
      Macro_expander.macro_context ->
      Macro_expander.pat_position ->
      Typed_ast.pat ->
      (Types.t -> Types.t) * (Types.src_t -> Types.src_t) *
      (Macro_expander.pat_position ->
        Macro_expander.macro_context -> Typed_ast.pat -> Typed_ast.pat option) ->
      Typed_ast.pat

    val expand_exp :
      Macro_expander.macro_context ->
      (Macro_expander.macro_context -> Typed_ast.exp -> Typed_ast.exp option) *
      (Types.t -> Types.t) * (Types.src_t -> Types.src_t) *
      (Macro_expander.pat_position ->
        Macro_expander.macro_context -> Typed_ast.pat -> Typed_ast.pat option) ->
      Typed_ast.exp -> Typed_ast.exp

  end

  val list_to_mac :
    (macro_context -> 'a -> 'b option) list ->
    macro_context -> 'a -> 'b option

  val list_to_bool_mac :
    (pat_position ->
      macro_context -> 'a -> 'b option)
    list ->
    pat_position ->
    macro_context -> 'a -> 'b option

```

## 10 Module Main

## 11 Module `Module_dependencies` : module dependency resolution

```
val process_files :  
  bool ->  
  string list ->  
  (string * bool) list ->  
  (string * string * (Ast.defs * Ast.lex_skips) * bool) list
```

`process_files allow_reorder lib_dirs files` parses the files in list `files`. It checks for `import` statements and tries to automatically load the needed files for those as well. Therefore, files are searched in the directories `lib_dirs`. If `allow_reorder` is set, it may also reorder the order of file in `files` to satisfy dependencies.

The result is a list of tuples `(module_name, filename, ast, needs_output)`. The flag `needs_output` states, whether an output file should be produced. It is set to false for all automatically imported modules. Since one might to also want to add library modules manually, the input `files` is a list of file names and need-output flags as well.

## 12 Module Name : source-file and internal short identifiers

### 12.1 plain names

```
type t
```

`t` is the type of plain names, names are essentially strings

```
val compare : t -> t -> int
```

#### 12.1.1 basic functions on plain names

```
val pp : Format.formatter -> t -> unit  
val from_string : string -> t  
val to_string : t -> string  
val from_rope : Ulib.Text.t -> t  
val to_rope : t -> Ulib.Text.t
```

#### 12.1.2 modifying names

```
val rename : (Ulib.Text.t -> Ulib.Text.t) -> t -> t
```



`rename r_fun n` renames `n` using the function `r_fun`. It looks at the text representation `n_text` of `n` and returns then the name corresponding to `r_fun n_text`.

`val starts_with_upper_letter : t -> bool`

`start_with_upper_letter n` checks, whether the name `n` starts with a character in the range A-Z.

`val uncapitalize : t -> t option`

`uncapitalize n` tries to uncapitalize the first letter of `n`. If `n` does not start with a uppercase character, `None` is returned, otherwise the modified name.

`val starts_with_lower_letter : t -> bool`

`start_with_lower_letter n` checks, whether the name `n` starts with a character in the range a-z.

`val capitalize : t -> t option`

`capitalize n` tries to capitalize the first letter of `n`. If `n` does not start with a lowercase character, `None` is returned, otherwise the modified name.

`val starts_with_underscore : t -> bool`

`start_with_underscore n` checks, whether the name `n` starts with an underscore character.

`val remove_underscore : t -> t option`

`remove_underscore n` tries to remove a leading underscore from name `n`. If `n` does not start with an underscore character, `None` is returned, otherwise the modified name.

### 12.1.3 generating fresh names

`val fresh : Ulib.Text.t -> (t -> bool) -> t`

`fresh n OK` generates a name `m`, such that `OK m` holds. `m` is of the form `n` followed by an integer postfix. First `n` without postfix is tried. Then counting up from 0 starts, till `OK` is satisfied.

`val fresh_num_list : int -> Ulib.Text.t -> (t -> bool) -> t list`

`fresh_num_list i n OK` generates a list of `i` fresh names. If no conflicts occur it returns a list of the form `[ni, n(i-1), ..., n1]`. Internally, `fresh n OK` is used `n` times. However, `OK` is updated to ensure, that the elements of the resulting list not only satisfy `OK`, but are also distinct from each other.

`val fresh_list : (t -> bool) -> t list -> t list`

`fresh_list OK ns` builds variants of the names in list `ns` such that all elements of the resulting list `ns'` satisfy `OK` and are distinct to each other.

## 12.2 names with whitespace and type

`type lskips_t`

`lskip` is the type of names with immediately preceding skips, i.e. whitespace or comments

`val lskip_pp : Format.formatter -> lskips_t -> unit`

`val from_x : Ast.x_l -> lskips_t`

creates a name from `Ast.x_l`, used during typechecking

`val from_ix : Ast.ix_l -> lskips_t`

creates a name from `Ast.ix_l`, used during typechecking

`val add_lskip : t -> lskips_t`

`add_lskip` converts a name into a name with skips by adding empty whitespace

`val strip_lskip : lskips_t -> t`

`strip_lskip` converts a name with whitespace into a name by dropping the preceding whitespace

`val get_lskip : lskips_t -> Ast.lex_skips`

`get_lskip n` gets the preceding whitespace of `n`

`val add_pre_lskip : Ast.lex_skips -> lskips_t -> lskips_t`

`add_pre_lskip sk n` adds additional whitespace in front of `n`

`val replace_lskip : lskips_t -> Ast.lex_skips -> lskips_t`

`replace_lskip sk n` replaces the whitespace in front of `n` with `sk`. The old whitespace is thrown away.

`val lskip_rename : (Ulib.Text.t -> Ulib.Text.t) -> lskips_t -> lskips_t`

`lskip_rename r_fun n` is a version of `rename` that can handle `lskip`s. It renames `n` using the function `r_fun` and preserves the original whitespace.

## 12.3 output functions

`val to_output_format :`

`(Output.id_annot -> Ulib.Text.t -> Output.t) ->`

`Output.id_annot -> lskips_t -> Output.t`

`to_output_format format_fun id_annot n` formats the name `n` as output. A name with output consists of preceding whitespace, the name as a text and a name-type. The space is formatted using `ws`, the other components together with `id_annot` are formatted with `format_fun`.

`val to_output : Output.id_annot -> lskips_t -> Output.t`

```

    to_output is the same as to_output_format Output.id

val to_output_quoted :
  string -> string -> Output.id_annot -> lskips_t -> Output.t
  to_output_quoted qs_begin qs_end id_annot n formats n with the quoting strings
  qs_begin and qs_end added before and after respectively.

val to_rope_tex : Output.id_annot -> t -> Ulib.Text.t
  to_rope_tex a n formats n as a for the tex-backend as a string. The preceeding whitespace
  is ignored.

```

## 13 Module Nvar

```

type t
val compare : t -> t -> int
val pp : Format.formatter -> t -> unit
val nth : int -> t
val from_rope : Ulib.Text.t -> t
val to_rope : t -> Ulib.Text.t

```

## 14 Module Output : Intermediate output format before going to strings

```

type t
type t' =
  | Kwd' of string
  | Ident' of Ulib.Text.t
  | Num' of int
type id_annot =
  | Term_const of bool * bool
    Term_const(is_quotation, needs_escaping)
  | Term_field
  | Term_method
  | Term_var
  | Term_var_toplevel
  | Term_spec
  | Type_ctor of bool * bool
    Term_ctor(is_quotation, needs_escaping)

```

- | Type\_var
- | Nexpr\_var
- | Module\_name
- | Class\_name
- | Target
- | Component

kind annotation for latex'd identifiers

## 14.1 constructing output

```
val emp : t
    Empty output

val kwd : string -> t
    kwd s constructs the output for keyword s

val num : int -> t
    num i constructs the output for number i

val str : Ulib.Text.t -> t
    str s constructs the output for string constant s

val ws : Ast.lex_skips -> t
    Whitespace

val err : string -> t
    err message is an error output. An exception is thrown with the given message if this
    output is created. Used for marking problems.

val meta : string -> t
    meta s creates a string directly as output such that the formatting can't interfere with
    string s any more

val comment : string -> t
    A comment

val comment_block : int option -> string list -> t
    comment_block min_width_opt content comment a whole list of lines in a block.

val new_line : t
    a new line

val space : t
    a single space
```

```

val texspace : t
    ??? Unsure what it is. Some kind of tex specific space, similar to space, but treated slightly
    differently by the Latex backend. It seems to be for example removed at beginnings and
    ends of lines and multiple ones are collapsed into a single space.

val id : id_annot -> Ulib.Text.t -> t
    An identifier

val (^) : t -> t -> t
    o1 ^o2 appends to outputs to each other

val flat : t list -> t
    flat [o0; ...; on] appends all the outputs in the list, i.e. it does o0 ^... ^on.

val concat : t -> t list -> t
    concat sep [o0; ...; on] appends all the outputs in the list using the separator sep, i.e.
    it does o0 ^sep ^o1 ^... ^sep ^on.

val prefix_if_not_emp : t -> t -> t
    prefix_if_not_emp o1 o2 returns o1 ^o2 if o2 is not empty and emp otherwise

```

## 14.2 Pretty Printing

### 14.2.1 Blocks

Blocks are used for pretty printing if the original whitespace should not be used. This is usually the case, if the source was generated by some macro, such that either no original spacing is present or it is likely to be broken. If the first argument of a block is **true** this block and all it's content is printed using OCaml's **Format** library. The other arguments of blocks correspond to blocks in the **Format** library. They describe indentation, the type of block and the content.

```

val block : bool -> int -> t -> t
val block_h : bool -> int -> t -> t
val block_v : bool -> int -> t -> t
val block_hv : bool -> int -> t -> t
val block_hov : bool -> int -> t -> t
val core : t -> t
    core out is a marker for marking the most important part of some output. It marks for
    example the rhs of a definition. Together with extract_core this is used to sometimes only
    print the most essential part of some output

val remove_core : t -> t
    remove_core o removes all occurrences of core from t by replacing core o' with just o'.

val extract_core : t -> t list
    extract_core o extracts all top-level cores from output o.

```

### 14.2.2 Spacing

```
val remove_initial_ws : t -> t
    removes initial whitespace (including comments) from output

val break_hint : bool -> int -> t
    break_hint add_space ind is a general hint for a line-break. If add_space is set a space is
    added in case no line-break is needed. Otherwise a line-break with the given indentation ind
    is applied.

val break_hint_cut : t
    break_hint_cut is short for break_hint false 0. It allows a newline at this position
    without indentation. If no newline is needed don't add any space.

val break_hint_space : int -> t
    break_hint_space ind is short for break_hint true ind. It adds a space or a newline. If
    a newline is needed use the given indentation.

val ensure_newline : t
    Make sure there is a newline starting here. This inserts a newline if necessary.
```

## 14.3 Output to Rope

```
val to_rope :
    Ulib.Text.t ->
    (Ast.lex_skip -> Ulib.Text.t) ->
    (t' -> t' -> bool) -> t -> Ulib.Text.t
    to_rope quote_char lex_skips_to_rope need_space t formats the output t as an
    unicode text. The quote_char argument is used around strings. The function
    lex_skips_to_rope is used to format whitespace. Finally the function need_space is used
    to determine, whether an extra space is needed between simplified outputs.

val ml_comment_to_rope : Ast.ml_comment -> Ulib.Text.t
    ml_comment_to_rope com formats an ML-comment as a text by putting (* and *) around it.
```

## 14.4 Latex Output

```
val to_rope_tex : t -> Ulib.Text.t
    to_rope_tex t corresponds to to_rope for the Latex backend. Since it is used for only one
    backend, the backend parameters of to_rope can be hard-coded.

val to_rope_option_tex : t -> Ulib.Text.t option
    to_rope_option_tex t is similar to to_rope_tex t. However, it checks whether the result
    is an empty text and returns None in this case.
```

```

val tex_escape : Ulib.Text.t -> Ulib.Text.t
val tex_command_escape : Ulib.Text.t -> Ulib.Text.t
val tex_command_label : Ulib.Text.t -> Ulib.Text.t
val tex_command_name : Ulib.Text.t -> Ulib.Text.t

```

## 15 Module Path : internal canonical long identifiers

```

type t
val compare : t -> t -> int
val pp : Format.formatter -> t -> unit
val from_id : Ident.t -> t
val mk_path : Name.t list -> Name.t -> t
val mk_path_list : Name.t list -> t
    mk_path_list names splits names into ns @ [n] and calls mk_path ns n. It fails, if names
    is empty.

val get_module_path : t -> t option
    get_module_path p returns the module path of path p. If it is a path of an identifier m0.
    ... . mn . f, then get_module returns the module path m0. ... . mn. If the path
    does not have a module prefix, i.e. if it is a single name f, None is returned.

val natpath : t
val listpath : t
val vectorpath : t
val boolpath : t
val bitpath : t
val setpath : t
val stringpath : t
val unitpath : t
val charpath : t
val numeralpath : t
val get_name : t -> Name.t
val get_toplevel_name : t -> Name.t
    get_toplevel_name p gets the outmost name of a path. This is important when checking
    prefixes. For example, the result for path module.submodule.name is module and for name it
    is name.

val check_prefix : Name.t -> t -> bool
val to_ident : Ast.lex_skips -> t -> Ident.t

```

```

val to_name : t -> Name.t
val to_name_list : t -> Name.t list * Name.t
val to_string : t -> string

```

## 16 Module Pattern\_syntax : general functions about patterns

general functions about patterns

### 16.1 Destructors and selector functions

```

val is_var_wild_pat : Typed_ast.pat -> bool
    is_var_wild_pat p checks whether the pattern p is a wildcard or a variable pattern. Before
    checking type-annotations, parenthesis, etc. are removed.

val is_var_pat : Typed_ast.pat -> bool
    is_var_pat p checks whether the pattern p is a variable pattern.

val is_ext_var_pat : Typed_ast.pat -> bool
    is_ext_var_pat p checks whether the pattern p is a variable pattern in the broadest sense.
    In contrast to is_var_pat p also variables with type-annotations and parenthesis are
    accepted. is_var_wild_pat p additionally accepts wildcard patterns.

val is_var_tup_pat : Typed_ast.pat -> bool
    is_var_tup_pat p checks whether the pattern p consists only of variable and tuple patterns.

val is_var_wild_tup_pat : Typed_ast.pat -> bool
    is_var_wild_tup_pat p checks whether the pattern p consists only of variable, wildcard
    and tuple patterns.

val dest_var_pat : Typed_ast.pat -> Name.t option
    dest_var_pat p destructs variable patterns and returns their name. If p is not a variable
    pattern, None is returned.

val dest_ext_var_pat : Typed_ast.pat -> Name.t option
    dest_ext_var_pat p is an extended version of dest_var_pat p. In addition to dest_var_pat
    p it can handle variable patterns with type annotations and is able to strip parenthesis.

val pat_to_ext_name : Typed_ast.pat -> Typed_ast.name_lskips_annot option
    pat_to_ext_name p is very similar to dest_ext_var_pat p. However, instead of returning
    just a name, pat_to_ext_name returns additionally the whitespace and the type in form of a
    name_lskips_annot.

val is_wild_pat : Typed_ast.pat -> bool

```



`is_wild_pat p` checks whether the pattern `p` is a wildcard pattern.

`val dest_tup_pat : int option -> Typed_ast.pat -> Typed_ast.pat list option`  
`dest_tup_pat lo p` destructs a tuple pattern. If `p` is no tuple pattern, `None` is returned. Otherwise, it destructs the tuple pattern into a list of patterns `pL`. If `lo` is not `None`, it checks whether the length of this list matches the length given by `lo`. If this is the case `Some pL` is returned, otherwise `None`.

`val mk_tup_pat : Typed_ast.pat list -> Typed_ast.pat`  
`mk_tup_pat [p1, ..., pn]` creates the pattern `(p1, ..., pn)`.

`val is_tup_pat : int option -> Typed_ast.pat -> bool`  
`is_tup_pat lo p` checks whether `p` is a tuple pattern of the given length. see `dest_tup_pat`

`val dest_tf_pat : Typed_ast.pat -> bool option`  
`dest_tf_pat p` destructs boolean literal patterns, i.e. `true` and `false` patterns.

`val is_tf_pat : Typed_ast.pat -> bool`  
`if_tf_pat p` checks whether `p` is the `true` or `false` pattern.

`val is_t_pat : Typed_ast.pat -> bool`  
`if_t_pat p` checks whether `p` is the `true` pattern.

`val is_f_pat : Typed_ast.pat -> bool`  
`if_f_pat p` checks whether `p` is the `false` pattern.

`val mk_tf_pat : bool -> Typed_ast.pat`  
`mk_tf_pat b` creates `true` or `false` pattern.

`val mk_paren_pat : Typed_ast.pat -> Typed_ast.pat`  
`mk_paren_pat p` adds parenthesis around a pattern

`val mk_opt_paren_pat : Typed_ast.pat -> Typed_ast.pat`  
`mk_opt_paren_pat p` adds parenthesis around a pattern, when needed

`val dest_num_pat : Typed_ast.pat -> int option`  
`dest_num_pat p` destructs number literal patterns

`val is_num_pat : Typed_ast.pat -> bool`  
`is_num_pat p` checks whether `p` is a number pattern.

`val mk_num_pat : Types.t -> int -> Typed_ast.pat`  
`mk_num_pat num_ty i` makes a number pattern.

`val dest_num_add_pat : Typed_ast.pat -> (Name.t * int) option`

```

    dest_num_add_pat p destructs number addition literal patterns

val mk_num_add_pat : Types.t -> Name.t -> int -> Typed_ast.pat
    mk_num_add_pat num_ty i makes a number addition pattern.

val is_num_add_pat : Typed_ast.pat -> bool
    is_num_add_pat p checks whether p is a number addition pattern.

val num_ty_pat_cases :
  (Name.t -> 'a) ->
  (int -> 'a) ->
  (Name.t -> int -> 'a) -> 'a -> (Typed_ast.pat -> 'a) -> Typed_ast.pat -> 'a
  num_ty_pat_cases f_v f_i f_a f_w f_else p performs case analysis for patterns of type
  num. Depending of which form the pattern p has, different argument functions are called:

    •  $v \rightarrow f\_v\ v$ 
    •  $c\ (\text{num constant}) \rightarrow f\_i\ i$ 
    •  $v + 0 \rightarrow f\_v\ v$ 
    •  $v + i\ (\text{for } i > 0) \rightarrow f\_a\ v\ i$ 
    •  $\_ \rightarrow f\_w$ 
    •  $p\ (\text{everything else}) \rightarrow f\_else\ p$ 

val dest_string_pat : Typed_ast.pat -> string option
    dest_string_pat p destructs number literal patterns

val is_string_pat : Typed_ast.pat -> bool
    is_string_pat p checks whether p is a number pattern.

val dest_cons_pat : Typed_ast.pat -> (Typed_ast.pat * Typed_ast.pat) option
    dest_cons_pat p destructs list-cons patterns.

val is_cons_pat : Typed_ast.pat -> bool

val dest_list_pat : int option -> Typed_ast.pat -> Typed_ast.pat list option
    dest_list_pat p destructs list patterns.

val is_list_pat : int option -> Typed_ast.pat -> bool

val dest_const_pat :
  Typed_ast.pat ->
  (Typed_ast.const_descr_ref Types.id * Typed_ast.pat list) option
    dest_contr_pat p destructs constructor patterns.

