**Deutsches
Forschungszentrum
für Künstliche
Intelligenz GmbH**

Document
D-94-14

TDL
A Type Description Language for HPSG
Part 2: User Guide

Hans-Ulrich Krieger, Ulrich Schäfer

December 1994

Deutsches Forschungszentrum für Künstliche Intelligenz GmbH

Postfach 20 80
67608 Kaiserslautern, FRG
Tel.: + 49 (631) 205-3211
Fax: + 49 (631) 205-3210

Stuhlsatzenhausweg 3
66123 Saarbrücken, FRG
Tel.: + 49 (681) 302-5252
Fax: + 49 (681) 302-5341

Deutsches Forschungszentrum für Künstliche Intelligenz

The German Research Center for Artificial Intelligence (Deutsches Forschungszentrum für Künstliche Intelligenz, DFKI) with sites in Kaiserslautern and Saarbrücken is a non-profit organization which was founded in 1988. The shareholder companies are Atlas Elektronik, Daimler-Benz, Fraunhofer Gesellschaft, GMD, IBM, Insiders, Mannesmann-Kienzle, Sema Group, Siemens and Siemens-Nixdorf. Research projects conducted at the DFKI are funded by the German Ministry for Research and Technology, by the shareholder companies, or by other industrial contracts.

The DFKI conducts application-oriented basic research in the field of artificial intelligence and other related subfields of computer science. The overall goal is to construct systems with technical knowledge and common sense which - by using AI methods - implement a problem solution for a selected application area. Currently, there are the following research areas at the DFKI:

- Intelligent Engineering Systems
- Intelligent User Interfaces
- Computer Linguistics
- Programming Systems
- Deduction and Multiagent Systems
- Document Analysis and Office Automation.

The DFKI strives at making its research results available to the scientific community. There exist many contacts to domestic and foreign research institutions, both in academy and industry. The DFKI hosts technology transfer workshops for shareholders and other interested groups in order to inform about the current state of research.

From its beginning, the DFKI has provided an attractive working environment for AI researchers from Germany and from all over the world. The goal is to have a staff of about 100 researchers at the end of the building-up phase.

Dr. Dr. D. Ruland
Director

TDL
A Type Description Language for HPSG
Part 2: User Guide

Hans-Ulrich Krieger, Ulrich Schäfer

DFKI-D-94-14

This work has been supported by a grant from The Federal Ministry for Research and Technology (FKZ ITWM-9002 0).

ISSN 0946-0098

TDL
A Type Description Language for HPSG
Part 2: User Guide

Hans-Ulrich Krieger, Ulrich Schäfer
{krieger, schaefer}@dfki.uni-sb.de
German Research Center for Artificial Intelligence (DFKI)
Stuhlsatzenhausweg 3
D-66123 Saarbrücken, Germany

Abstract

This documentation serves as a user's guide to the type description language *TDL* which is employed in natural language projects at the DFKI. It is intended as a guide for grammar writers rather than as a comprehensive internal documentation. Some familiarity with grammar formalisms/theories such as Head-Driven Phrase Structure Grammar (HPSG) is assumed. The manual describes the syntax of the *TDL* formalism, the user-accessible control functions and variables, and the various tools such as type grapher, feature editor, *TDL*2LaTeX, `Emacs` *TDL* mode, and print interface[1].

[1] We would like to thank Elizabeth Hinkelman for reading a draft version of this manual.

Contents

1 Introduction

This is the second part of *TDL – A type description language for HPSG*. This documentation serves as a user guide to *TDL*. It is intended as a guide for grammar writers rather than as a comprehensive internal documentation. Some familiarity with grammar formalisms theories such as Head-Driven Phrase Structure Grammar [Pollard & Sag 87; Pollard & Sag 94] is assumed. The manual describes the syntax of the *TDL* formalism, the user accessible control functions and variables, and the various tools such as type grapher, feature editor, *TDL*2LaTeX, `Emacs` *TDL* mode, and print interface.
For motivation, architecture, properties of the type hierarchy, implementational issues and comparison to related systems, refer to [Krieger & Schäfer 93a], [Krieger & Schäfer 94a], [Krieger & Schäfer 94b], [Krieger 95], and [Schäfer 95].
The *TDL* system is integrated into various natural language systems such as DISCO [Uszkoreit et al. 94], and PRACMA [Jameson et al. 94].

Corrections and other information can be ftp'd from `ftp://cl-ftp.dfki.uni-sb.de:/pub/tdl`.
World Wide Web: (publications, software, etc.): `http://cl-www.dfki.uni-sb.de/`
Email: `tdl@dfki.uni-sb.de`

2 The *TDL* System

The *TDL* distribution includes COMMON LISP source files in the following directories, which correspond to the modules of the system definition.