val is_const_pat : Typed_ast.pat -> bool

val dest_record_pat :
  Typed_ast.pat ->
  (Typed_ast.const_descr_ref Types.id * Typed_ast.pat) list option

```

`dest_record_pat p` destructs record patterns.

`val is_record_pat : Typed_ast.pat -> bool`

## 16.2 Classification of Patterns

`val is_constructor :`

`Ast.l -> Typed_ast.env -> Target.target -> Typed_ast.const_descr_ref -> bool`  
`is_constructor l env targ c` checks whether `c` is a constructor for target `targ` in environment `env`. If you want to know whether it is for any target, use the identity target. Internally, it checks whether `type_defs_get_constr_families` returns a non-empty list.

`val is_buildin_constructor :`

`Ast.l -> Typed_ast.env -> Target.target -> Typed_ast.const_descr_ref -> bool`  
`is_buildin_constructor l env targ c` checks whether `c` is a build-in constructor for target `targ` in environment `env`. Build-in constructors are constructors, which the target pattern compilation can handle.

`val is_not_buildin_constructor :`

`Ast.l -> Typed_ast.env -> Target.target -> Typed_ast.const_descr_ref -> bool`  
`is_not_buildin_constructor l env targ c` checks whether `c` is a constructor for target `targ` in environment `env`, but not a build-in one. Not build-in constructors get compiled away during pattern compilation.

`val direct_subpats : Typed_ast.pat -> Typed_ast.pat list`

`direct_subpats p` returns a list of all the direct subpatterns of `p`.

`val subpats : Typed_ast.pat -> Typed_ast.pat list`

`subpats p` returns a list of all the subpatterns of `p`. In contrast to `direct_subpats p` really all subpatterns are returned, not only direct ones. This means that the result of `direct_subpats p` is a subset of `subpats p`.

`val exists_subpat : (Typed_ast.pat -> bool) -> Typed_ast.pat -> bool`

`exists_pat cf p` checks whether `p` has a subpattern `p'` such that `cf p'` holds.

`val for_all_subpat : (Typed_ast.pat -> bool) -> Typed_ast.pat -> bool`

`for_all_subpat cf p` checks whether all subpatterns `p'` of `p` satisfy `cf p'`.

`val single_pat_exhaustive : Typed_ast.pat -> bool`

`single_pat_exhaustive p` checks whether the pattern `p` is exhaustive.

`val pat_vars_src : Typed_ast.pat -> (Name.lskips_t, unit) Types.annot list`

`pat_vars_src p` returns a list of all the variable names occurring in the pattern. The names are annotated with the type and the whitespace information.

### 16.3 miscellaneous

```
val pat_extract_lskips : Typed_ast.pat -> Ast.lex_skips
    pat_extract_lskips p extracts all whitespace from a pattern

val split_var_annot_pat : Typed_ast.pat -> Typed_ast.pat
    split_var_annot_pat p splits annotated variable patterns in variable patterns + type
    annotation. All other patterns are returned unchanged.

exception Pat_to_exp_unsupported of Ast.l * string

val pat_to_exp : Typed_ast.env -> Typed_ast.pat -> Typed_ast.exp
    pat_to_exp env p tries to convert p into a corresponding expression. This might fail, e.g. if
    p contains wildcard patterns. If it fails a pat_to_exp_unsupported exception is raised.
```

## 17 Module Patterns : pattern compilation

pattern compilation

### 17.1 Pattern Compilation

```
type match_props = {
  is_exhaustive : bool ;
  missing_pats : Typed_ast.pat list list ;
  redundant_pats : (int * Typed_ast.pat) list ;
  overlapping_pats : ((int * Typed_ast.pat) * (int * Typed_ast.pat)) list ;
}

val check_match_exp : Typed_ast.env -> Typed_ast.exp -> match_props option
    check_match_exp env e checks the pattern match expression e in environment env. If e is
    not a pattern match, None is returned. Otherwise, a record of type match_props is returned
    that contains information on whether the match is exhaustive, contains redundant parts etc.

val check_pat_list :
  Typed_ast.env -> Typed_ast.pat list -> match_props option
    check_pat_list env pl checks the pattern list pL in environment env. If pL is empty or
    the compilation fails, None is returned. Otherwise, a record of type match_props is returned
    that contains information on whether the match is exhaustive, contains redundant parts etc.

val check_match_exp_warn : Typed_ast.env -> Typed_ast.exp -> unit
    check_match_exp_warn env e internally calls check_match_exp env e. Instead of
    returning the properties of the match expression, it prints appropriate warning messages,
    though.

val check_match_def :
  Typed_ast.env -> Typed_ast.def -> (Name.t * match_props) list
```

`check_match_def env d` checks a definition using pattern matching `d` in environment `env`. Definitions of mutually recursive functions can contain multiple top-level pattern matches. Therefore, a list is returned. This list consists of pairs of the name of the defined function and its properties. If the definition does not have a top-level pattern match, i.e. if it is not a function definition, the empty list is returned.

```
val check_match_def_warn : Typed_ast.env -> Typed_ast.def -> unit
```

`check_match_def_warn env d` checks a definition and prints appropriate warning messages.

```
type match_check_arg
```

```
val cleanup_match_exp :
```

```
Typed_ast.env -> bool -> Typed_ast.exp -> Typed_ast.exp option
```

`cleanup_match_exp env add_missing e` tries to cleanup the match-expression `e` by removing redundant rows. Moreover, missing patterns are added at the end, if the argument `add_missing` is set.

```
val compile_match_exp :
```

```
Target.target ->
```

```
match_check_arg ->
```

```
Typed_ast.env -> Typed_ast.exp -> Typed_ast.exp option
```

`compile_match_exp target_opt pat_OK env e` compiles match-expressions. In contrast to `check_match_exp` only case-expressions are checked. Other types of pattern matches have to be brought into this form first.

If the case-expression `e` contains a pattern `p` such that `pat_OK p` does not hold, the whole case-expression is processed and transformed into an expression with the same semantics that contains only supported patterns. During this compilation, warning messages might be issued. This warning uses `target_opt`. Otherwise, it is not used.

```
val compile_exp :
```

```
Target.target ->
```

```
match_check_arg ->
```

```
Typed_ast.env ->
```

```
Macro_expander.macro_context -> Typed_ast.exp -> Typed_ast.exp option
```

```
val compile_def :
```

```
Target.target ->
```

```
match_check_arg -> Typed_ast.env -> Def_trans.def_macro
```

```
val is_isabelle_pattern_match : match_check_arg
```

```
val is_hol_pattern_match : match_check_arg
```

```
val is_coq_pattern_match : match_check_arg
```

```
val is_ocaml_pattern_match : match_check_arg
```

```
val is_pattern_match_const : bool -> match_check_arg
```

## 17.2 Other pattern functions

```
val check_number_patterns : Typed_ast.env -> Typed_ast.pat -> unit
    checked_number_patterns env p checks that all number patterns which are part of p are of
    type nat or natural.

val remove_function :
    Typed_ast.env ->
    (Typed_ast.exp -> Typed_ast.exp) -> Typed_ast.exp -> Typed_ast.exp option
    remove_function env case_f e replaces the function expression e with with fun x ->
    match x with .... The function case_f is then applied to the new match-expression.

val remove_fun :
    Typed_ast.env ->
    (Typed_ast.exp -> Typed_ast.exp) -> Typed_ast.exp -> Typed_ast.exp option
    remove_fun env case_f e replaces the fun-expression e. If e is of the form fun p0 ...
    pn -> e' such that not all patterns pi are variable patterns, it is replaced with fun x0 ...
    xn -> match (x0, ..., xn) with (p0, ..., pn) -> e'. The function case_f is then
    applied to the new match-expression.

val remove_toplevel_match :
    Target.target ->
    match_check_arg -> Typed_ast.env -> Def_trans.def_macro
    remove_toplevel_match tries to introduce matching directly in the function definition by
    eliminating match-expressions in the body.

val collapse_nested_matches :
    match_check_arg ->
    Typed_ast.env -> Typed_ast.exp -> Typed_ast.exp option
    collapse_nested_matches tries to eliminate nested matches by collapsing them. It is used
    internally by pattern compilation.
```

## 18 Module Pcombinators

```
type 'a parser
val return : 'a -> 'a parser
val (>>=) : 'a parser ->
    ('a -> 'b parser) -> 'b parser
val fail : 'a parser
val eof : unit parser
val predicate : (char -> bool) -> char parser
val (++) : 'a parser -> 'a parser -> 'a parser
```

```

val (+?+) : 'a parser -> 'a parser -> 'a parser
val many : 'a parser -> 'a list parser
val many1 : 'a parser -> 'a list parser
val repeat : int -> 'a parser -> 'a list parser
val sep_by : 'a parser ->
  'b parser -> 'a list parser
val sep_by1 : 'a parser ->
  'b parser -> 'a list parser
val one_of : char list -> char parser
val char_exact : char -> char parser
val string_exact : string -> string parser
val int_exact : int -> string parser
val bool_exact : bool -> string parser
val digit : int parser
val digits : int parser
val whitespace : string parser
val whitespace1 : string parser
type 'a parse_result =
  | Yes of 'a
  | No of string
val parse : string -> 'a parser -> 'a parse_result
val parse_and_print : string -> 'a parser -> ('a -> string) -> unit

```

## 19 Module Pp

```

val pp_str : Format.formatter -> string -> unit
val lst :
  ('a, Format.formatter, unit) Pervasives.format ->
  (Format.formatter -> 'b -> unit) -> Format.formatter -> 'b list -> unit
val opt :
  (Format.formatter -> 'a -> unit) -> Format.formatter -> 'a option -> unit
val pp_to_string : (Format.formatter -> 'a) -> string

```

## 20 Module Precedence : a prefix operation

```

type t =
  | P_prefix
    a prefix operation

```

```

| P_infix of int
    a non-associative infix operation of the given precedence, higher precenced bind
    stronger
| P_infix_left of int
    a left-associative infix operation
| P_infix_right of int
    a right-associative infix operation
| P_special
    an operation with special syntax (e.g. if-then-else)

type context =
| Field
| App_right
| App_left
| Infix_left of t
| Infix_right of t
| Delimited

type exp_kind =
| App
| Infix of t
| Let
| Atomic

type pat_context =
| Plist
| Pas_left
| Pcons_left
| Pcons_right
| Pdelimited

type pat_kind =
| Papp
| Pas
| Padd
| Pcons
| Patomic

val is_infix : t -> bool
val needs_parens : context -> exp_kind -> bool
val pat_needs_parens : pat_context -> pat_kind -> bool
val get_prec :
    Target.target -> Typed_ast.env -> Typed_ast.const_descr_ref -> t
    get_prec target env c looks up the precedence of constant c in environment env for the
    target target. Thereby, it follows target-representations of this constant.

val get_prec_exp : Target.target -> Typed_ast.env -> Typed_ast.exp -> t

```



`get_prec target env e` looks up the precedence of expression `e` in environment `env` for the target `target`. If the expression is essentially a constant (i.e. a constant with perhaps parenthesis or types added), the precedence of this constant is returned using `get_prec`. Otherwise `P_prefix` is returned.

## 21 Module `Process_file` : The full environment built after all type-checking, and transforming

```
val parse_file : string -> Ast.defs * Ast.lex_skips
type instances = Types.instance list Types.Pfmap.t
val output :
  Typed_ast.env ->
  Typed_ast.var_avoid_f ->
  Target.target -> string option -> Typed_ast.checked_module list -> unit
val output_alltexdoc :
  Typed_ast.env ->
  Typed_ast.var_avoid_f ->
  string -> string -> Typed_ast.checked_module list -> unit
  output_alltexdoc produces the latex output for all modules in a single file
val always_replace_files : bool Pervasives.ref
  always_replace_files determines whether Lem only updates modified files. If it is set to
  true, all output files are written, regardless of whether the files existed before. If it is set to
  false and an output file already exists, the output file is only updated, if its content really
  changes. For some backends like OCaml, HOL, Isabelle, this is beneficial, since it prevents
  them from reprocessing these unchanged files.
val only_auxiliary : bool Pervasives.ref
  only_auxiliary determines whether Lem generates only auxiliary files
val output_sig : Format.formatter -> Typed_ast.env -> unit
```

## 22 Module `Rename_top_level` : renaming and module flattening for some targets

```
val flatten_modules :
  Path.t -> Typed_ast.env -> Typed_ast.def list -> Typed_ast.def list
val rename_defs_target :
  Target.target ->
  Typed_ast.syntax.used_entities ->
  Typed_ast.NameSet.t -> Typed_ast.env -> Typed_ast.env
```

`rename_target topt ue consts e` processes the entities (constants, constructors, types, modules ...) stored in `ue` and renames them for target `topt`. This renaming is target specific. It avoids the names in set `consts` and modifies the descriptions of constants, types, etc. in environment `e`. The modified environment is returned.

## 23 Module Reporting : reporting errors and warnings

### 23.1 Warnings

```
type warn_source =
```

```
| Warn_source_exp of Typed_ast.exp
| Warn_source_def of Typed_ast.def
| Warn_source_unkown
```

Warnings can be caused by definitions or expressions. The type `warn_source` allows to pass the origin easily to warnings

```
val warn_source_to_locln : warn_source -> Ast.l
```

```
type warning =
```

```
| Warn_general of bool * Ast.l * string
```

`Warn_general vl ls m` is a general warning with message `m`, locations `ls` and a flag `vl` whether to print these locations verbosely.

```
| Warn_rename of Ast.l * string * (string * Ast.l) option * string * Target.target
```

Warning about renaming an identifier. The arguments are the old name, an optional intermediate one, the new name and the target

```
| Warn_pattern_compilation_failed of Ast.l * Typed_ast.pat list * warn_source
    pattern compilation failed
```

```
| Warn_pattern_not_exhaustive of Ast.l * Typed_ast.pat list list
    pattern match is not exhaustive
```

```
| Warn_def_not_exhaustive of Ast.l * string * Typed_ast.pat list list
    a function is defined using non-exhaustive pattern-matching
```

```
| Warn_pattern_redundant of Ast.l * (int * Typed_ast.pat) list * Typed_ast.exp
    redundant patterns in pattern-match
```

```
| Warn_def_redundant of Ast.l * string * (int * Typed_ast.pat) list * Typed_ast.def
    redundant patterns in function definition
```

```
| Warn_pattern_needs_compilation of Ast.l * Target.target * Typed_ast.exp * Typed_ast.exp
    Warn_pattern_needs_compilation l topt old_e new_e warns about the
    compilation of old_e to new_e for target topt
```

```
| Warn_unused_vars of Ast.l * string list * warn_source
```

```

    unused variables detected
| Warn_fun_clauses_resorted of Ast.l * Target.target * string list * Typed_ast.def
    clauses of mutually recursive function definitions resorted
| Warn_record_resorted of Ast.l * Typed_ast.exp
    record fields resorted
| Warn_no_decidable_equality of Ast.l * string
    no decidable equality
| Warn_compile_message of Ast.l * Target.target * Path.t * string
    Warn_compile_message (l, target, c, m) warns using constant c form target
    target.
| Warn_import of Ast.l * string * string
    Warn_import (l, module_name, file_name) warns about auto-importing module
    module_name from file_name.
| Warn_overridden_instance of Ast.l * Types.src_t * Types.instance
    Warn_overridden_instance (l, ty, i) warns that the instance i that has already
    been defined is overridden for type ty at location l.
| Warn_ambiguous_code of Ast.l * string
    warn about ambiguous code that could be parsed in several ways and that therefore
    might confuse users

Warnings are problems that Lem can deal with. Depending on user settings, they can be
completely ignored, reported to the user or even be treated as an error.

val warnings_active : bool Pervasives.ref
    if the flag warnings_active is set, warning messages are printed, otherwise they are thrown
    away.

val report_warning : Typed_ast.env -> warning -> unit
    report_warning env w reports a warning. Depending on the settings for the warning type
    this might mean, do nothing, print a warning message or print an error message and exit Lem

val report_warning_no_env : warning -> unit
    report_warning_no_env w reports a warning, when no-environment is available. In contrast
    to report_warning the warning messages might be more basic, since no information can be
    extracted from the environment.

```

## 23.2 Auxiliary Functions

```

val warn_opts : (string * Arg.spec * string) list
    Command line options for warnings

val ignore_pat_compile_warnings : unit -> unit
    Turn off pattern compilation warnings, used by main

```

### 23.3 Debuging

```
val print_debug_exp : Typed_ast.env -> string -> Typed_ast.exp list -> unit
val print_debug_def : Typed_ast.env -> string -> Typed_ast.def list -> unit
val print_debug_pat : Typed_ast.env -> string -> Typed_ast.pat list -> unit
val print_debug_typ : Typed_ast.env -> string -> Types.t list -> unit
val print_debug_src_t : Typed_ast.env -> string -> Types.src_t list -> unit
```

## 24 Module Reporting\_basic : Basic error reporting

**Reporting\_basic** contains functions to report errors and warnings. It contains functions to print locations (**Ast.l**) and lexing positions. Despite **Ast** it should not depend on any other Lem-file. This guarentees that it can be used throughout the whole devolpment.

The main functionality is reporting errors. This is done by raising a **Fatal\_error** exception. This is caught inside Lem and reported via **report\_error**. There are several predefined types of errors which all cause different error messages. If none of these fit, **Err\_general** can be used.

Reporting functions that need access to parts of the Lem development like **Typed\_ast** are collected in **Reporting**.

### 24.1 Auxiliary Functions

```
val loc_to_string : bool -> Ast.l -> string
  loc_to_string short l formats l as a string. If short is set, only the most originating
  location is formatted, not what methods transformed l.

val print_err : bool -> bool -> bool -> Ast.l -> string -> string -> unit
  print_err fatal print_loc_source print_only_first_loc l head mes prints an error
  / warning message to std-err. It starts with printing location information stored in l. If
  print_loc_source is set, the original input described by l is retrieved and shown. It then
  prints "head: mes". If fatal is set, the program exists with error-code 1 afterwards.
```

### 24.2 Debuging

```
val debug_flag : bool Pervasives.ref
  Should debug be printed

val print_debug : string -> unit
  print_debug s prints the string s with some debug prefix to the standard error output.
```

## 24.3 Errors

type error =

| Err\_general of bool \* Ast.l \* string

General errors, used for multi purpose. If you are unsure, use this one.

| Err\_unreachable of Ast.l \* string

Unreachable errors should never be thrown. It means that some code was excuted that the programmer thought of as unreachable

| Err\_todo of bool \* Ast.l \* string

Err\_todo indicates that some feature is unimplemented. Normally, it should be build using `err_todo` in order simplify searching for occorences in the source code.

| Err\_trans of Ast.l \* string

| Err\_trans\_header of Ast.l \* string

| Err\_syntax of Lexing.position \* string

| Err\_syntax\_locn of Ast.l \* string

| Err\_lex of Lexing.position \* char

| Err\_type of Ast.l \* string

A typechecking error

| Err\_internal of Ast.l \* string

| Err\_rename of Ast.l \* string

| Err\_cyclic\_build of string

resolving module dependencies detected a cyclic dependency of the given module

| Err\_cyclic\_inline of Ast.l \* string \* string

Err\_cyclic\_inline `l target const` means that the inline of some constant `const` is cyclic for target `target`

| Err\_resolve\_dependency of Ast.l \* string list \* string

could not find a Module that should be imported in given list of directories

| Err\_reorder\_dependency of Ast.l \* string

Err\_reorder\_dependency (`l, m`) module `m` is needed at location `l`, but not allowed to be imported, because this would require reording the user input

| Err\_fancy\_pattern\_constant of Ast.l \* string

a constant occouring in a pattern has a fancy target-representation, that cannot be dealt with for patterns

In contrast to warnings, errors always kill the current run of Lem. They can't be recovered from. `Err_todo` should not be used directly, but only through `err_todo` in order to make search easier.

Errors usually have location information and a message attached. Some also carry a boolean flag indicating, the original source corresponding to the location information should be looked up and printed.

exception Fatal\_error of error

Since errors are always fatal, they are reported by raising an Fatal\_error exception instead of calling a report-function.

val err\_todo : bool -> Ast.l -> string -> exn

err\_todo b l m is an abbreviation for Fatal\_error (Err\_todo (b, l, m))

val err\_general : bool -> Ast.l -> string -> exn

err\_general b l m is an abbreviation for Fatal\_error (Err\_general (b, l, m))

val err\_unreachable : Ast.l -> string -> exn

err\_unreachable l m is an abbreviation for Fatal\_error (Err\_unreachable (l, m))

val err\_type : Ast.l -> string -> exn

err\_type l msg is an abbreviation for Fatal\_error (Err\_type (l, m), i.e. for a general type-checking error at location l with error message msg.

val err\_type\_pp :

Ast.l -> string -> (Format.formatter -> 'a -> unit) -> 'a -> exn

err\_type l msg pp n is similar to err\_type. However it uses the formatter pp to format n, resulting in a string label. The error message then has the form label : msg.

val report\_error : error -> 'a

Report error should only be used by main to print the error in the end. Everywhere else, raising a Fatal\_error exception is recommended.

## 25 Module Seplist : general thing of lists with optional separators

type ('a, 'b) t

val empty : ('a, 'b) t

val cons\_sep : 'a -> ('b, 'a) t -> ('b, 'a) t

val cons\_sep\_alt : 'a -> ('b, 'a) t -> ('b, 'a) t

cons\_sep\_alt doesn't add the separator if the list is empty

val cons\_entry : 'a -> ('a, 'b) t -> ('a, 'b) t

val is\_empty : ('a, 'b) t -> bool

val sing : 'a -> ('a, 'b) t

sing a constructs a seplist with entry a. It does the same as cons\_entry a empty.

val hd : ('a, 'b) t -> 'a

gets the first entry, if there is one

```

val hd_sep : ('a, 'b) t -> 'b
    gets the first separator, if there is one

val tl : ('a, 'b) t -> ('a, 'b) t
    Removes the first entry, fails if there is none, or if a separator is first

val tl_alt : ('a, 'b) t -> ('a, 'b) t
    Removes the first entry, fails if there is none, removes any separator that precedes the first
    entry

val tl_sep : ('a, 'b) t -> ('a, 'b) t
    Removes the first separator, fails if there is none, or if an entry is first

val append : 'a -> ('b, 'a) t -> ('b, 'a) t -> ('b, 'a) t
    append d s11 s12 appends the seplists s11 and s12. If s11 ends with a value and s12
    starts with a value, a default separator s is added. If s11 ends with a separator and s12
    starts with a separator, the separator of s12 is dropped.

val flatten : 'a -> ('b, 'a) t list -> ('b, 'a) t
    flatten d s11 flattens a list of seplists by applying append repeatedly

val to_list : ('a, 'b) t -> 'a list
    Makes a normal list, ignoring separators

val to_pair_list : 'a -> ('b, 'a) t -> 'a option * ('b * 'a) list
    Makes a normal list of pairs. The first separator is returned separately, an default one added
    for the last entry, if the lists ends with a value

val from_pair_list : 'a option -> ('b * 'a) list -> 'b option -> ('b, 'a) t
    constructs a seplists from a list of pairs. In contrast to from_list, the last separator is kept

val from_pair_list_sym :
    'a option -> ('b * 'a) list -> 'b option -> ('a, 'b) t
    from_pair_list_sym first_val_opt sep_val_list last_sep_opt constructs a seplists
    from a list of pairs sep_val_list. In contrast to from_pair_list, the separator is the first
    component of these pairs. This also means that we now need an optional first value before
    the list and an optional last separator after the list, whereas from_pair_list has an optional
    first separator and last value.

val drop_first_sep : ('a, 'b) t -> 'b option * ('a, 'b) t
    If s1 starts with a separator, it is dropped and returned, otherwise nothing happens.

val to_sep_list : ('a -> 'b) -> ('c -> 'b) -> ('a, 'c) t -> 'b list
    Flattens into a normal list with separators and elements intermixed

```

```

type ('a, 'b) optsep =
  | Optional
  | Require of 'a
  | Forbid of ('a -> 'b)
val to_sep_list_first :
  ('a, 'b) optsep ->
  ('c -> 'b) -> ('a -> 'b) -> ('c, 'a) t -> 'b list
  Flattens into a normal list with separators and elements intermixed, with special control
  over the first separator. Optional indicates no special treatment (works as to_sep_list),
  Require adds the given initial separator if there is none, and Forbid removes the initial
  separator if there is one. In the latter case, the initial separator is processed by the function
  argument to Forbid

val to_sep_list_last :
  ('a, 'b) optsep ->
  ('c -> 'b) -> ('a -> 'b) -> ('c, 'a) t -> 'b list
  As to_sep_list_first, but for the last separator

val to_list_map : ('a -> 'b) -> ('a, 'c) t -> 'b list
val iter : ('a -> unit) -> ('a, 'b) t -> unit
val from_list : ('a * 'b) list -> ('a, 'b) t
  The from list functions ignore the last separator in the input list

val from_list_prefix : 'a -> bool -> ('b * 'a) list -> ('b, 'a) t
val from_list_suffix : ('a * 'b) list -> 'b -> bool -> ('a, 'b) t
val from_list_default : 'a -> 'b list -> ('b, 'a) t
  from_list_default d l constructs a seplist from a list of entries l using the separator d as
  default separator between all entries.

val length : ('a, 'b) t -> int
val map : ('a -> 'b) -> ('a, 'c) t -> ('b, 'c) t
val map_changed : ('a -> 'a option) -> ('a, 'b) t -> ('a, 'b) t option
  Returns None if the function returns None on all of the elements, otherwise returns a list
  that uses the original element where the function returns None

val map_acc_right :
  ('a -> 'b -> 'c * 'b) -> 'b -> ('a, 'd) t -> ('c, 'd) t * 'b
  Maps with an accumulating parameter. The _right version builds the accumulator
  right-to-left, and the _left version builds it left-to-right.

val map_acc_left :
  ('a -> 'b -> 'c * 'b) -> 'b -> ('a, 'd) t -> ('c, 'd) t * 'b
val fold_right : ('a -> 'b -> 'b) -> 'b -> ('a, 'c) t -> 'b

```



```

    fold right implemented via map_acc_right

val fold_left : ('a -> 'b -> 'b) -> 'b -> ('a, 'c) t -> 'b
    fold left implemented via map_acc_left

val for_all : ('a -> bool) -> ('a, 'b) t -> bool
val exists : ('a -> bool) -> ('a, 'b) t -> bool
val find : 'a -> ('b -> bool) -> ('b, 'a) t -> 'b * 'a
val pp :
  (Format.formatter -> 'a -> unit) ->
  (Format.formatter -> 'b -> unit) ->
  Format.formatter -> ('a, 'b) t -> unit
val replace_all_seps : ('a -> 'a) -> ('b, 'a) t -> ('b, 'a) t

```

## 26 Module Syntactic\_tests

```

val check_positivity_condition_def : Typed_ast.def -> unit
val check_decidable_equality_def : Typed_ast.env -> Typed_ast.def -> unit
val check_id_restrict_e : Typed_ast.env -> Typed_ast.exp -> unit
val check_id_restrict_p : Typed_ast.env -> Typed_ast.pat -> unit

```

## 27 Module Target : Datatype and Function for Targets

```

type non_ident_target =
  | Target_hol
  | Target_ocaml
  | Target_isa
  | Target_coq
  | Target_tex
  | Target_html
  | Target_lem

```

A datatype for Targets. In contrast to the one in `ast.ml` this one does not carry white-space information.

```

type target =
  | Target_no_ident of non_ident_target
  | Target_ident

```

`target` for the typechecked ast is either a real target as in the AST or the identity target

```

val ast_target_to_target : Ast.target -> non_ident_target

```

`ast_target_to_target t` converts an ast-target to a target. This essentially means dropping the white-space information.

```
val target_to_ast_target : non_ident_target -> Ast.target
```

`target_to_ast_target t` converts a target `t` to an `ast_target`. This essentially means adding empty white-space information.

```
val ast_target_compare : Ast.target -> Ast.target -> int
```

`ast_target_compare` is a comparison function for ast-targets.

```
val target_compare : non_ident_target -> non_ident_target -> int
```

`target_compare` is a comparison function for targets.

```
module Targetmap :
sig
  include Finite_map.Fmap
  val apply_target : 'a t -> Target.target -> 'a option

  apply_target m targ looks up the targ in map m. Target-maps only store information
  for real targets, not the identity one. If therefore targ is Target_ident, i.e. represents
  the identity backend, None is returned.

  val insert_target : 'a t -> Target.target * 'a -> 'a t

  insert_target m (targ, v) inserts value v for targ in map m. Target-maps only
  store information for real targets, not the identity one. If therefore targ is
  Target_ident, i.e. represents the identity backend, the map is not(!) updated.

end

target keyed finite maps
```

```
module Targetset :
  Set.S with type elt = non_ident_target
  target sets
```

```
val all_targets_list : non_ident_target list
```

A list of all the targets.

```
val all_targets : Targetset.t
```

The set of all the targets.

```
val all_targets_non_explicit : Targetset.t
```

The set of targets used when negating or no mentioning explicit targets. Targets like Lem are excluded by default.

```

val non_ident_target_to_string : non_ident_target -> string
    non_ident_target_to_string t returns a string description of a target t.

val target_to_string : target -> string
    target_to_string t_opt returns a string description of a target. If some target is given, it
    does the same as target_to_string. Otherwise, it returns a string description of the
    identity backend.

val non_ident_target_to_mname : non_ident_target -> Name.t
    non_ident_target_to_mname t returns a name for a target. It is similar to
    non_ident_target_to_string t. However, it returns capitalised versions.

val target_to_output : Ast.target -> Output.t
    target_to_output t returns output for a target t.

val is_human_target : target -> bool
    is_human_target targ checks whether targ is a target intended to be read by humans and
    therefore needs preserving the original structure very closely. Examples for such targets are
    the tex-, html- and identity-targets.

val dest_human_target : target -> non_ident_target option
    dest_human_target targ destructs targ to get the non-identity target. If it s a
    human-target, None is returned, otherwise the non-identity target.

```

## 28 Module Target\_binding : resolve\_module\_path l env sk m tries to find the module-path m in environment env.

It returns a shortest suffix  $m'$  of  $m$  that resolves to the same module in  $env$ , and adds the lskips  $sk$  to the returned ident.

```

val resolve_module_path :
    Ast.l -> Typed_ast.env -> Types.ident_option -> Path.t -> Ident.t
    resolve_module_path l env sk m tries to find the module-path m in environment env. It
    returns a shortest suffix  $m'$  of m that resolves to the same module in env, and adds the lskips
    sk to the returned ident.

val resolve_type_path :
    Ast.l -> Typed_ast.env -> Types.ident_option -> Path.t -> Ident.t
    resolve_type_path l env sk p tries to find the type of (absolute) path p in environment
    env. It returns a shortest suffix  $p'$  of p that resolves to the same type in env, and adds the
    lskips sk to the returned ident.

```

```

val resolve_const_ref :
  Ast.l ->
  Typed_ast.env ->
  Target.target -> Types.ident_option -> Typed_ast.const_descr_ref -> Ident.t
  resolve_const_ref l env target io c_ref tries to find the constant c_ref in
  environment env. Let p be the absolute path for c_ref. If tries io as default, if given. If
  that fails, it returns a shortest suffix p' of p that resolves to the same constant in lenv, and
  adds the lskips from io to the returned ident.

```

## 29 Module Target\_syntax

```

val fix_infix_and_parens :
  Typed_ast.env -> Target.target -> Typed_ast.def list -> Typed_ast.def list

```

## 30 Module Target\_trans : get\_transformation targ returns the (pre-backend) transformation function for target targ

```

val get_transformation :
  Target.target ->
  Typed_ast.env ->
  Typed_ast.checked_module -> Typed_ast.env * Typed_ast.checked_module
  get_transformation targ returns the (pre-backend) transformation function for target
  targ

```

```

val get_avoid_f :
  Target.target -> Typed_ast.NameSet.t -> Typed_ast.var_avoid_f
  get_avoid_f targ returns the target specific variable avoid function. Before this function
  can be used, it needs to get the set of constants to avoid.

```

```

val add_used_entities_to_avoid_names :
  Typed_ast.env ->
  Target.target ->
  Typed_ast_syntax.used_entities -> Typed_ast.NameSet.t -> Typed_ast.NameSet.t
  add_used_entities_to_avoid_names env targ ue ns adds the used entities in ue to the
  name-set ns. This nameset is intended to contain the names to avoid when using
  get_avoid_f or rename_def_params. Since for each target different names need to be
  avoided, the intended target is required as well. Finally, the environment is needed to
  look-up target representations.

```

```

val rename_def_params :
  Target.target ->

```

```
Typed_ast.NameSet.t ->
```

```
Typed_ast.checked_module list -> Typed_ast.checked_module list
```

Rename the arguments to definitions, if they clash with constants in a given set of constants. This was previously part of the transformation returned by `get_transformation`. It got moved out in order to see all the renamings of definitions before changing their arguments.

```
val ident_force_pattern_compile : bool Pervasives.ref
```

This flag enables pattern compilation for the identity backend. Used for debugging.

```
val ident_force_dictionary_passing : bool Pervasives.ref
```

This flag enables dictionary passing transformations for the identity backend. Used for debugging.

## 31 Module Trans : macros for target\_trans

```
exception Trans_error of Ast.t * string
```

```
type 'a macro = Macro_expander.macro_context -> 'a -> 'a option
```

```
type pat_macro = Macro_expander.pat_position -> Typed_ast.pat macro
```

```
module Macros :
```

```
  functor (E : sig
```

```
    val env : Typed_ast.env
```

```
  end) -> sig
```

### 31.1 Record Macros

```
val remove_singleton_record_updates : Typed_ast.exp Trans.macro
```

`remove_singleton_record_updates` replaces updates of records that have only one field with the construction of a completely new record.

```
val remove_multiple_record_updates : Typed_ast.exp Trans.macro
```

`remove_multiple_record_updates` replaces record updates simultaneously updating multiple fields with a nested record update, each affecting only one field, that achieves the same effect.

```
val sort_record_fields : Typed_ast.exp Trans.macro
```

`sort_record_fields` sorts the fields of a record expression into the same order as in the definition of the record type. If they do not need resorting, everything is fine, otherwise a warning is produced.

## 31.2 Set and List Comprehension Macros

`val remove_list_comprehension : Typed_ast.exp Trans.macro`

`remove_list_comprehension` removes list comprehensions by turning them into fold and insert operations. A `Trans_error` exception is thrown, if not only bounded quantification is used.

`val remove_set_comprehension : Typed_ast.exp Trans.macro`

`remove_set_comprehension` removes set comprehensions by turning them into fold and insert operations. A `Trans_error` exception is thrown, if not only bounded quantification is used.

`val remove_set_comprehension_image_filter : bool -> Typed_ast.exp Trans.macro`

`remove_set_comprehension allow_sigma` removes set comprehensions by turning them into set-image, set-filter and set-product operations. For example `{ f (x,y,z) | forall ((x,y) IN A) (z IN B) | P (x, y, z) }` is turned into `Set.image f (Set.filter P (Set.cross A B))`. If `allow_sigma` is set and the quantifiers depend on each other, `set_sigma` is used instead. So, for example `{ f (x,y,z) | forall ((x,y) IN A) (z IN B x) | P (x, y, z) }` is turned into `Set.image f (Set.filter P (Set.set_sigma A (fun (x, y) -> B x)))`.

In contrast to `remove_set_comprehension` no exception is thrown, if the translation fails. This is because it is intended to be used with theorem prover backends, which can handle unbounded quantification differently.

`val remove_setcomp : Typed_ast.exp Trans.macro`

`remove_setcomp` removes set comprehensions with implicit bound variable to ones with explicitly bound ones. For example `{ (x, y) | x > y }` might, depending on context be turned in `{ (x, y) | forall x | x > y }`, `{ (x, y) | forall x y | x > y }` or something similar.

`val cleanup_set_quant : Typed_ast.exp Trans.macro`

`cleanup_set_quant` moves restricted and unrestricted quantification in set comprehensions to the condition part, if the bound variables are only used by the condition. This means, that expressions of the form `{ f x | forall (p IN e) ... | P x }` become `{ f x | forall ... | exists (p IN e). P x }` if `x` is not a member of FV `p`.

`val remove_set_comp_binding : Typed_ast.exp Trans.macro`

`remove_set_comp_binding` tries to turn `Comb_binding` expressions into `Set_comb` ones. Given a term of the form `{ f x z | forall x z | P x z y1 ... yn }` it checks that only unbounded quantification is used and that the set of bound variables is exactly the set of free variables of the expression `f x z`. If this is the case, the expression is transformed to `{ f x z | P x z y1 ... yn }`. Otherwise `remove_set_comp_binding` fails.

`val remove_set_restr_quant : Typed_ast.exp Trans.macro`

`remove_set_restr_quant` turns restricted quantification in set comprehensions into unrestricted quantification. Expressions of the form `{ f x | forall (p IN e) | P x }` become `{ f x | FV(p) | forall FV(p). p IN e /\ P x }`. This requires turning pattern `p` into an expression. This is likely to fail for more complex patterns. In these cases, `remove_set_restr_quant` fails and pattern compilation is needed.

### 31.3 Quantifier Macros

`val list_quant_to_set_quant : Typed_ast.exp Trans.macro`

`list_quant_to_set_quant` turns `forall (x MEM L). P x` into `forall (x IN Set.from_list L). P x`

`val remove_restr_quant : (Typed_ast.pat -> bool) -> Typed_ast.exp Trans.macro`

`remove_restr_quant pat_OK` turns restricted quantification into unrestricted quantification, if then pattern does not satisfy `pat_OK`. For example, expressions of the form `forall (p IN e). P x` becomes `forall FV(p). p IN e -> P x`, if `pat_OK p` does not hold. `pat_OK` is used to configure, which types of restricted quantification are supported by the backend. For example, HOL 4 supports patterns consisting of variables, tuples and wildcard patterns, while Isabelle does not like wildcard ones. This macros tries to turn pattern `p` into an expression. This is likely to fail for more complex patterns. In these cases, `remove_restr_quant pat_OK` fails and pattern compilation is needed.

`val remove_quant : Typed_ast.exp Trans.macro`

`remove_quant` turns quantifiers into iteration. It throws an `Trans_error` exception, if used on unrestricted quantification. Given an expression `forall (x IN X). P x` this returns `Set.forall X (fun x -> P x)`. It also works for existential quantification and quantification over lists.

`val remove_quant_coq : Typed_ast.exp Trans.macro`

`remove_quant_coq` the same as above but does not apply in the body of lemma or theorem statements. Specific to the Coq backend.

### 31.4 Pattern Macros

`val remove_unit_pats : Trans.pat_macro`

`remove_unit_pats` replaces unit-patterns `()` with wildcard ones `_`.

`val coq_type_annot_pat_vars : Trans.pat_macro`

Add type annotations to pattern variables whose type contains a type variable (only add for arguments to top-level functions)

## 31.5 Type Class Macros

`val remove_method : Target.target -> bool -> Typed_ast.exp Trans.macro`

`remove_method target add_dict` is used to remove occurrences of class methods. If a class method is encountered, the `remove_method` macro first tries to resolve the type-class instantiation statically and replace the method with it's instantiation. If this static resolving attempt fails, it is checked, whether the method is inlined for this target. If this is not the case and the flag `add_dict` is set, the method is replaced with a lookup in a dictionary. This dictionary is added by the `Def_trans.class_constraint_to_parameter` to the arguments of each definition that has type class constraints.

`val remove_method_pat : Trans.pat_macro`

`remove_method_pat` is used to remove occurrences of class methods. If a class method is encountered, `remove_method_pat` macro tries to resolve the type-class instantiation statically and replace the method with it's instantiation.

`val remove_num_lit : Typed_ast.exp Trans.macro`

`remove_num_lit` replaces `L_num (sk, i)` with `fromNumeral (L_numeral (sk, i))`. This is the first step into using type classes to handle numerals.

`val remove_class_const : Target.target -> Typed_ast.exp Trans.macro`

`remove_class_const` remove constants that have class constraints by adding explicit dictionary parameters.

## 31.6 Misc

`val remove_function : Typed_ast.exp Trans.macro`

`remove_function` turns `function | pat1 -> exp1 ... | patn -> expn end` into `fun x -> match x with | pat1 -> exp1 ... | patn -> expn end`.

`val remove_sets : Typed_ast.exp Trans.macro`

Warning: OCaml specific! `remove_sets` transforms set expressions like `{e1, ..., en}` into `Ocaml.Pset.from_list (type_specific compare) [e1, ..., en]`

`val string_lits_isa : Typed_ast.exp Trans.macro`

`string_lits_isa` translates non-representable string literals into list of characters for Isabelle

`val remove_fun_pats : bool -> Typed_ast.exp Trans.macro`

`remove_fun_pats keep_tup` removes patterns from expressions of the form `fun p1 ... pn -> e` by introducing `function` expressions. Variable patterns and - if `keep_tup` is set - tuple patterns are kept.



### 31.7 Macros I don't understand

```
val add_nexp_param_in_const : Typed_ast.exp Trans.macro
val remove_vector_access : Typed_ast.exp Trans.macro
val remove_vector_sub : Typed_ast.exp Trans.macro
val remove_do : Typed_ast.exp Trans.macro
end
```

### 32 Module Typecheck : check\_defs backend\_targets mod\_name filename mod\_in\_output env ast typescheck the parsed module ast from file filename in environment env.

It is assumed that mainly the backends `backend_targets` will be used later, i.e. only for these backends problems like missing definitions are reported. However, information for all targets is still The new definitions are added to the environment as new module `mod_name`. The result is a new environment as well as the type-checked ast of the module. The flag `mod_in_output` is stored in the resulting module description. It signals, whether the module will be written to file.

```
val check_defs :
  Target.Targetset.t ->
  Name.t ->
  string ->
  bool ->
  Typed_ast.env ->
  Ast.defs * Ast.lex_skips ->
  Typed_ast.env * (Typed_ast.def list * Ast.lex_skips)
  check_defs backend_targets mod_name filename mod_in_output env ast typescheck
  the parsed module ast from file filename in environment env. It is assumed that mainly
  the backends backend_targets will be used later, i.e. only for these backends problems like
  missing definitions are reported. However, information for all targets is still The new
  definitions are added to the environment as new module mod_name. The result is a new
  environment as well as the type-checked ast of the module. The flag mod_in_output is stored
  in the resulting module description. It signals, whether the module will be written to file.
```

### 33 Module Typecheck\_ctxt : The distinction between cur\_env, new\_defs and export\_env is interesting.

`cur_env` contains the local environment as seen by a function inside the module. `new_defs` in contrast contains only the definitions made inside the module. It is used to check for duplicate definitions. `export_env` is the outside view of the module. It contains all definitions made inside the module (i.e. `new_defs`) as well as the included modules (see command `include`).

```

type defn_ctxt = {
  all_tdefs : Types.type_defs ;
  ctxt_c_env : Typed_ast.c_env ;
  ctxt_e_env : Typed_ast.mod_descr Types.Pfmap.t ;
  all_instances : Types.i_env ;
  lemmata_labels : Typed_ast.NameSet.t ;
  ctxt_mod_target_rep : Typed_ast.mod_target_rep Target.Targetmap.t ;
  ctxt_mod_in_output : bool ;
  cur_env : Typed_ast.local_env ;
  new_defs : Typed_ast.local_env ;
  export_env : Typed_ast.local_env ;
  new_tdefs : Path.t list ;
  new_instances : Types.instance_ref list ;
}

val add_d_to_ctxt : defn_ctxt ->
  Path.t -> Types.tc_def -> defn_ctxt
  The distinction between cur_env, new_defs and export_env is interesting. cur_env
  contains the local environment as seen by a function inside the module. new_defs in contrast
  contains only the definitions made inside the module. It is used to check for duplicate
  definitions. export_env is the outside view of the module. It contains all definitions made
  inside the module (i.e. new_defs) as well as the included modules (see command include).

val add_p_to_ctxt : defn_ctxt ->
  Name.t * (Path.t * Ast.l) -> defn_ctxt

val add_f_to_ctxt :
  defn_ctxt ->
  Name.t * Types.const_descr_ref -> defn_ctxt

val add_v_to_ctxt :
  defn_ctxt ->
  Name.t * Types.const_descr_ref -> defn_ctxt

val union_v_ctxt :
  defn_ctxt ->
  Typed_ast.const_descr_ref Typed_ast.Nfmap.t -> defn_ctxt

val add_m_to_ctxt :
  Ast.l ->
  defn_ctxt ->
  Name.t -> Typed_ast.mod_descr -> defn_ctxt

val add_m_alias_to_ctxt :
  Ast.l ->
  defn_ctxt -> Name.t -> Path.t -> defn_ctxt

val add_instance_to_ctxt :
  defn_ctxt ->
  Types.instance -> defn_ctxt * Types.instance_ref

val add_lemma_to_ctxt : defn_ctxt -> Name.t -> defn_ctxt

```

```
val defn_ctxt_to_env : defn_ctxt -> Typed_ast.env
```

A definition context contains among other things an environment split up over several fields. This functions extracts this environment.

```
val ctxt_c_env_set_target_rep :
```

```
  Ast.l ->
```

```
  defn_ctxt ->
```

```
  Typed_ast.const_descr_ref ->
```

```
  Target.non_ident_target ->
```

```
  Typed_ast.const_target_rep ->
```

```
  defn_ctxt * Typed_ast.const_target_rep option
```

`ctxt_c_env_set_target_rep l ctxt c targ new_rep` updates the target-representation of constant `c` for target `targ` in context `ctxt` to `new_rep`. This results into a new environment. If an representation was already stored (and is now overridden), it is returned as well. If it can't be overridden, an exception is raised.

```
val ctxt_all_tdefs_set_target_rep :
```

```
  Ast.l ->
```

```
  defn_ctxt ->
```

```
  Path.t ->
```

```
  Target.non_ident_target ->
```

```
  Types.type_target_rep ->
```

```
  defn_ctxt * Types.type_target_rep option
```

`ctxt_all_tdefs_set_target_rep l ctxt ty targ new_rep` updates the target-representation of type `ty` for target `targ` in context `ctxt` to `new_rep`. This results into a new environment. If an representation was already stored (and is now overridden), it is returned as well.

```
val ctxt_begin_submodule : defn_ctxt -> defn_ctxt
```

`ctxt_start_submodule ctxt` is used when a new submodule is processed. It resets all the new-information like the field `new_defs`, but keeps the other informations (including the current environment) around.

```
val ctxt_end_submodule :
```

```
  Ast.l ->
```

```
  defn_ctxt ->
```

```
  Name.t list -> Name.t -> defn_ctxt -> defn_ctxt
```

`ctxt_end_submodule l ctxt_before mod_path mod_name ctxt_submodule` is used when a new submodule is no longer processed. It resets some information (like the local environment of `ctxt_submodule` back to the values in `ctxt_before`. The context `ctxt_before` is supposed to be the one valid before starting to process the submodule. The new definitions of the submodule are moved to a new module `mod_name` at path `mod_path`.

## 34 Module Typed\_ast : Sets of Names

```
module NameSet :
  Set.S with type elt = Name.t and type t = Set.Make(Name).t
  Sets of Names

module Nfmap :
  Finite_map.Fmap with type k = Name.t
  Name keyed finite maps

val nfmap_domain : 'a Nfmap.t -> NameSet.t
type name_l = Name.lskips_t * Ast.l
type lskips = Ast.lex_skips
  Whitespace, comments, and newlines

type 'a lskips_seplist = ('a, lskips) Seplist.t
val no_lskips : lskips
  The empty lskip

val space : lskips
  A space lskip

val lskips_only_comments : lskips list -> lskips
  Get only the comments (and a trailing space)

val lskips_only_comments_first : lskips list -> lskips
  Get the first lskip of the list and only comments from the rest

type env_tag =
  | K_let
    A let definition, the most common case. Convers val as well, details see above.
  | K_field
    A field
  | K_constr
    A type constructor
  | K_relation
    A relation
  | K_method
    A class method
  | K_instance
```

A method instance

`env_tag` is used by `const_descr` to describe the type of constant. Constants can be defined in multiple ways: the most common way is via a `let`-statement. Record-type definitions introduce fields-accessor functions and variant types introduce constructors. There are methods, instances and relations as well. A `let` definition can be made via a `val` definition and multiple, target specific lets.

```
type p_env = (Path.t * Ast.l) Nfmap.t
```

Maps a type name to the unique path representing that type and the first location this type is defined

```
type lit = (lit_aux, unit) Types.annot
```

```
type lit_aux =
```

```
| L_true of lskips
```

```
| L_false of lskips
```

```
| L_zero of lskips
```

This is a bit, not a num

```
| L_one of lskips
```

see above

```
| L_numeral of lskips * int
```

A numeral literal, it has fixed type "numeral" and is used in patterns and after translating `L_num` to it.

```
| L_num of lskips * int
```

A number literal. This is like a numeral one wrapped with the "from\_numeral" function

```
| L_char of lskips * char
```

```
| L_string of lskips * string
```

```
| L_unit of lskips * lskips
```

```
| L_vector of lskips * string * string
```

For vectors of bits, specified with hex or binary, first string is either 0b or 0x, second is the binary or hex number as a string

```
| L_undefined of lskips * string
```

A special undefined value that explicitly states that nothing is known about it. This is useful for expressing underspecified functions. It has been introduced to easier support pattern compilation of non-exhaustive patterns.

```
type const_descr_ref = Types.const_descr_ref
```

```
type name_kind =
```

```
| Nk_typeconstr of Path.t
```

```
| Nk_const of const_descr_ref
```

```
| Nk_constr of const_descr_ref
```

```
| Nk_field of const_descr_ref
```

```

| Nk_module of Path.t
| Nk_class of Path.t
type pat = (pat_aux, pat_annot) Types.annot
type pat_annot = {
  pvars : Types.t Nfmap.t ;
}
type pat_aux =
| P_wild of lskips
| P_as of lskips * pat * lskips * name_l
  * lskips
| P_typ of lskips * pat * lskips * Types.src_t
  * lskips
| P_var of Name.lskips_t
| P_const of const_descr_ref Types.id * pat list
| P_backend of lskips * Ident.t * Types.t * pat list
| P_record of lskips
  * (const_descr_ref Types.id * lskips * pat)
  lskips_seplist * lskips
| P_vector of lskips * pat lskips_seplist * lskips
| P_vectorC of lskips * pat list * lskips
| P_tup of lskips * pat lskips_seplist * lskips
| P_list of lskips * pat lskips_seplist * lskips
| P_paren of lskips * pat * lskips
| P_cons of pat * lskips * pat
| P_num_add of name_l * lskips * lskips * int
| P_lit of lit
| P_var_annot of Name.lskips_t * Types.src_t

```

A type-annotated pattern variable. This is redundant with the combination of the P\_typ and P\_var cases above, but useful as a macro target.

```

type cr_special_fun =
| CR_special_uncurry of int
  CR_special_uncurry n formats a function with n arguments curried, i.e. turn the
  arguments into a tupled argument, surrounded by parenthesis and separated by ","
| CR_special_rep of string list * exp list
  CR_special_rep sr args encodes a user given special representation. replace the
  arguments in the expression list and then interleave the results with sr

```

```

type const_target_rep =
| CR_inline of Ast.l * bool * name_lskips_annot list * exp
  CR_inline (loc, allow_override, vars, e) means inlining the constant with the
  expression e and replacing the variable vars inside e with the arguments of the
  constant. The flag allow_override signals whether the declaration might be safely
  overridden. Automatically generated target-representations (e.g. for ocaml

```

constructors) should be changeable by the user, whereas multiple user-defined ones should cause a type error.

| `CR_infix` of `Ast.l` \* `bool` \* `Ast.fixity_decl` \* `Ident.t`

`CR_infix` (`loc`, `allow_override`, `fixity`, `i`) declares infix notation for the constant with the giving identifier.

| `CR_undefined` of `Ast.l` \* `bool`

`CR_undefined` (`loc`, `allow_override`) declares undefined constant.

| `CR_simple` of `Ast.l` \* `bool` \* `name_lskips_annot list` \* `exp`

`CR_simple` (`loc`, `allow_override`, `vars`, `e`) is similar to `CR_inline`. Instead of inlining during macro expansion and therefore allowing further processing afterwards, `CR_simple` performs the inlining only during printing in the backend.

| `CR_special` of `Ast.l` \* `bool` \* `cr_special_fun` \* `name_lskips_annot list`

`CR_special` (`loc`, `allow_override`, `to_out`, `vars`) describes special formatting of this constant. The (renamed) constant (including path prefix) and all arguments are transformed to output. `to_out` represents a function that is then given the formatted name and the appropriate number of these outputs. The expected arguments are described by `vars`. If there are more arguments than variables, they are appended. If there are less, for expressions local functions are introduced. For patterns, an exception is thrown. Since values of `const_target_rep` need to be written out to file via `output_value` in order to cache libraries, it cannot be a function of type `Output.t list -> Output.t list` directly. Instead, the type `cr_special_fun` is used as an indirection.

type `rel_io` =

| `Rel_mode_in`  
| `Rel_mode_out`

`rel_io` represents whether an argument of an inductive relation is considered as an input or an output

type `rel_mode` = `rel_io list`

`rel_output_type` specifies the type of the result

type `rel_output_type` =

| `Out_list`

Return a list of possible outputs

| `Out_pure`

Return one possible output or fail if no such output exists

| `Out_option`

Return one possible output or `None` if no such output exists

| `Out_unique`

Return the output if it is unique or `None` otherwise

```

type rel_info = {
  ri_witness : (Path.t * const_descr_ref Nfmap.t) option ;
    Contains the path of the witness type and a mapping from rules to constructors. None
    if no witness type has been generated
  ri_check : const_descr_ref option ;
    A reference to the witness checking function or None if it is not generated
  ri_fns : ((rel_mode * bool * rel_output_type) *
    const_descr_ref)
  list ;
    A list of functions generated from the relation together with their modes
}

```

rel\_info represents information about functions and types generated from this relation 0

```

type const_descr = {
  const_binding : Path.t ;
    The path to the definition
  const_tparams : Types.tnvar list ;
    Its type parameters. Must have length 1 for class methods.
  const_class : (Path.t * Types.tnvar) list ;
    Its class constraints (must refer to above type parameters). Must have length 1 for
    class methods
  const_no_class : const_descr_ref Target.Targetmap.t ;
    If the constant has constraints, i.e. const_class is not empty, we need another
    constant without constraints for dictionary passing. This field stores the reference to
    this constant, if one such constant has already been generated.
  const_ranges : Types.range list ;
    Its length constraints (must refer to above type parameters). Can be equality or GtEq
    inequalities
  const_type : Types.t ;
    Its type
  relation_info : rel_info option ;
    If the constant is a relation, it might contain additional information about this
    relation. However, it might be None for some relations as well.
  env_tag : env_tag ;
    What kind of definition it is.
  const_targets : Target.Targetset.t ;
    The set of targets the constant is defined for.
  spec_l : Ast.l ;

```



The location for the first occurrence of a definition/specification of this constant.

`target_rename : (Ast.l * Name.t) Target.Targetmap.t ;`

Target-specific renames of for this constant.

`target_ascii_rep : (Ast.l * Name.t) Target.Targetmap.t ;`

Optional ASCII representation for this constant.

`target_rep : const_target_rep Target.Targetmap.t ;`

Target-specific representation of for this constant

`compile_message : string Target.Targetmap.t ;`

An optional warning message that should be printed, if the constant is used

`termination_setting : Ast.termination_setting Target.Targetmap.t ;`

Can termination be proved automatically by various backends?

}

The description of a top-level definition

`type v_env = const_descr_ref Nfmap.t`

`type f_env = const_descr_ref Nfmap.t`

`type m_env = Path.t Nfmap.t`

`type e_env = mod_descr Types.Pfmap.t`

`type c_env`

`local_env` represents `local_environments`, i.e. essentially maps from names to the entities they represent

`type local_env = {`

`m_env : m_env ;`

module map

`p_env : p_env ;`

type map

`f_env : f_env ;`

field map

`v_env : v_env ;`

constructor and constant map

}

`type env = {`

`local_env : local_env ;`

the current local environment

`c_env : c_env ;`

global map from constant references to the constant descriptions

```

t_env : Types.type_defs ;
      global type-information

i_env : Types.i_env ;
      global instances information

e_env : e_env ;
      global map from module paths to the module descriptions
}

type mod_target_rep =
  | MR_rename of Ast.l * Name.t
      Rename the module

type mod_descr = {
  mod_binding : Path.t ;
      The full path of this module

  mod_env : local_env ;
      The local environment of the module

  mod_target_rep : mod_target_rep Target.Targetmap.t ;
      how to represent the module for different backends

  mod_filename : string option ;
      the filename the module is defined in (if it is a top-level module)

  mod_in_output : bool ;
      is this module written to a file (true) or an existing file used (false) ?
}

type exp
type exp_subst =
  | Sub of exp
  | Sub_rename of Name.t
type exp_aux = private
  | Var of Name.lskips_t
  | Backend of lskips * Ident.t
      An identifier that should be used literally by a backend. The identifier does not
      contain whitespace. Initial whitespace is represented explicitly.

  | Nvar_e of lskips * Nvar.t
  | Constant of const_descr_ref Types.id
  | Fun of lskips * pat list * lskips * exp
  | Function of lskips
    * (pat * lskips * exp * Ast.l)
    lskips_seplist * lskips
  | App of exp * exp
  | Infix of exp * exp * exp

```

The middle exp must be a Var, Constant, or Constructor

```
| Record of lskips * fexp lskips_seplist * lskips
| Recup of lskips * exp * lskips
  * fexp lskips_seplist * lskips
| Field of exp * lskips * const_descr_ref Types.id
| Vector of lskips * exp lskips_seplist * lskips
| VectorSub of exp * lskips * Types.src_nexp * lskips
  * Types.src_nexp * lskips
| VectorAcc of exp * lskips * Types.src_nexp * lskips
| Case of bool * lskips * exp * lskips
  * (pat * lskips * exp * Ast.l)
  lskips_seplist * lskips
```

The boolean flag as first argument is used to prevent pattern compilation from looping in rare cases. If set to `true`, no pattern compilation is tried. The default value is `false`.

```
| Typed of lskips * exp * lskips * Types.src_t
  * lskips
| Let of lskips * letbind * lskips * exp
| Tup of lskips * exp lskips_seplist * lskips
| List of lskips * exp lskips_seplist * lskips
| Paren of lskips * exp * lskips
| Begin of lskips * exp * lskips
| If of lskips * exp * lskips * exp
  * lskips * exp
| Lit of lit
| Set of lskips * exp lskips_seplist * lskips
| Setcomp of lskips * exp * lskips * exp
  * lskips * NameSet.t
| Comp_binding of bool * lskips * exp * lskips * lskips
  * quant_binding list * lskips * exp
  * lskips
```

`true` for list comprehensions, `false` for set comprehensions

```
| Quant of Ast.q * quant_binding list * lskips * exp
| Do of lskips * Path.t Types.id * do_line list
  * lskips * exp * lskips
  * (Types.t * bind_tyargs_order)
```

The last argument is the type of the value in the monad

```
type do_line =
  | Do_line of (pat * lskips * exp * lskips)
type bind_tyargs_order =
  | BTO_input_output
    ['a, 'b]
  | BTO_output_input
```

`['b, 'a]`

A bind constant of a monad  $M$  has type  $M \text{ 'a} \rightarrow (\text{'a} \rightarrow M \text{ 'b}) \rightarrow M \text{ 'b}$ . Here, I call `'a` the input type and `'b` the output type. Depending on how the bind constant is defined in detail its free type variable list (stored in constant-description record, field `const_tparams`) might be either of the form `['a, 'b]` or `['b, 'a]`. This type is used to distinguish the two possibilities.

```
type fexp = const_descr_ref Types.id * lskips * exp * Ast.l
```

```
type name_lskips_annot = (Name.lskips_t, unit) Types.annot
```

```
type quant_binding =
```

```
  | Qb_var of name_lskips_annot
```

```
  | Qb_restr of bool * lskips * pat * lskips * exp
```

```
    * lskips
```

          true for list quantifiers, false for set quantifiers

```
type funcl_aux = name_lskips_annot * const_descr_ref *
```

```
  pat list * (lskips * Types.src_t) option *
```

```
  lskips * exp
```

```
type letbind = letbind_aux * Ast.l
```

```
type letbind_aux =
```

```
  | Let_val of pat * (lskips * Types.src_t) option * lskips
```

```
    * exp
```

`Let_val (p, ty_opt, sk, e)` describes binding the pattern `p` to exp `e` in a local let statement, i.e. a statement like `let p = e in ...`

```
  | Let_fun of name_lskips_annot * pat list
```

```
    * (lskips * Types.src_t) option * lskips
```

```
    * exp
```

`Let_fun (n, ps, ty_opt, sk, e)` describes defining a local function `f` with arguments `ps` locally. It represents a statement like `let n ps = e in ....` Notice that the arguments of `Let_fun` are similar to `funcl_aux`. However, `funcl_aux` has a constant-references, as it is used in top-level definitions, whereas `Let_fun` is used only for local functions.

```
type tyvar = lskips * Ulib.Text.t * Ast.l
```

```
type nvar = lskips * Ulib.Text.t * Ast.l
```

```
type tnvar =
```

```
  | Tn_A of tyvar
```

```
  | Tn_N of nvar
```

```
type texp =
```

```
  | Te_opaque
```

          introduce just a new type name without definition

```
  | Te_abbrev of lskips * Types.src_t
```

          a type abbreviation with the type `Te_abbrev`

```
| Te_record of lskips * lskips
* (name_l * const_descr_ref * lskips *
  Types.src_t)
lskipseplist * lskips
```

`Te_record (_, _, field_list, _)` defines a record type. The fields and their types are stored in `field_list`. The entries of `field_list` consist of the name of the field, the reference to its constant description and the type of the field as well as white-spaces.

```
| Te_variant of lskips
* (name_l * const_descr_ref * lskips *
  Types.src_t lskipseplist)
lskipseplist
```

`Te_variant (_, _, constr_list, _)` defines a variant type. The constructors and their types are stored in `constr_list`. The entries of `constr_list` consist of the name of the constructor, the reference to its constant description and the type of its arguments as well as white-spaces.

Type expressions for defining types

```
type range =
| GtEq of Ast.l * Types.src_nexp * lskips * Types.src_nexp
| Eq of Ast.l * Types.src_nexp * lskips * Types.src_nexp
type constraints =
| Cs_list of (Ident.t * tnvar) lskipseplist
* lskips option * range lskipseplist
* lskips
type constraint_prefix =
| Cp_forall of lskips * tnvar list * lskips
* constraints option
type typschm = constraint_prefix option * Types.src_t
type instschm = constraint_prefix option * lskips * Ident.t * Path.t *
Types.src_t * lskips
```

Instance Scheme, constraint prefix, sk, class-ident as printed, resolved class-path the id points to, instantiation type, sk

```
val cr_special_fun_uses_name : cr_special_fun -> bool
cr_special_fun_uses_name f checks, whether f uses its first argument, i.e. whether it
uses the formatted name of the constant. This information is important to determine,
whether the constant needs to be renamed.
```

```
type targets_opt = (bool * lskips * Ast.target lskipseplist *
lskipseplist)
option
```

`targets_opt` represents a set of targets. There are 3 types of values

- ‘None’ represents the universal set, i.e. all targets
- ‘Some (false, sk\_1, tl, sk\_2)’ (in source ‘{ t1; ...; tn }’) is the set of all targets in the list ‘tl’
- ‘Some (true, sk\_1, tl, sk\_2)’ (in source ‘~{ t1; ...; tn }’) is the set of all targets **not** in the list ‘tl’

```
val in_targets_opt : Target.target -> targets_opt -> bool
```

`in_targets_opt targ targets_opt` checks whether the target ‘targ’ is in the set of targets represented by ‘targets\_opt’. If targ is the a human readable target, `true` is returned.

```
val in_target_set : Target.target -> Target.Targetset.t -> bool
```

`in_target_set targ targetset` checks whether the target ‘targ’ is in the set of targets `targetset`. It is intended for checking whether to output certain parts of the TAST. Therefore, `in_target_set` returns true for all human readable targets and only checks for others.

```
val targets_opt_to_list : targets_opt -> Target.non_ident_target list
```

`target_opt_to_list targets_opt` returns a distinct list of all the targets in the option.

```
type val_spec = lskips * name_l * const_descr_ref *
  Ast.ascii_opt * lskips * typschm
```

```
type class_val_spec = lskips * targets_opt * name_l *
  const_descr_ref * Ast.ascii_opt * lskips * Types.src_t
```

```
type fun_def_rec_flag =
  | FR_non_rec
  | FR_rec of lskips
```

`fun_def_rec_flag` is used to encode, whether a `Fun_def` is recursive. The recursive one carries some whitespace for printing after the `rec`-keyword.

```
type val_def =
  | Let_def of lskips * targets_opt
    * (pat * (Name.t * const_descr_ref) list *
      (lskips * Types.src_t) option * lskips *
      exp)
  | Fun_def of lskips * fun_def_rec_flag * targets_opt
    * funcl_aux lskips_seplist
```

`Fun_def (sk1, rec_flag, topt, clauses)` encodes a function definition, which might consist of multiple clauses.

```
  | Let_inline of lskips * lskips * targets_opt
    * name_lskips_annot * const_descr_ref
    * name_lskips_annot list * lskips * exp
```

```
type name_sect =
```

```
  | Name_restrict of (lskips * name_l * lskips * lskips *
```

```

string * lskips)
type indreln_rule_quant_name =
  | QName of name_lskips_annot
  | Name_typ of lskips * name_lskips_annot * lskips
  * Types.src_t * lskips
type indreln_rule_aux =
  | Rule of Name.lskips_t * lskips * lskips
  * indreln_rule_quant_name list * lskips
  * exp option * lskips * name_lskips_annot
  * const_descr_ref * exp list
  A rule of the form Rule(clause_name_opt, sk1, sk2, bound_vars, sk3,
  left_hand_side_opt, sk4, rel_name, c, args) encodes a clause clause_name: forall
  bound_vars. (left_hand_side ==> rel_name args). c is the reference of the relation
  rel_name.

type indreln_rule = indreln_rule_aux * Ast.l
type indreln_witness =
  | Indreln_witness of lskips * lskips * Name.lskips_t * lskips
  Name of the witness type to be generated

type indreln_indfn =
  | Indreln_fn of Name.lskips_t * lskips * Types.src_t * lskips option
  Name and mode of a function to be generated from an inductive relation

type indreln_name =
  | RName of lskips * Name.lskips_t * const_descr_ref
  * lskips * typschm * indreln_witness option
  * (lskips * Name.lskips_t * lskips) option
  * indreln_indfn list option * lskips
  Type annotation for the relation and information on what to generate from it. RName(sk1,
  rel_name, rel_name_ref, sk2, rel_type, witness_opt, check_opt, indfns opt,
  sk3)

type target_rep_rhs =
  | Target_rep_rhs_infix of lskips * Ast.fixity_decl * lskips * Ident.t
  Declaration of an infix constant
  | Target_rep_rhs_term_replacement of exp
  the standard term replacement, replace with the exp for the given backend
  | Target_rep_rhs_type_replacement of Types.src_t
  the standard term replacement, replace with the type for the given backend
  | Target_rep_rhs_special of lskips * lskips * string * exp list
  fancy represenation of terms

```

```

| Target_rep_rhs_undefined
    undefined, don't throw a problem during typechecking, but during output
type declare_def =
| Decl_compile_message of lskips * targets_opt * lskips
  * const_descr_ref Types.id * lskips * lskips
  * string
    Decl_compile_message_decl (sk1, targs, sk2, c, sk3, sk4, message), declares
    printing warning message message, if constant c is used for one of the targets in targs
| Decl_target_rep_term of lskips * Ast.target * lskips * Ast.component
  * const_descr_ref Types.id * name_lskips_annot list
  * lskips * target_rep_rhs
    Decl_target_rep_term (sk1, targ, sk2, comp, c, args, sk3, rhs) declares a
    target-representation for target targ and constant c with arguments args. Since fields
    and constant live in different namespaces, comp is used to declare whether a field or a
    constant is meant. The rhs contains details about the representation.
| Decl_target_rep_type of lskips * Ast.target * lskips * lskips
  * Path.t Types.id * tnvar list * lskips * Types.src_t
    Decl_target_rep_type (sk1, targ, sk2, sk3, id, args, sk4, rhs) declares a
    target-representation. for target targ and type id with arguments args.
| Decl_ascii_rep of lskips * targets_opt * lskips * Ast.component
  * name_kind Types.id * lskips * lskips
  * Name.t
| Decl_rename of lskips * targets_opt * lskips * Ast.component
  * name_kind Types.id * lskips * Name.lskips_t
| Decl_rename_current_module of lskips * targets_opt * lskips
  * lskips * lskips * Name.lskips_t
| Decl_termination_argument of lskips * targets_opt * lskips
  * const_descr_ref Types.id * lskips
  * Ast.termination_setting
| Decl_pattern_match_decl of lskips * targets_opt * lskips
  * Ast.exhaustivity_setting * Path.t Types.id * tnvar list
  * lskips * lskips
  * const_descr_ref Types.id lskips_seplist
  * lskips * const_descr_ref Types.id option
type def_aux =
| Type_def of lskips
  * (name_l * tnvar list * Path.t * texp *
    name_sect option)
  lskips_seplist
    Type_def (sk, sl) defines one or more types. The entries of sl are the type
    definitions. They contain a name of the type, the full path of the defined type, the free
    type variables, the main type definition and restrictions on variable names of this type

```



```

| Val_def of val_def
    The list contains the class constraints on those variables

| Lemma of lskips * Ast.lemma_typ * targets_opt * name_l
  * lskips * exp
| Module of lskips * name_l * Path.t * lskips
  * lskips * def list * lskips
| Rename of lskips * name_l * Path.t * lskips
  * Path.t Types.id
    Renaming an already defined module

| OpenImport of Ast.open_import * Path.t Types.id list
    open and/or import modules

| OpenImportTarget of Ast.open_import * targets_opt * (lskip * string) list
    open and/or import modules only for specific targets

| Indreln of lskips * targets_opt
  * indreln_name lskips_seplist
  * indreln_rule lskips_seplist
    Inductive relations

| Val_spec of val_spec
| Class of Ast.class_decl * lskips * name_l * tnvar
  * Path.t * lskips * class_val_spec list
  * lskips
| Instance of Ast.instance_decl * Types.instance_ref * instschm
  * val_def list * lskips
    Instance (default?, instance_scheme, methods, sk2)

| Comment of def
    Does not appear in the source, used to comment out definitions for certain backends

| Declaration of declare_def
    Declarations that change the behaviour of lem, but have no semantic meaning

type def = (def_aux * lskips option) * Ast.l * local_env
    A definition consists of a the real definition represented as a def_aux, followed by some
    white-space. There is also the location of the definition and the local-environment present
    after the definition has been processed.

val tnvar_to_types_tnvar : tnvar -> Types.tnvar * Ast.l
val empty_local_env : local_env
val empty_env : env
val e_env_lookup : Ast.l -> e_env -> Path.t -> mod_descr
    e_env_lookup l e_env p looks up the module with path p in environment e_env and
    returns the corresponding description. If this lookup fails, a fatal error is thrown using
    location l for the error message.

```

```

val c_env_lookup : Ast.l ->
  c_env -> const_descr_ref -> const_descr
  c_env_lookup l c_env c_ref looks up the constant reference c_ref in environment c_env
  and returns the corresponding description. If this lookup fails, a fatal error is thrown using
  location l for the error message.

val c_env_store_raw : c_env ->
  const_descr -> c_env * const_descr_ref
  c_env_store_raw c_env c_d stores the description c_d environment c_env. Thereby, a new
  unique reference is generated and returned along with the modified environment. It stores
  the real c_d passed. The function c_env_store preprocesses c_d to add common features
  like for example capitalizing constructors for the Ocaml backend.

val c_env_update : c_env ->
  const_descr_ref -> const_descr -> c_env
  c_env_update c_env c_ref c_d updates the description of constant c_ref with c_d in
  environment c_env.

val env_c_env_update : env ->
  const_descr_ref -> const_descr -> env
  env_c_env_update env c_ref c_d updates the description of constant c_ref with c_d in
  environment env.

val c_env_all_consts : c_env -> const_descr_ref list
  c_env_all_consts c_env returns the constants defined in c_env

val exp_to_locl : exp -> Ast.l
val exp_to_ttyp : exp -> Types.t
val append_lskips : lskips -> exp -> exp
  append_lskips adds new whitespace/newline/comments to the front of an expression (before
  any existing whitespace/newline/comments in front of the expression)

val pat_append_lskips : lskips -> pat -> pat
val alter_init_lskips : (lskips -> lskips * lskips) ->
  exp -> exp * lskips
  alter_init_lskips finds all of the whitespace/newline/comments preceding an expression
  and passes it to the supplied function in a single invocation. The preceding
  whitespace/newline/comments are replaced with the fst of the function's result, and the snd
  of the function's result is returned from alter_init_lskips

val pat_alter_init_lskips :
  (lskips -> lskips * lskips) ->
  pat -> pat * lskips
val def_aux_alter_init_lskips :

```

```

    (lskip -> lskip * lskip) ->
    def_aux -> def_aux * lskip
val def_alter_init_lskip :
    (lskip -> lskip * lskip) ->
    def -> def * lskip
val oi_alter_init_lskip :
    (lskip -> lskip * lskip) ->
    Ast.open_import -> Ast.open_import * lskip
val pp_const_descr : Format.formatter -> const_descr -> unit
val pp_env : Format.formatter -> env -> unit
val pp_local_env : Format.formatter -> local_env -> unit
val pp_c_env : Format.formatter -> c_env -> unit
val pp_instances :
    Format.formatter -> Types.instance list Types.Pfmap.t -> unit
type imported_modules =
    | IM_paths of Path.t list
    | IM_targets of targets_opt * string list
type checked_module = {
    filename : string ;
    module_path : Path.t ;
    imported_modules : imported_modules list ;
    imported_modules_rec : imported_modules list ;
    untyped_ast : Ast.defs * Ast.lex_skips ;
    typed_ast : def list * Ast.lex_skips ;
    generate_output : bool ;
}
type var_avoid_f = bool * (Name.t -> bool) * (Ulib.Text.t -> (Name.t -> bool) -> Name.t)
    var_avoid_f is a type of a tuple (avoid_ty_vars, name_ok, do_rename). The flag
    avoid_ty_vars states, whether clashes with type variables should be avoided. The name_ok
    n checks whether the name n is OK. If it is not OK, the function do_rename n_text check
    renames n. As input it takes the text of n, a function check that checks whether the new
    name clashes with any names to be avoided or existing variable names in the context.

module type Exp_context =
sig
    val env_opt : Typed_ast.env option
        The environment the expressions are considered in

    val avoid : Typed_ast.var_avoid_f option
        Avoiding certain names for local variables. Given a name and a set of names that must
        be avoided, choose a new name if necessary

```

```

end

module Exps_in_context :
  functor (C : Exp_context) -> sig

    val exp_subst :
      Types.t Types.TNfmap.t * Typed_ast.exp_subst Typed_ast.Nfmap.t ->
      Typed_ast.exp -> Typed_ast.exp
    val push_subst :
      Types.t Types.TNfmap.t * Typed_ast.exp_subst Typed_ast.Nfmap.t ->
      Typed_ast.pat list -> Typed_ast.exp -> Typed_ast.pat list * Typed_ast.exp
    val exp_to_term : Typed_ast.exp -> Typed_ast.exp_aux
    val exp_to_free : Typed_ast.exp -> Types.t Typed_ast.Nfmap.t
    val type_eq : Ast.l -> string -> Types.t -> Types.t -> unit
    val mk_lnumeral :
      Ast.l -> Typed_ast.lskips -> int -> Types.t option -> Typed_ast.lit
    val mk_lnum : Ast.l -> Typed_ast.lskips -> int -> Types.t -> Typed_ast.lit
    val mk_lbool :
      Ast.l -> Typed_ast.lskips -> bool -> Types.t option -> Typed_ast.lit
    val mk_lbit :
      Ast.l -> Typed_ast.lskips -> int -> Types.t option -> Typed_ast.lit
    val mk_lundef :
      Ast.l -> Typed_ast.lskips -> string -> Types.t -> Typed_ast.lit
    val mk_lstring :
      Ast.l -> Typed_ast.lskips -> string -> Types.t option -> Typed_ast.lit
    val mk_twild : Ast.l -> Typed_ast.lskips -> Types.t -> Types.src_t
    val mk_tvar : Ast.l -> Typed_ast.lskips -> Tyvar.t -> Types.t -> Types.src_t
    val mk_tfn :
      Ast.l ->
      Types.src_t ->
      Typed_ast.lskips -> Types.src_t -> Types.t option -> Types.src_t
    val mk_ttup :
      Ast.l ->
      Types.src_t Typed_ast.lskips_seplist -> Types.t option -> Types.src_t
    val mk_tapp :
      Ast.l -> Path.t Types.id -> Types.src_t list -> Types.t option -> Types.src_t
    val mk_tparen :
      Ast.l ->
      Typed_ast.lskips ->
      Types.src_t -> Typed_ast.lskips -> Types.t option -> Types.src_t
    val mk_pwild : Ast.l -> Typed_ast.lskips -> Types.t -> Typed_ast.pat
    val mk_pas :
      Ast.l ->

```

```

Typed_ast.lskips ->
Typed_ast.pat ->
Typed_ast.lskips ->
Typed_ast.name_l -> Typed_ast.lskips -> Types.t option -> Typed_ast.pat
val mk_ptyp :
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.pat ->
  Typed_ast.lskips ->
  Types.src_t -> Typed_ast.lskips -> Types.t option -> Typed_ast.pat
val mk_pvar : Ast.l -> Name.lskips_t -> Types.t -> Typed_ast.pat
val mk_pconst :
  Ast.l ->
  Typed_ast.const_descr_ref Types.id ->
  Typed_ast.pat list -> Types.t option -> Typed_ast.pat
val mk_pbackend :
  Ast.l ->
  Typed_ast.lskips ->
  Ident.t -> Types.t -> Typed_ast.pat list -> Types.t option -> Typed_ast.pat
val mk_precord :
  Ast.l ->
  Typed_ast.lskips ->
  (Typed_ast.const_descr_ref Types.id * Typed_ast.lskips * Typed_ast.pat)
  Typed_ast.lskips_seplist ->
  Typed_ast.lskips -> Types.t option -> Typed_ast.pat
val mk_ptup :
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.pat Typed_ast.lskips_seplist ->
  Typed_ast.lskips -> Types.t option -> Typed_ast.pat
val mk_plist :
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.pat Typed_ast.lskips_seplist ->
  Typed_ast.lskips -> Types.t -> Typed_ast.pat
val mk_pvector :
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.pat Typed_ast.lskips_seplist ->
  Typed_ast.lskips -> Types.t -> Typed_ast.pat
val mk_pvectorc :
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.pat list -> Typed_ast.lskips -> Types.t -> Typed_ast.pat

```

```

val mk_pparen :
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.pat -> Typed_ast.lskips -> Types.t option -> Typed_ast.pat
val mk_pcons :
  Ast.l ->
  Typed_ast.pat ->
  Typed_ast.lskips -> Typed_ast.pat -> Types.t option -> Typed_ast.pat
val mk_pnum_add :
  Ast.l ->
  Typed_ast.name_l ->
  Typed_ast.lskips ->
  Typed_ast.lskips -> int -> Types.t option -> Typed_ast.pat
val mk_plit : Ast.l -> Typed_ast.lit -> Types.t option -> Typed_ast.pat
val mk_pvar_annot :
  Ast.l -> Name.lskips_t -> Types.src_t -> Types.t option -> Typed_ast.pat
val mk_var : Ast.l -> Name.lskips_t -> Types.t -> Typed_ast.exp
val mk_nvar_e :
  Ast.l -> Typed_ast.lskips -> Nvar.t -> Types.t -> Typed_ast.exp
val mk_backend :
  Ast.l -> Typed_ast.lskips -> Ident.t -> Types.t -> Typed_ast.exp
val mk_const :
  Ast.l ->
  Typed_ast.const_descr_ref Types.id -> Types.t option -> Typed_ast.exp
val mk_fun :
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.pat list ->
  Typed_ast.lskips -> Typed_ast.exp -> Types.t option -> Typed_ast.exp
val mk_function :
  Ast.l ->
  Typed_ast.lskips ->
  (Typed_ast.pat * Typed_ast.lskips * Typed_ast.exp * Ast.l)
  Typed_ast.lskips_seplist ->
  Typed_ast.lskips -> Types.t option -> Typed_ast.exp
val mk_app :
  Ast.l -> Typed_ast.exp -> Typed_ast.exp -> Types.t option -> Typed_ast.exp
val mk_infix :
  Ast.l ->
  Typed_ast.exp ->
  Typed_ast.exp -> Typed_ast.exp -> Types.t option -> Typed_ast.exp
val mk_record :
  Ast.l ->

```

```

Typed_ast.lskips ->
(Typed_ast.const_descr_ref Types.id * Typed_ast.lskips * Typed_ast.exp *
 Ast.l)
Typed_ast.lskips_seplist ->
Typed_ast.lskips -> Types.t option -> Typed_ast.exp
val mk_recup :
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.exp ->
  Typed_ast.lskips ->
  (Typed_ast.const_descr_ref Types.id * Typed_ast.lskips * Typed_ast.exp *
   Ast.l)
  Typed_ast.lskips_seplist ->
  Typed_ast.lskips -> Types.t option -> Typed_ast.exp
val mk_field :
  Ast.l ->
  Typed_ast.exp ->
  Typed_ast.lskips ->
  Typed_ast.const_descr_ref Types.id -> Types.t option -> Typed_ast.exp
val mk_case :
  bool ->
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.exp ->
  Typed_ast.lskips ->
  (Typed_ast.pat * Typed_ast.lskips * Typed_ast.exp * Ast.l)
  Typed_ast.lskips_seplist ->
  Typed_ast.lskips -> Types.t option -> Typed_ast.exp
val mk_typed :
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.exp ->
  Typed_ast.lskips ->
  Types.src_t -> Typed_ast.lskips -> Types.t option -> Typed_ast.exp
val mk_let_val :
  Ast.l ->
  Typed_ast.pat ->
  (Typed_ast.lskips * Types.src_t) option ->
  Typed_ast.lskips -> Typed_ast.exp -> Typed_ast.letbind
val mk_let_fun :
  Ast.l ->
  Typed_ast.name_lskips_annot ->
  Typed_ast.pat list ->
  (Typed_ast.lskips * Types.src_t) option ->

```

```

    Typed_ast.lskips -> Typed_ast.exp -> Typed_ast.letbind
val mk_let :
    Ast.l ->
    Typed_ast.lskips ->
    Typed_ast.letbind ->
    Typed_ast.lskips -> Typed_ast.exp -> Types.t option -> Typed_ast.exp
val mk_tup :
    Ast.l ->
    Typed_ast.lskips ->
    Typed_ast.exp Typed_ast.lskips_seplist ->
    Typed_ast.lskips -> Types.t option -> Typed_ast.exp
val mk_list :
    Ast.l ->
    Typed_ast.lskips ->
    Typed_ast.exp Typed_ast.lskips_seplist ->
    Typed_ast.lskips -> Types.t -> Typed_ast.exp
val mk_vector :
    Ast.l ->
    Typed_ast.lskips ->
    Typed_ast.exp Typed_ast.lskips_seplist ->
    Typed_ast.lskips -> Types.t -> Typed_ast.exp
val mk_vaccess :
    Ast.l ->
    Typed_ast.exp ->
    Typed_ast.lskips ->
    Types.src_nexp -> Typed_ast.lskips -> Types.t -> Typed_ast.exp
val mk_vaccessr :
    Ast.l ->
    Typed_ast.exp ->
    Typed_ast.lskips ->
    Types.src_nexp ->
    Typed_ast.lskips ->
    Types.src_nexp -> Typed_ast.lskips -> Types.t -> Typed_ast.exp
val mk_paren :
    Ast.l ->
    Typed_ast.lskips ->
    Typed_ast.exp -> Typed_ast.lskips -> Types.t option -> Typed_ast.exp
val mk_begin :
    Ast.l ->
    Typed_ast.lskips ->
    Typed_ast.exp -> Typed_ast.lskips -> Types.t option -> Typed_ast.exp
val mk_if :
    Ast.l ->
    Typed_ast.lskips ->

```



```

Typed_ast.exp ->
Typed_ast.lskips ->
Typed_ast.exp ->
Typed_ast.lskips -> Typed_ast.exp -> Types.t option -> Typed_ast.exp
val mk_lit : Ast.l -> Typed_ast.lit -> Types.t option -> Typed_ast.exp
val mk_set :
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.exp Typed_ast.lskips_seplist ->
  Typed_ast.lskips -> Types.t -> Typed_ast.exp
val mk_setcomp :
  Ast.l ->
  Typed_ast.lskips ->
  Typed_ast.exp ->
  Typed_ast.lskips ->
  Typed_ast.exp ->
  Typed_ast.lskips -> Typed_ast.NameSet.t -> Types.t option -> Typed_ast.exp
val mk_comp_binding :
  Ast.l ->
  bool ->
  Typed_ast.lskips ->
  Typed_ast.exp ->
  Typed_ast.lskips ->
  Typed_ast.lskips ->
  Typed_ast.quant_binding list ->
  Typed_ast.lskips ->
  Typed_ast.exp -> Typed_ast.lskips -> Types.t option -> Typed_ast.exp
val mk_quant :
  Ast.l ->
  Ast.q ->
  Typed_ast.quant_binding list ->
  Typed_ast.lskips -> Typed_ast.exp -> Types.t option -> Typed_ast.exp
val mk_do :
  Ast.l ->
  Typed_ast.lskips ->
  Path.t Types.id ->
  Typed_ast.do_line list ->
  Typed_ast.lskips ->
  Typed_ast.exp ->
  Typed_ast.lskips ->
  Types.t * Typed_ast.bind_tyargs_order -> Types.t option -> Typed_ast.exp
val t_to_src_t : Types.t -> Types.src_t
val pat_subst :
  Types.t Types.TNfmap.t * Name.t Typed_ast.Nfmap.t ->

```

```

Typed_ast.pat -> Typed_ast.pat
end

val local_env_union : local_env -> local_env -> local_env
val funcl_aux_seplist_group :
  funcl_aux lskips_seplist ->
  bool * lskips option *
  (Name.t * funcl_aux lskips_seplist) list
  Mutually recursive function definitions may contain multiple clauses for the same function.
  These can however appear interleaved with clauses for other functions.
  funcl_aux_seplist_group seplist sorts the clauses according to the function names and
  states, whether any resorting was necessary. Moreover, the initial lskip is returned, if present.

val class_path_to_dict_name : Path.t -> Types.tnvar -> Name.t
  class_path_to_dict_name cp tv creates a name for the class cp with type argument tv.
  This name is used during dictionary passing. If a function has a type constraint that
  type-variable tv is of type-class cp, the function call class_path_to_dict_name cp tv is
  used to generate the name of a new argument. This argument is a dictionary that is used to
  eliminate the use of type classes.

  This design is very fragile and should probably be changed in the future!
  class_path_to_dict_name needs to generate names that globally do not clash with
  anything else, including names generated by class_path_to_dict_name itself. The
  generated name is independently used by both definition macros adding the argument to the
  definition and expression macros that use the added argument. The name used in both
  places has to coincide! Therefore, the name cannot be modified depending on the context.
  Renaming to avoid clashes with other arguments / local variables is not possible.

val ident_get_lskip : 'a Types.id -> Ast.lex_skips
val ident_replace_lskip :
  Types.ident_option -> Ast.lex_skips -> Types.ident_option
val oi_get_lskip : Ast.open_import -> Ast.lex_skips

```

## 35 Module Typed\_ast\_syntax : syntax functions for typed\_ast

### 35.1 Types

```

val bool_ty : Types.t
  The boolean type

val nat_ty : Types.t
  The natural number type

```

## 35.2 Navigating Environments

```
val lookup_env_opt :  
  Typed_ast.env -> Name.t list -> Typed_ast.local_env option  
  lookup_env_opt env path is used to navigate inside a environment env. It returns the local  
  environment which is reachable via the path path. If no such environment exists, None is  
  returned.  
  
val lookup_env : Typed_ast.env -> Name.t list -> Typed_ast.local_env  
  lookup_env is similar to lookup_env_opt, but reports an internal error instead of returning  
  None, if no environment can be found.  
  
val env_apply :  
  Typed_ast.env ->  
  Ast.component option ->  
  Name.t -> (Typed_ast.name_kind * Path.t * Ast.l) option  
  env_apply env comp_opt n looks up the name n in the environment env. If component  
  comp is given, only this type of component is searched. Otherwise, it checks whether n refers  
  to a type, field, constructor or constant. env_apply returns the kind of this name, it's full  
  path and the location of the original definition.  
  
val lookup_mod_descr_opt :  
  Typed_ast.env -> Name.t list -> Name.t -> Typed_ast.mod_descr option  
  lookup_mod_descr_opt env path mod_name is used to navigate inside an environment env.  
  It returns the module with name mod_name, which is reachable via the path path. If no such  
  environment exists, None is returned.  
  
val lookup_mod_descr :  
  Typed_ast.env -> Name.t list -> Name.t -> Typed_ast.mod_descr  
  lookup_mod_descr env path mod_name is used to navigate inside an environment env. It  
  returns the module with name mod_name, which is reachable via the path path. If no such  
  environment exists, Reporting_basic is used to report an internal error.  
  
val names_get_const :  
  Typed_ast.env ->  
  Name.t list -> Name.t -> Types.const_descr_ref * Typed_ast.const_descr  
  names_get_const env path n looks up the constant with name n reachable via path path  
  in the environment env  
  
val strings_get_const :  
  Typed_ast.env ->  
  string list -> string -> Types.const_descr_ref * Typed_ast.const_descr  
  strings_get_const is a wrapper around names_get_const that uses strings instead of  
  names.
```

```

val get_const :
  Typed_ast.env -> string -> Types.const_descr_ref * Typed_ast.const_descr
  get_const env label is a wrapper around string_get_const that maps a label to an
  actual constant description.

val const_exists : Typed_ast.env -> string -> bool
  const_exists env label checks, whether the constant with label label is available in the
  environment env. If it is get_const env label succeeds, otherwise it fails.

  names_get_const_ref env path n looks up the constant with name n reachable via path path
  in the environment env

val const_descr_to_kind :
  Types.const_descr_ref * Typed_ast.const_descr -> Typed_ast.name_kind
  const_descr_to_kind r d assumes that d is the description associated with reference r. It
  then determines the kind of constant (field, constructor, constant) depending on the
  information stored in d.

val strings_get_const_id :
  Typed_ast.env ->
  Ast.l ->
  string list ->
  string ->
  Types.t list -> Types.const_descr_ref Types.id * Typed_ast.const_descr
  strings_get_const_id env l path n inst uses get_const env path n to construct a
  const_descr and then wraps it in an id using location l and instantiations inst.

val get_const_id :
  Typed_ast.env ->
  Ast.l ->
  string ->
  Types.t list -> Types.const_descr_ref Types.id * Typed_ast.const_descr
  get_const_id env l label inst uses strings_get_const_id with an indirection to look
  up a constant for a given label.

val strings_mk_const_exp :
  Typed_ast.env ->
  Ast.l -> string list -> string -> Types.t list -> Typed_ast.exp
  strings_mk_const_exp uses get_const_id to construct a constant expression.

val mk_const_exp :
  Typed_ast.env -> Ast.l -> string -> Types.t list -> Typed_ast.exp
  mk_const_exp uses strings_mk_const_exp with an indirection through a label.

val dest_field_types :
  Ast.l ->
  Typed_ast.env ->
  Types.const_descr_ref -> Types.t * Path.t * Typed_ast.const_descr

```

`dest_field_types l env f` looks up the types of the field `f` in environment `env`. It first gets the description `f_descr` of the field `f` in `env`. It then looks up the type of `f`. For fields, this type is always of the form `field_type -> (free_vars) rec_ty_path`. `dest_field_types` checks that `free_vars` corresponds with the free typevariables of `f_descr`. If the type of `f` is not of the described form, or if `free_vars` does not correspond, the constant did not describe a proper field. In this case, `dest_field_types` fails. Otherwise, it returns `(field_type, rec_ty_path, f_descr)`.

`val get_field_type_descr :`

`Ast.t -> Typed_ast.env -> Types.const_descr_ref -> Types.type_descr`

`get_field_type_descr l env f` uses `dest_field_types l env f` to get the base type of the field `f`. It then looks up the description of this type in the environment.

`val get_field_all_fields :`

`Ast.t -> Typed_ast.env -> Types.const_descr_ref -> Types.const_descr_ref list`

`get_field_all_fields l env f` uses `get_field_type_descr l env f` to look up the type description of the record type of the field `f`. It then returns a list of all the other fields of this record.

`val lookup_class_descr :`

`Ast.t -> Typed_ast.env -> Path.t -> Types.class_descr`

`lookup_class_descr l env c_path` looks up the description of type-class `c_path` in environment `env`. If `c_path` is no valid type-class, an exception is raised.

`val lookup_field_for_class_method :`

`Ast.t -> Types.class_descr -> Types.const_descr_ref -> Types.const_descr_ref`

`lookup_field_for_class_method l cd method_ref` looks up the field reference corresponding to the method identified by `method_ref` in the description `cd` of a type class. If the reference does not point to a method of this type-class, an exception is raised.

`val lookup_inst_method_for_class_method :`

`Ast.t -> Types.instance -> Types.const_descr_ref -> Types.const_descr_ref`

`lookup_inst_method_for_class_method l i method_ref` looks up the instance method reference corresponding to the method identified by `method_ref` in the instance `i`. If the reference does not point to a method of this instance, an exception is raised.

`val class_descr_get_dict_type : Types.class_descr -> Types.t -> Types.t`

Given a class-description `cd` and an argument type `arg`, the function `class_descr_get_dict_type cd arg` generates the type of the dictionary for the class and argument type.

`val class_all_methods_inlined_for_target :`

`Ast.t -> Typed_ast.env -> Target.target -> Path.t -> bool`

Some targets may choose to not use type-classes to implement certain functions. An example is the equality type-class, which is implemented using just the build-in equality of HOL, Coq and Isabelle instead of one determined by the type-class. If all methods of a type-class are specially treated like this, the type-class does not need to be generated at all. This involves not generating the record definition, not generating instances and not using dictionary style passing for the class. The function `class_all_methods_inlined_for_target l env targ class_path` checks, whether all methods of `class_path` are inlined for target `targ`.

```
val update_const_descr :
  Ast.l ->
  (Typed_ast.const_descr -> Typed_ast.const_descr) ->
  Types.const_descr_ref -> Typed_ast.env -> Typed_ast.env
  update_const_descr l up c env updates the description of the constant c in environment
  env using the function up.

val c_env_store :
  Typed_ast.c_env ->
  Typed_ast.const_descr -> Typed_ast.c_env * Types.const_descr_ref
  c_env_store c_env c_d stores the description c_d environment c_env. Thereby, a new
  unique reference is generated and returned along with the modified environment.

val c_env_save :
  Typed_ast.c_env ->
  Types.const_descr_ref option ->
  Typed_ast.const_descr -> Typed_ast.c_env * Types.const_descr_ref
  c_env_save c_env c_ref_opt c_d is a combination of c_env_update and c_env_store. If
  c_ref_opt is given, c_env_update is called, otherwise c_env_store.
```

### 35.3 target-representations

```
val const_target_rep_to_loc : Typed_ast.const_target_rep -> Ast.l
  const_target_rep_to_loc rep returns the location, at which rep is defined.

val const_target_rep_allow_override : Typed_ast.const_target_rep -> bool
  const_target_rep_allow_override rep returns whether this representation can be
  redefined. Only auto-generated target-reps should be redefinable by the user.

val type_target_rep_to_loc : Types.type_target_rep -> Ast.l
  type_target_rep_to_loc rep returns the location, at which rep is defined.

val type_target_rep_allow_override : Types.type_target_rep -> bool
  type_target_rep_allow_override rep returns whether this representation can be
  redefined. Only auto-generated target-reps should be redefinable by the user.
```

```

val constant_descr_to_name :
  Target.target -> Typed_ast.const_descr -> bool * Name.t * Name.t option
  constant_descr_to_name targ cd looks up the representation for target targ in the
  constant description cd. It returns a tuple (n_is_shown, n, n_ascii). The name n is the
  name of the constant for this target, n_ascii an optional ascii alternative. n_is_shown
  indicates, whether this name is actually printed. Special representations or inline
  representation might have a name, that is not used for the output.

val const_descr_ref_to_ascii_name :
  Typed_ast.c_env -> Types.const_descr_ref -> Name.t
  const_descr_ref_to_ascii_name env c tries to find a simple identifier for constant c. The
  exact identifier does not matter, but should somehow be familiar to the user. It looks up the
  constant names, ascii-representations and renamings for various backends. If everything fails,
  it just makes a name up.

val type_descr_to_name :
  Target.target -> Path.t -> Types.type_descr -> Name.t
  type_descr_to_name targ ty td looks up the representation for target targ in the type
  description td. Since in contrast to constant-description, type-descriptions don't contain
  the full type-name, but only renamings, the original type-name is passed as argument ty. It
  is assumed that td really belongs to ty.

val constant_descr_rename :
  Target.non_ident_target ->
  Name.t ->
  Ast.l ->
  Typed_ast.const_descr -> Typed_ast.const_descr * (Ast.l * Name.t) option
  const_descr_rename targ n' l' cd looks up the representation for target targ in the
  constant description cd. It then updates this description by renaming to the new name n'
  and new location l'. The updated description is returned along with information of where
  the constant was last renamed and to which name.

val mod_target_rep_rename :
  Target.non_ident_target ->
  string ->
  Name.t ->
  Ast.l ->
  Typed_ast.mod_target_rep Target.Targetmap.t ->
  Typed_ast.mod_target_rep Target.Targetmap.t
  mod_descr_rename targ mod_name n' l' md updates the representation for target targ in
  the module description md by renaming to the new name n' and new location l'. In case a
  target representation was already present, a type-check error is raised.

val type_descr_rename :
  Target.non_ident_target ->

```

Name.t ->

Ast.l -> Types.type\_descr -> Types.type\_descr \* (Ast.l \* Name.t) option

type\_descr\_rename targ n' l' td looks up the representation for target targ in the type description td. It then updates this description by renaming to the new name n' and new location l'. The updated description is returned along with information of where the type was last renamed and to which name.

val type\_defs\_rename\_type :

Ast.l ->

Types.type\_defs ->

Path.t -> Target.non\_ident\_target -> Name.t -> Types.type\_defs

type\_def\_rename\_type l d p t n renames the type with path p in the defs d to the name n for target t. Renaming means that the module structure is kept. Only the name is changed.

val const\_descr\_has\_target\_rep :

Target.target -> Typed\_ast.const\_descr -> bool

const\_descr\_has\_target\_rep targ d checks whether the description d contains a target-representation for target targ.

## 35.4 Constructing, checking and destructing expressions

val mk\_name\_lskips\_annot :

Ast.l -> Name.lskips\_t -> Types.t -> Typed\_ast.name\_lskips\_annot

mk\_name\_lskips\_annot creates an annotated name

val dest\_var\_exp : Typed\_ast.exp -> Name.t option

Destructor for variable expressions

val is\_var\_exp : Typed\_ast.exp -> bool

is\_var\_exp e checks whether e is a variable expression

val dest\_tup\_exp : int option -> Typed\_ast.exp -> Typed\_ast.exp list option

Destructor for tuple expressions. Similar to pattern destructors for tuples an optional argument to check the number of elements of the tuple.

val is\_tup\_exp : int option -> Typed\_ast.exp -> bool

is\_tup\_exp s\_opt e checks whether e is a tuple of size s\_opt.

val is\_var\_tup\_exp : Typed\_ast.exp -> bool

is\_var\_tup\_exp e checks, whether e is an expression consisting only of variables and tuples. I.e. simple variable expressions, tuples containing only variables and tuples containing other variable-tuples are accepted.

val mk\_tf\_exp : bool -> Typed\_ast.exp



`mk_tf_exp` creates true and false expressions.

```
val dest_tf_exp : Typed_ast.exp -> bool option
    dest_tf_exp destructs true and false expressions.
```

```
val is_tf_exp : bool -> Typed_ast.exp -> bool
    is_tf_exp v e checks whether e is a true or false expression.
```

```
val dest_const_exp : Typed_ast.exp -> Types.const_descr_ref Types.id option
    Destructor for constants expressions
```

```
val is_const_exp : Typed_ast.exp -> bool
    is_const_exp e checks whether e is a constant expression
```

```
val dest_num_exp : Typed_ast.exp -> int option
    dest_num_exp e destructs a number literal expression.
```

```
val is_num_exp : Typed_ast.exp -> bool
    is_num_exp checks whether e is a number literal expression.
```

```
val mk_num_exp : Types.t -> int -> Typed_ast.exp
    mk_num_exp creates a number literal expression.
```

```
val is_empty_backend_exp : Typed_ast.exp -> bool
    is_empty_backend_exp checks whether the expression is “
```

```
val mk_eq_exp :
    Typed_ast.env -> Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp
    mk_eq_exp env e1 e2 constructs the expression e1 = e2. The environment env is needed
    to lookup the equality constant.
```

```
val mk_and_exp :
    Typed_ast.env -> Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp
    mk_and_exp env e1 e2 constructs the expression e1 && e2. The environment env is needed
    to lookup the conjunction constant.
```

```
val mk_and_exps : Typed_ast.env -> Typed_ast.exp list -> Typed_ast.exp
    mk_and_exps env es constructs the conjunction of all expressions in es. The environment
    env is needed to lookup the conjunction constant.
```

```
val mk_le_exp :
    Typed_ast.env -> Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp
    mk_le_exp env e1 e2 constructs the expression e1 <= e2. The environment env is needed
    to lookup the less-equal constant.
```

```

val mk_sub_exp :
  Typed_ast.env -> Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp
  mk_sub_exp env e1 e2 constructs the expression e1 - e2. The environment env is needed
  to lookup the subtraction constant.

val mk_from_list_exp : Typed_ast.env -> Typed_ast.exp -> Typed_ast.exp
  mk_from_list_exp env e constructs the expression Set.from_list e. The environment
  env is needed to lookup the from-list constant.

val mk_cross_exp :
  Typed_ast.env -> Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp
  mk_cross_exp env e1 e2 constructs the expression cross e1 e2. The environment env is
  needed to lookup the cross constant.

val mk_set_sigma_exp :
  Typed_ast.env -> Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp
  mk_set_sigma_exp env e1 e2 constructs the expression set_sigma e1 e2. The
  environment env is needed to lookup the sigma constant.

val mk_set_filter_exp :
  Typed_ast.env -> Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp
  mk_set_filter_exp env e_P e_s constructs the expression Set.filter e_P e_s. The
  environment env is needed to lookup the constant.

val mk_set_image_exp :
  Typed_ast.env -> Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp
  mk_set_image_exp env e_f e_s constructs the expression Set.image e_f e_s. The
  environment env is needed to lookup the constant.

val mk_fun_exp : Typed_ast.pat list -> Typed_ast.exp -> Typed_ast.exp
  mk_fun_exp [p1, ..., pn] e constructs the expression fun p1 ... pn -> e.

val mk_opt_fun_exp : Typed_ast.pat list -> Typed_ast.exp -> Typed_ast.exp
  mk_opt_fun_exp pL e returns mk_fun_exp pL e if pL is not empty and e otherwise.

val mk_app_exp :
  Ast.l -> Types.type_defs -> Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp
  mk_app_exp d e1 e2 constructs the expression e1 e2. The type definitions d are needed for
  typechecking.

val mk_list_app_exp :
  Ast.l ->
  Types.type_defs -> Typed_ast.exp -> Typed_ast.exp list -> Typed_ast.exp
  mk_list_app_exp d f [a1 ... an] constructs the expression f a1 ... an by
  repeatedly calling mk_app_exp.

```

```

val mk_eta_expansion_exp :
  Types.type_defs -> Name.t list -> Typed_ast.exp -> Typed_ast.exp
  mk_eta_expansion_exp d vars e for variables vars = [x1, ..., xn] tries to build the
  expression fun x1 ... xn -> (e x1 ... xn). The variable names might be changed to
  ensure that they are distinct to each other and all variables already present in e.

val mk_paren_exp : Typed_ast.exp -> Typed_ast.exp
  mk_paren_exp e adds parenthesis around expression e. Standard whitespaces are applied.
  This means that whitespace (except comments) are deleted before expression e.

val mk_opt_paren_exp : Typed_ast.exp -> Typed_ast.exp
  mk_opt_paren_exp e adds parenthesis around expression e if it seems sensible. For
  parenthesis, variable expressions and tuples, the parenthesis are skipped, though.

val may_need_paren : Typed_ast.exp -> bool
  may_need_paren e checks, whether e might need parenthesis. If returns, whether
  mk_opt_paren_exp e would modify the expression.

val mk_case_exp :
  bool ->
  Ast.l ->
  Typed_ast.exp ->
  (Typed_ast.pat * Typed_ast.exp) list -> Types.t -> Typed_ast.exp
  mk_case_exp final l e rows ty constructs a case (match) expression. In contrast to
  Typed_ast.mk_case it uses standard spacing and adds parenthesis.

val mk_let_exp :
  Ast.l -> Name.t * Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp
  mk_let_exp l (n, e1) e2 constructs the expression let n = e1 in e2 using default
  spacing.

val mk_if_exp :
  Ast.l -> Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp -> Typed_ast.exp
  mk_if_exp l c e_t e_f constructs the expression if c then e_t else e_f using default
  spacing.

val mk_undefined_exp : Ast.l -> string -> Types.t -> Typed_ast.exp
  mk_undefined_exp l m ty constructs an undefined expression of type ty with message m.

val mk_dummy_exp : Types.t -> Typed_ast.exp
  mk_dummy_exp ty constructs a dummy expression of type ty. This is an expression that
  should never be looked at. It is only guaranteed to be an expression of this type.

val dest_app_exp : Typed_ast.exp -> (Typed_ast.exp * Typed_ast.exp) option
  dest_app_exp e tries to destruct an function application expression e.

```

```

val strip_app_exp : Typed_ast.exp -> Typed_ast.exp * Typed_ast.exp list
  strip_app_exp e tries to destruct multiple function applications. It returns a pair
  (base_fun, arg_list) such that e is of the form base_fun arg_list_1 ... arg_list_n.
  If e is not a function application expression, the list arg_list is empty.

val dest_infix_exp :
  Typed_ast.exp -> (Typed_ast.exp * Typed_ast.exp * Typed_ast.exp) option
  dest_infix_exp e tries to destruct an infix expression e. If e is of the form l infix_op r
  then Some (l, infix_op, r) is returned, otherwise None.

val is_infix_exp : Typed_ast.exp -> bool
  is_infix_exp e checks whether e is an infix operation

val strip_infix_exp : Typed_ast.exp -> Typed_ast.exp * Typed_ast.exp list
  strip_infix_exp e is similar to dest_infix_exp, but returns the result in the same way as
  strip_app_exp. If e is of the form l infix_op r then (infix_op, [l;r]) is returned,
  otherwise (e, []).

val strip_app_infix_exp :
  Typed_ast.exp -> Typed_ast.exp * Typed_ast.exp list * bool
  strip_app_infix_exp e is a combination of strip_infix_exp and strip_app_exp. The
  additional boolean result states, whether e is an infix operation. If e is an infix operation
  strip_infix_exp is called and the additional boolean result is true. Otherwise
  strip_app_exp is called and the result is set to false.

```

### 35.5 Constructing, checking and destructing definitions

```

val is_type_def_abbrev : Typed_ast.def -> bool
  is_type_def_abbrev d checks whether the definition d is a type-abbreviation definition.

val is_type_def_record : Typed_ast.def -> bool
  is_type_def_abbrev d checks whether the definition d is a definition of a record_type.

```

### 35.6 Collecting information about uses constants, types, modules ...

```

type used_entities = {
  used_consts : Types.const_descr_ref list ;
  used_consts_set : Types.Cdset.t ;
  used_types : Path.t list ;
  used_types_set : Types.Pset.t ;
  used_modules : Path.t list ;
  used_modules_set : Types.Pset.t ;
  used_tnvars : Types.TNset.t ;
}

```

The type `used_entities` collects lists of used constant references, modules and types of some expression, definition, pattern ... `used_entities` is using lists, because the order in which entities occur might be important for renaming. However, these lists should not contain duplicates.

```
val empty_used_entities : used_entities
```

An empty collection of entities

```
val add_exp_entities : used_entities ->
```

```
  Typed_ast.exp -> used_entities
```

```
val add_def_aux_entities :
```

```
  Target.target ->
```

```
  bool ->
```

```
  used_entities ->
```

```
  Typed_ast.def_aux -> used_entities
```

`add_def_aux_entities targ only_new ue def` adds all the modules, types, constants ...

used by definition `def` for target `targ` to `ue`. If the flag `only_new` is set, only the newly defined are added. Notice, that the identity backend won't throw parts of modules away.

Therefore the result for the identity backend is the union of the results for all other backends.

```
val add_def_entities :
```

```
  Target.target ->
```

```
  bool ->
```

```
  used_entities ->
```

```
  Typed_ast.def -> used_entities
```

`add_def_entities` is called `add_def_aux_entities` after extracting the appropriate `def_aux`.

```
val get_checked_modules_entities :
```

```
  Target.target ->
```

```
  bool -> Typed_ast.checked_module list -> used_entities
```

`get_checked_module_entities targ only_new ml` gets all the modules, types, constants ... used by modules `ml` for target `targ`. If the flag `only_new` is set, only the newly defined are returned. Notice, that the identity backend won't throw parts of modules away.

Therefore the result for the identity backend is the union of the results for all other backends.

## 35.7 Miscellaneous

```
val remove_init_ws : Ast.lex_skips -> Ast.lex_skips * Ast.lex_skips
```

`remove_init_ws` should be used with function like `Typed_ast.alter_init_lskips`. It removes whitespace expect comments.

```
val drop_init_ws : Ast.lex_skips -> Ast.lex_skips * Ast.lex_skips
```

`drop_init_ws` should be used with function like `Typed_ast.alter_init_lskips`. It removes whitespace including comments.

```

val space_init_ws : Ast.lex_skips -> Ast.lex_skips * Ast.lex_skips
    space_init_ws should be used with function like Typed_ast.alter_init_lskips. It
    replaces whitespace including comments with a single space.

val space_com_init_ws : Ast.lex_skips -> Ast.lex_skips * Ast.lex_skips
    space_com_init_ws should be used with function like Typed_ast.alter_init_lskips. It
    replaces whitespace except comments with a single space.

val strip_paren_typ_exp : Typed_ast.exp -> Typed_ast.exp
    strip_paren_typ_exp e strips parenthesis and type-annotations from expression e.
    Warning: This might delete white-space!

val is_recursive_def : Typed_ast.def_aux -> bool * bool
    is_recursive_def d checks whether d is recursive. It returns a pair of booleans
    (is_syntactic_rec, is_real_rec). The flag is_syntactic_rec states, whether the
    definition was made using the rec-keyword. The flag is_real_rec states, whether the
    function actually appears inside its own definition.

val try_termination_proof :
    Target.target -> Typed_ast.c_env -> Typed_ast.def_aux -> bool * bool * bool
    try_termination_proof targ c_env d calls is_recursive_def d. It further checks,
    whether a termination proof for target targ should be tried by checking the termination
    settings of all involved constants. It returns a triple (is_syntactic_rec, is_real_rec,
    try_auto_termination).

val is_pp_loc : Ast.l -> bool
    is_pp_loc l checks whether l is of the form Ast.Trans (true, _, _). This means that
    the entity marked with l should be formatted using a pretty printer that calculates
    whitespaces new instead of using the ones provided by the user.

val is_pp_exp : Typed_ast.exp -> bool
val is_pp_def : Typed_ast.def -> bool
val val_def_get_name : Typed_ast.val_def -> Name.t option
    val_def_get_name d tries to extract the name of the defined function.

val val_def_get_class_constraints_no_target_rep :
    Typed_ast.env ->
    Target.target -> Typed_ast.val_def -> (Path.t * Types.tnvar) list
    val_def_get_class_constraints_no_target_rep env targ vd collects the class
    constraints of all top-level function definitions in vd, which don't have a target-specific
    representation for target targ. Warning: constraints may appear multiple times in the
    resulting list

val val_def_get_class_constraints :
    Typed_ast.env -> Typed_ast.val_def -> (Path.t * Types.tnvar) list

```

`val_def_get_class_constraints env vd` collects the class constraints of all top-level function definitions in `vd`. Warning: constraints may appear multiple times in the resulting list

```
val val_def_get_free_tnvars :
  Typed_ast.env -> Typed_ast.val_def -> Types.TNset.t
  val_def_get_free_tnvars env vd returns the set of all free type-variables used by vd.
```

```
val env_tag_to_string : Typed_ast.env_tag -> string
  env_tag_to_string tag formats tag as a string. This functions should only be used for
  human-readable output in e.g. error-messages.
```

```
val constr_family_to_id :
  Ast.l ->
  Typed_ast.env ->
  Types.t ->
  Types.constr_family_descr ->
  (Types.const_descr_ref Types.id list *
   (Types.t -> Types.const_descr_ref Types.id) option)
  option

  constr_family_to_id l env ty cf tries to instantiate the constructor family cf to be
  used on a match statement where the matched type is ty. If it succeeds the properly
  instantiated construtor ids + the instantiated case split function is returned. However,
  returning the case-split function is a bit complicated. It depends on the return type of
  match expression as well. Moreover, it might not be there at all, if the targets build-in
  pattern matching should be used to construct one. Therefore, an optional function from a
  type (the return type) to an id is returned for the case-split function.
```

```
val check_constr_family :
  Ast.l -> Typed_ast.env -> Types.t -> Types.constr_family_descr -> unit
  check_constr_family is similar to constr_family_to_id. It does not return the
  instantiations though, but produces a nicely formatted error, in case no such instantiations
  could be found.
```

```
val check_for_inline_cycles : Target.target -> Typed_ast.c_env -> unit
  check_for_inline_cycles targ env checks whether any constant in env would be inlined
  (possible over several steps) onto itself. If this happens, an exception is thrown.
```

## 36 Module Types : Structural comparison of types, without expanding type abbreviations.

Probably better not to use. Consider using `compare_expand` instead.

```
type tnvvar =
```

```

    | Ty of Tyvar.t
    | Nv of Nvar.t
val pp_tnvar : Format.formatter -> tnvar -> unit
val tnvar_to_rope : tnvar -> Ulib.Text.t
val tnvar_compare : tnvar -> tnvar -> int
module TNvar :
  sig
    type t = Types.tnvar
    val compare : t -> t -> int
    val pp : Format.formatter -> t -> unit
  end
module Pfmap :
  Finite_map.Fmap with type k = Path.t
module Pset :
  Set.S with type elt = Path.t
module TNfmap :
  Finite_map.Fmap with type k = TNvar.t
module TNset :
  sig
    include Set.S
    val pp : Format.formatter -> t -> unit
  end
type t_uvar
type n_uvar
type t = {
  mutable t : t_aux ;
}
type t_aux =
  | Tvar of Tyvar.t
  | Tfn of t * t
  | Ttup of t list
  | Tapp of t list * Path.t
  | Tbackend of t list * Path.t
  | Tne of nexp
  | Tuvar of t_uvar
type nexp = {
  mutable nexp : nexp_aux ;
}
type nexp_aux =

```



```

    | Nvar of Nvar.t
    | Nconst of int
    | Nadd of nexp * nexp
    | Nmult of nexp * nexp
    | Nneg of nexp
    | Nuvar of n_uvar
type range =
    | LtEq of Ast.l * nexp
    | Eq of Ast.l * nexp
    | GtEq of Ast.l * nexp
val range_with : range -> nexp -> range
val range_of_n : range -> nexp
val mk_gt_than : Ast.l -> nexp -> nexp -> range
val mk_eq_to : Ast.l -> nexp -> nexp -> range
val compare : t -> t -> int
    Structural comparison of types, without expanding type abbreviations. Probably better not
    to use. Consider using compare_expand instead.

val multi_fun : t list -> t -> t
val type_subst : t TNfmap.t -> t -> t
val nexp_subst : t TNfmap.t -> nexp -> nexp
val free_vars : t -> TNset.t
val is_var_type : t -> bool
val is_instance_type : t -> bool
    is the type ok to be used in an non-default type-class instantiation?

val tnvar_to_name : tnvar -> Name.t
val tnvar_to_type : tnvar -> t
val tnvar_split : tnvar list -> tnvar list * tnvar list
type const_descr_ref
    A reference to a constant description. These constant description references are used by
    typed_ast. This module also contains the appropriate mapping functionality to constant
    descriptions. However, the references need to be defined here, because types need
    information about associated constants. Record types need a list of all their field constants.
    Moreover, every type can contain a list of constructor descriptions.

val string_of_const_descr_ref : const_descr_ref -> string
    string_of_const_descr_ref formats a reference in a human readable form. No other
    guarentees are given. This function should only be used for debugging and reporting internal
    errors. Its implementation can change at any point to something completely different and
    should not be relied on.

```

```

module Cmap :
  Finite_map.Fmap with type k = const_descr_ref
module Cset :
  Set.S with type elt = const_descr_ref
type 'a cmap
  cmap is a type for maps of const_descr_ref. In contrast to finite maps represented by
  module Cmap, the keys might be autogenerated.

val cmap_empty : unit -> 'a cmap
  Constructs an empty cmap

val cmap_lookup : 'a cmap -> const_descr_ref -> 'a option
  cmap_lookup m r looks up the reference r in map m

val cmap_update : 'a cmap -> const_descr_ref -> 'a -> 'a cmap
  cmap_update m r v updates map m at reference r with value v.

val cmap_insert : 'a cmap -> 'a -> 'a cmap * const_descr_ref
  cmap_insert m v inserts value v into m. A fresh (not occurring in m) reference is generated
  for v and returned together with the modified map.

val cmap_domain : 'a cmap -> const_descr_ref list
  cmap_domain m returns the list of all const description references in the map

val nil_const_descr_ref : const_descr_ref
  nil_const_descr_ref is a nil reference, i.e. a reference that will never be bound by any
  cmap.

val is_nil_const_descr_ref : const_descr_ref -> bool
  is_nil_const_descr_ref r checks whether r is the nil reference.

type ('a, 'b) annot = {
  term : 'a ;
  locn : Ast.l ;
  typ : t ;
  rest : 'b ;
}

val annot_to_typ : ('a, 'b) annot -> t
type ident_option =
  | Id_none of Ast.lex_skips
  | Id_some of Ident.t
type 'a id = {
  id_path : ident_option ;

```

The identifier as written at the usage point. None if it is generated internally, and therefore has no original source

`id_locn : Ast.l ;`

The location of the usage point

`descr : 'a ;`

A description of the binding that the usage refers to

`instantiation : t list ;`

The usage site instantiation of the type parameters of the definition

}

Represents a usage of an 'a (usually in `constr_descr`, `field_descr`, `const_descr`)

`type src_t = (src_t_aux, unit) annot`

`type src_t_aux =`

| `Typ_wild` of `Ast.lex_skips`  
 | `Typ_var` of `Ast.lex_skips * Tyvar.t`  
 | `Typ_len` of `src_nexp`  
 | `Typ_fn` of `src_t * Ast.lex_skips * src_t`  
 | `Typ_tup` of `(src_t, Ast.lex_skips) Seplist.t`  
 | `Typ_app` of `Path.t id * src_t list`  
 | `Typ_backend` of `Path.t id * src_t list`

a backend type that should be used literally

| `Typ_paren` of `Ast.lex_skips * src_t * Ast.lex_skips`

`type src_nexp = {`

`nterm : src_nexp_aux ;`  
`nloc : Ast.l ;`  
`nt : nexp ;`

}

`type src_nexp_aux =`

| `Nexp_var` of `Ast.lex_skips * Nvar.t`  
 | `Nexp_const` of `Ast.lex_skips * int`  
 | `Nexp_mult` of `src_nexp * Ast.lex_skips * src_nexp`  
 | `Nexp_add` of `src_nexp * Ast.lex_skips * src_nexp`  
 | `Nexp_paren` of `Ast.lex_skips * src_nexp * Ast.lex_skips`

`val src_t_to_t : src_t -> t`

`val src_type_subst : src_t TNfmap.t -> src_t -> src_t`

`val id_alter_init_lskips :`

`(Ast.lex_skips -> Ast.lex_skips * Ast.lex_skips) ->`  
`'a id -> 'a id * Ast.lex_skips`

`val typ_alter_init_lskips :`

`(Ast.lex_skips -> Ast.lex_skips * Ast.lex_skips) ->`  
`src_t -> src_t * Ast.lex_skips`

```

val nextp_alter_init_lskips :
  (Ast.lex_skips -> Ast.lex_skips * Ast.lex_skips) ->
  src_nextp -> src_nextp * Ast.lex_skips
type constr_family_descr = {
  constr_list : const_descr_ref list ;
  constr_exhaustive : bool ;
  constr_case_fun : const_descr_ref option ;
  constr_default : bool ;
  constr_targets : Target.Targetset.t ;
}
type type_target_rep =
  | TYR_simple of Ast.l * bool * Ident.t
  | TYR_subst of Ast.l * bool * tnvar list * src_t
    the target representation of a type
type type_descr = {
  type_tparams : tnvar list ;
    a list of type and length parameters
  type_abbrev : t option ;
    if it is an abbreviation, the type it abbreviates
  type_varname_regexp : string option ;
    an optional regular expression that variable names that have the type must match
  type_fields : const_descr_ref list option ;
    if it is a record type, the list of fields
  type_constr : constr_family_descr list ;
    the constructors of this type
  type_rename : (Ast.l * Name.t) Target.Targetmap.t ;
    target representation of the type
  type_target_rep : type_target_rep Target.Targetmap.t ;
    target representation of the type
}
  a type description *
type class_descr = {
  class_tparam : tnvar ;
    the type parameter of the type class
  class_record : Path.t ;
    for dictionary style passing a corresponding record is defined, this is its path
  class_methods : (const_descr_ref * const_descr_ref) list ;

```

The methods of the class. For each method there is a corresponding record field. Therefore, methods are represented by pairs (method\_ref, field\_ref). Details like the names and types can be looked up in the environment.

```

class_rename : (Ast.l * Name.t) Target.Targetmap.t ;
class_target_rep : type_target_rep Target.Targetmap.t ;
class_is_inline : bool ;
}

type tc_def =
  | Tc_type of type_descr
  | Tc_class of class_descr
type type_defs = tc_def Pmap.t
val type_defs_update_tc_type :
  Ast.l ->
  type_defs ->
  Path.t -> (type_descr -> type_descr option) -> type_defs
  type_defs_update_tc_type l d p up updates the description of type p in d using the
  function up. If there is no type p in d or if up returns None, an exception is raised.

val type_defs_update_tc_class :
  Ast.l ->
  type_defs ->
  Path.t -> (class_descr -> class_descr option) -> type_defs
  type_defs_update_tc_class l d p up updates the description of type p in d using the
  function up. If there is no type p in d or if up returns None, an exception is raised.

val type_defs_update_fields :
  Ast.l ->
  type_defs -> Path.t -> const_descr_ref list -> type_defs
  type_defs_update_fields l d p fl updates the fields of type p in d.

val type_defs_add_constr_family :
  Ast.l ->
  type_defs -> Path.t -> constr_family_descr -> type_defs
val type_defs_get_constr_families :
  Ast.l ->
  type_defs ->
  Target.target ->
  t -> const_descr_ref -> constr_family_descr list
  type_defs_get_constr_families l d targ t c gets all constructor family descriptions for
  type t for target targ in type environment d, which contain the constant c.

val type_defs_lookup_type : Ast.l -> type_defs -> t -> type_descr option
  type_defs_lookup_type l d t looks up the description of type t in defs d.

```

```

val type_defs_lookup : Ast.l -> type_defs -> Path.t -> type_descr
    type_defs_lookup l d p looks up the description of type with path p in defs d.

val type_defs_update : type_defs -> Path.t -> type_descr -> type_defs
    type_defs_update d p td updates the description of type with path p in defs d with td.

val mk_tc_type_abbrev : tnvar list -> t -> tc_def
    Generates a type abbreviation

val mk_tc_type : tnvar list -> string option -> tc_def
    mk_tc_type vars reg_exp_opt generates a simple description of a type, which uses the
    type arguments vars and the reg_exp_opt for restricting the names of variables of this type.

val match_types : t -> t -> t TNfmap.t option
    match_types t_pat t tries to match type t_pat against type t. If it succeeds, it returns a
    substitution sub that applied to t_pat returns t. This function is rather simple. It does not
    use type synonyms or other fancy features.

type instance = {
  inst_l : Ast.l ;
    The location, the instance was declared

  inst_is_default : bool ;
    Is it a fallback / default instance or a real one ?

  inst_binding : Path.t ;
    The path of the instance

  inst_class : Path.t ;
    The type class, that is instantiated

  inst_type : t ;
    The type, the type-class is instantiated with

  inst_tyvars : tnvar list ;
    The free type variables of this instance

  inst_constraints : (Path.t * tnvar) list ;
    Type class constraints on the free type variables of the instance

  inst_methods : (const_descr_ref * const_descr_ref) list ;
    The methods of this instance. Since each instance method corresponds to one class
    method it instantiates, the methods are given as a list of pairs (class_method_ref,
    instance_method_ref).

  inst_dict : const_descr_ref ;
    a dictionary for the instance

```

```

}
    an instance of a type class

type typ_constraints =
  | Tconstraints of TNset.t * (Path.t * tnvar) list * range list
val head_norm : type_defs -> t -> t
val dest_fn_type : type_defs option -> t -> (t * t) option
    dest_fn_type d_opt t tries to destruct a function type t. Before the destruction,
    head_norm d t is applied, if d_opt is of the form Some d. If the result is a function type, t1
    -> t2, the Some (t1, t2) is returned. Otherwise the result is None.

val strip_fn_type : type_defs option -> t -> t list * t
    strip_fn_type d t tries to destruct a function type t by applying dest_fn repeatedly.

val check_equal : type_defs -> t -> t -> bool
    check_equal d t1 t2 checks whether t1 and t2 are equal in type environment d. It
    expands the type to perform this check. Therefore, it is more reliable than compare t1 t2 =
    0, which only performs a structural check, but does not unfold type definitions.

val assert_equal : Ast.l -> string -> type_defs -> t -> t -> unit
    assert_equal l m d t1 t2 performs the same check as check_equal d t1 t2. However,
    while check_equal returns whether the types are equal, assert_equal raises a type-exception
    in case they are not. l and m are used for printing this exception.

val compare_expand : type_defs -> t -> t -> int
    compare_expand d t1 t2 is similar check_equal d t1 t2. Instead of just checking for
    equality, it compares the values though. During this comparison, type abbreviations are
    unfolded. Therefore, it is in general preferable to the very similar method compare, which
    performs comparisons without unfolding.

type instance_ref
    A reference to an instance.

val string_of_instance_ref : instance_ref -> string
    string_of_instance_ref formats a reference in a human readable form. No other
    guarantees are given. This function should only be used for debugging and reporting internal
    errors. Its implementation can change at any point to something completely different and
    should not be relied on.

type i_env
    an instance environment carries information about all defined instances

val empty_i_env : i_env
    an empty instance environment

```

```

val i_env_add : i_env -> instance -> i_env * instance_ref
    i_env_add i_env i adds an additional instance i to the instance environment. It returns
    the modified environment as well as the reference of the added instance.

val i_env_lookup : Ast.l -> i_env -> instance_ref -> instance
    i_env_lookup l i_env ref looks up the reference in environment i_env. If this reference is
    not present, an exception is raised.

val get_matching_instance :
    type_defs ->
    Path.t * t ->
    i_env -> (instance * t TNfmap.t) option
    get_matching_instance type_env (class, ty) i_env searches for an instantiation of
    type class class instantiated with type ty in the type environment i_env. The type
    environment type_env is necessary to match ty against other instantiations of class. An
    instance can itself have free type variables. If a matching instance is found, it is returned to
    together with the substitution, which needs to be applied to the free type variables of the
    instance in order to match type t exactly. The typevariables of an instances might have
    attached type constraints. It is not (!) checked, that the found substitution satisfies these
    constraints. However, they are taken into account to rule out impossible instances, if there
    are multiple options.

val nexp_from_list : nexp list -> nexp

module type Global_defs =
    sig
        val d : Types.type_defs
        val i : Types.i_env
    end

module Constraint :
    functor (T : Global_defs) -> sig
        val new_type : unit -> Types.t
        val new_nexp : unit -> Types.nexp
        val equate_types : Ast.l -> string -> Types.t -> Types.t -> unit
        val in_range : Ast.l -> Types.nexp -> Types.nexp -> unit
        val add_constraint : Path.t -> Types.t -> unit
        val add_length_constraint : Types.range -> unit
        val add_tyvar : Tyvar.t -> unit
        val add_nvar : Nvar.t -> unit
        val inst_leftover_uvars : Ast.l -> Types.typ_constraints
        val check_numeric_constraint_implication :
            Ast.l -> Types.range -> Types.range list -> unit
    end

```



```

end

val pp_type : Format.formatter -> t -> unit
val pp_nexp : Format.formatter -> nexp -> unit
val pp_range : Format.formatter -> range -> unit
val pp_class_constraint : Format.formatter -> Path.t * tnvar -> unit
val pp_instance : Format.formatter -> instance -> unit
val pp_typschr :
  Format.formatter ->
  tnvar list -> (Path.t * tnvar) list -> t -> unit
val t_to_string : t -> string
val print_debug_typ_raw : string -> t list -> unit
  print_debug_typ_raw s [ty0, ..., tn] prints a debug message s ty0, ..., tn using
  Reporting_basic.print_debug.

val t_to_var_name : t -> Name.t

```

### 37 Module Tyvar : type of internal(?) type variables

```

type t
val compare : t -> t -> int
val pp : Format.formatter -> t -> unit
val nth : int -> t
val from_rope : Ulib.Text.t -> t
val to_rope : t -> Ulib.Text.t

```

### 38 Module Util : Mixed useful things

```

module Duplicate :
  functor (S : Set.S) -> sig
    type dups =
      | No_dups of S.t
      | Has_dups of S.elc
    val duplicates : S.elc list -> dups
  end

val remove_duplicates : 'a list -> 'a list
  remove_duplicates l removes duplicate elements from the list l. The elements keep there
  original order. The first occurrence of an element is kept, all others deleted.

```

```

val remove_duplicates_gen : ('a -> 'a -> bool) -> 'a list -> 'a list
    remove_duplicates_gen p l removes duplicate elements from the list l. It is a generalised
    version of remove_duplicates where the equality check is performed by p.

val get_duplicates : 'a list -> 'a list
    get_duplicates l returns the elements that appear multiple times in the list l.

val get_duplicates_gen : ('a -> 'a -> bool) -> 'a list -> 'a list
    get_duplicates_gen p l returns the elements that appear multiple times in the list l. It is
    a generalised version of get_duplicates where the equality check is performed by p.

```

### 38.1 Option Functions

```

val option_map : ('a -> 'b) -> 'a option -> 'b option
    option_map f None returns None, whereas option_map f (Some x) returns Some (f x).

val option_cases : 'a option -> ('a -> 'b) -> (unit -> 'b) -> 'b
    option_cases None f_s f_n returns f_n, whereas option_cases (Some x) f_s f_n
    returns f_s x.

val option_bind : ('a -> 'b option) -> 'a option -> 'b option
    option_bind f None returns None, whereas option_bind f (Some x) returns f x.

val option_default : 'a -> 'a option -> 'a
    option_default d None returns the default value d, whereas option_default d (Some x)
    returns x.

val option_default_map : 'a option -> 'b -> ('a -> 'b) -> 'b
    option_default_map v d f is short for option_default d (option_map f v). This
    means that option_default_map None d f returns d, whereas option_default_map (Some
    x) d f returns f x.

val option_get_exn : exn -> 'a option -> 'a
    option_get_exn exn None throws the exception exn, whereas option_get_exn exn (Some
    x) returns x.

val changed2 :
    ('a -> 'b -> 'c) ->
    ('a -> 'a option) -> 'a -> ('b -> 'b option) -> 'b -> 'c option
    changed2 f g x h y applies g to x and h to y. If both function applications return None,
    then None is returned. Otherwise f is applied to the results. For this application of f, x is
    used in case g x returns None and similarly y in case h y returns None.

```

## 38.2 List Functions

```
val list_index : ('a -> bool) -> 'a list -> int option
  list_index p l returns the first index i such that the predicate p (l[i]) holds. If no such
  i exists, None is returned.

val list_subset : 'a list -> 'a list -> bool
  list_subset l1 l2 tests whether all elements of l1 also occur in l2.

val list_diff : 'a list -> 'a list -> 'a list
  list_diff l1 l2 removes all elements from l1 that occur in l2.

val list_longer : int -> 'a list -> bool
  list_longer n l checks whether the list l has more than n elements. It is equivalent to
  List.length l > n, but more efficient, as it aborts counting, when the limit is reached.

val list_null : 'a list -> bool
  list_null l checks whether the list l is empty, i.e. if l = [] holds.

val option_first : ('a -> 'b option) -> 'a list -> 'b option
  option_first f l searches for the first element x of l such that the f x is not None. If such
  an element exists, f x is returned, otherwise None.

val map_changed : ('a -> 'a option) -> 'a list -> 'a list option
  map_changed f l maps f over l. If for all elements of l the function f returns None, then
  map_changed f l returns None. Otherwise, it uses x for all elements, where f x returns
  None, and returns the resulting list.

val map_changed_default :
  ('a -> 'b) -> ('a -> 'b option) -> 'a list -> 'b list option
  map_changed_default d f l maps f over l. If for all elements of l the function f returns
  None, then map_changed f l returns None. Otherwise, it uses d x for all elements x, where
  f x returns None, and returns the resulting list.

val list_mapi : (int -> 'a -> 'b) -> 'a list -> 'b list
  list_mapi f l maps f over l. In contrast to the standard map function, f gets the current
  index of the list as an extra argument. Counting starts at 0.

val list_iter_sep : (unit -> unit) -> ('a -> unit) -> 'a list -> unit
  list_iter_sep sf f [a1; ...; an] applies function f in turn to a1; ...; an and calls sf
  () in between. It is equivalent to begin f a1; sf(); f a2; sf(); ...; f an; () end.

val intercalate : 'a -> 'a list -> 'a list
  intercalate sep as inserts sep between the elements of as, i.e. it returns a list of the form
  a1; sep; ... sep; an.
```

```

val interleave : 'a list -> 'a list -> 'a list
    interleave l1 l2 interleaves lists l1 and l2, by alternately taking an element of l1 and
    l2 till one of the lists is empty. Then the remaining elements are added. The first element is
    from l1.

val replicate : int -> 'a -> 'a list
    replicate n e creates a list that contains n times the element e.

val map_filter : ('a -> 'b option) -> 'a list -> 'b list
    map_filter f l maps f over l and removes all entries x of l with f x = None.

val map_all : ('a -> 'b option) -> 'a list -> 'b list option
    map_all f l maps f over l. If at least one entry is None, None is returned. Otherwise, the
    Some function is removed from the list.

val list_to_front : int -> 'a list -> 'a list
    list_to_front i l resorts the list l by bringing the element at index i to the front.

val undo_list_to_front : int -> 'a list -> 'a list
    undo_list_to_front i l resorts the list l by moving the head element to index index i It's
    the inverse of list_to_front i l.

val split_after : int -> 'a list -> 'a list * 'a list
    split_after n l splits the first n elements from list l, i.e. it returns two lists l1 and l2,
    with length l1 = n and l1 @ l2 = l. Fails if n is too small or large.

val list_firstn : int -> 'a list -> 'a list
    list_firstn n l gets the first n elements from list l, i.e. it does the same as fst
    (split_after n l). It fails if n is too small or large.

val list_dropn : int -> 'a list -> 'a list
    list_dropn n l drops the first n elements from list l, i.e. it does the same as snd
    (split_after n l). It fails if n is too small or large.

val list_dest_snoc : 'a list -> 'a list * 'a
    list_dest_snoc l splits the last entry off a list. This means that list_dest_snoc (l @
    [x]) returns (l, x). It raises a Failure "list_dest_snoc" exception, if the list l is empty.

val list_pick : ('a -> bool) -> 'a list -> ('a * 'a list) option
    list_pick p l tries to pick the first element from l that satisfies predicate p. If such an
    element is found, it is returned together with the list l where this element has been removed.

val compare_list : ('a -> 'b -> int) -> 'a list -> 'b list -> int

```

### 38.3 Files

```
val copy_file : string -> string -> unit
    copy_file src dst copies file src to file dst. Only files are supported, no directories.

val move_file : string -> string -> unit
    move_file src dst moves file src to file dst. In contrast to Sys.rename no error is
    produced, if dst already exists. Moreover, in case Sys.rename fails for some reason (e.g.
    because it does not work over filesystem boundaries), copy_file and Sys.remove are used
    as fallback.

val same_content_files : string -> string -> bool
    same_content_files file1 file2 checks, whether the files file1 and file2 have the
    same content. If at least one of the files does not exist, false is returned.
    same_content_files throws an exception, if one of the files exists, but cannot be read.

val absolute_dir : string -> string option
    absolute_dir dir tries to get the absolute path name of directory dir. If this fails (usually,
    because dir does not exist), None is returned.

val dir_eq : string -> string -> bool
    dir_eq d1 d2 uses absolute_dir to check whether the two directories are equal.
```

### 38.4 Strings

```
val string_to_list : string -> char list
    string_to_list l translates the string l to the list of its characters.

val string_for_all : (char -> bool) -> string -> bool
    string_for_all p s checks whether all characters of s satisfy p.

val is_simple_ident_string : string -> bool
    is_simple_ident_string s checks whether s is a "simple" identifier. The meaning of
    simple is fuzzy. Essentially it means that s can be used by all backends. Currently the
    restricting is that s is non-empty, starts with a letter and contains only letters, numbers and
    underscores.

val string_split : char -> string -> string list * string
    string_split c string splits the string into a list of strings on occurrences of the char c.
    The last remaining string is handed out separately. This encodes, that the resulting string
    list is never empty

val uncapitalize_prefix : string -> string
```

`uncapitalize_prefix n` tries to uncapitalize the first few letters of `n`. In contrast to `uncapitalize`, it continues with the next letter, till a non-uppercase letter is found. The idea is to produce nicer looking names when uncapitalizing. Turning `UTF8.lem` into `utf8Script.sml` for example is strange and `utf8Script.sml` looks nicer.

```
val string_map : (char -> char) -> string -> string
    string_map f s maps f over all characters of a copy of s. It corresponds to String.map,
    which is unluckily only available for OCaml 4

val message_singular_plural : string * string -> 'a list -> string
    message_singular_plural (sing_message, multiple_message) l is used to determine
    whether the singular or plural form should be used in messages. If the list l contains no
    elements or exactly one element, sing_message is returned. Otherwise, i.e. for multiple
    elements, the result is multiple_message.

val fresh_string : string list -> string -> string
    fresh_string forbidden generates a stateful function gen_fresh that generates fresh
    strings. gen_fresh s will return a string similar to s that has never been returned before
    and is not part of forbidden. By storing the result in internal state, it is ensured that the
    same result is never returned twice. This function is used for example to generate unique
    labels.
```

## 38.5 Useful Sets

```
module StringSet :
    Set.S with type elt = string
    Sets of Integers

module IntSet :
    Set.S with type elt = int

module IntIntSet :
    Set.S with type elt = int * int

module ExtraSet :
    functor (S : Set.S) -> sig

        val add_list : S.t -> S.elt list -> S.t
            Add a list of values to an existing set.

        val remove_list : S.t -> S.elt list -> S.t
            Removes a list of values to an existing set.

        val from_list : S.elt list -> S.t
            Construct a set from a list.
```

```
val list_union : S.t list -> S.t
    Builds the union of a list of sets

val list_inter : S.t list -> S.t
    Builds the intersection of a list of sets. If the list is empty, a match exception is thrown.

end

Some useful extra functions for sets
```