Directory	Module	Package
`tdl/compile/`	compile	`TDL-COMPILE`
`tdl/control/`	control	`TDL`
`tdl/elisp/`	`Emacs` lisp files	–
`tdl/encode/`	hierarchy	`TDL-HIERARCHY`
`tdl/expand/`	expand	`TDL`
`tdl/grapher/`	*TDL* Grapher system	`CLIM-USER`
`tdl/packages/`	package definitions	`CL-USER`
`tdl/parse/`	parse	`TDL-PARSE`
`tdl/recycler/`	*TDL* Recycler system	`TDL-RECYCLER`
`tdl/simplify/`	simplify	`TDL-SIMPLIFY`
`tdl/statistics/`	statistics	`TDL-STATISTICS`

The *TDL* system depends on the systems ZEBU (LALR(1) parser), *UDiNe* (unifier) and FEGRAMED (feature editor). The *TDL* Recycler is a tool which translates grammar files from *TDLExtraLight* [Krieger & Schäfer 93b] into the new *TDL* syntax. *TDL*2LaTeX and *TDL* Grapher are part of the *TDL* system.
The system is implemented in portable COMMON LISP [Steele 90] and has been tested with Franz Allegro Common Lisp, Macintosh Common Lisp, Lucid Common Lisp, and CLISP[2].

3 Starting *TDL*

To start *TDL*,

1. Start COMMON LISP.
2. `(load-system "tdl")`[3] loads necessary parts of *TDL* such as the unifier *UDiNe*, type definition reader, feature editor (FEGRAMED), type hierarchy management and the *TDL*2LaTeX interface. Alternatively, `(load-system "tdl-grapher")` can be used to start system `tdl` *and* the type grapher. The portable system definition facility DEFSYSTEM is described in [Kantrowitz 91].

[2] Thanks to Stephan Oepen and Bernd Kiefer for checking and improving portability.
[3] The availability of this function presupposes that the DISCO loadup environment (file loadup.lisp) has been successfully loaded into the COMMON LISP system. Refer to the DISCO installation and operation guide for details.

3. After loading the LISP code, the following prompt appears on the screen:

```
        Welcome to the Type Description Language TDL.

USER(2): _
```

4. The $\mathcal{TDL}$ reader is invoked by simply typing `(tdl)`. You can either work interactively (e.g., create a domain, define types, etc.) or load $\mathcal{TDL}$ grammar files by using the `include` command. If an error has occurred, e.g., a syntax error, `(tdl)` restarts the $\mathcal{TDL}$ reader.

5. `ldt` exits the $\mathcal{TDL}$ reader and returns to COMMON LISP. The COMMON LISP function `(EXIT)` quits the interpreter. If you are in an `Emacs` environment, `C-x C-c` kills the `Emacs` process.

It is also possible to define one's own portable system definitions in the [Kantrowitz 91] paradigm which could then automatically start $\mathcal{TDL}$ and include grammar definitions, etc.

4 Syntax of $\mathcal{TDL}$

The $\mathcal{TDL}$ syntax provides type definitions, instance definitions (for rules and lexicon entries), templates (parameterized macros), specification of declarative control information, as well as *statements* (calls to built-in functions) that are especially useful for the interactive development of NL grammars.
There is no difference between the syntax of $\mathcal{TDL}$ grammar files and the syntax for the interactive mode. All syntactic constructs can be used in either mode.
Note that the arguments of statements need to be quoted if they are symbols or lists containing symbols. This is necessary if the statement is defined as a COMMON LISP function, but not if the statement is defined as a COMMON LISP macro. Almost all statements are defined as functions. The only macros defined by the $\mathcal{TDL}$ system are `defcontrol`, `leval`, `alias`, `print-control`, `print-switch`, `set-switch`, and `with-print-mode`. Examples:

```
pgp 'agr-type :label-hide-list '(x y z).
```

– but:

```
defcontrol agr-type ((:delay (u *) (v x.y))).
```

It is important not to forget the dot delimiter at the end of $\mathcal{TDL}$ expressions since the $\mathcal{TDL}$ reader will wait for it. It is possible to mix LISP code and $\mathcal{TDL}$ definitions in a file. Some examples are shown in Section 4.3.
Newline characters, spaces or comments (Section 4.12) can be inserted anywhere between tokens (symbols, braces, parentheses, etc.).

4.1 $\mathcal{TDL}$ BNF

The $\mathcal{TDL}$ syntax is given in extended BNF (Backus-Naur Form). Terminal symbols (characters to be typed in) are printed in `typewriter` style. Nonterminal symbols are printed in *italic* style. The grammar starts with the *start* production. The following table explains the meanings of the metasymbols used in extended BNF.

metasymbols	**meaning**
$\ldots \mid \ldots$	alternative expressions
$[\ \ldots\ ]$	one optional expression
$[\ \ldots \mid \ldots \mid \ldots\ ]$	one or none of the expressions
$\{\ \ldots \mid \ldots \mid \ldots\ \}$	exactly one of the expressions
$\{\ \ldots\ \}^*$	n successive expressions, where $n \in \{0, 1, \ldots\}$
$\{\ \ldots\ \}^+$	n successive expressions, where $n \in \{1, 2, \ldots\}$

4.1.1 TDL Main Constructors

start → {*block* | *statement*}*

block → `begin :control.` { *type-def* | *instance-def* | *start* }* `end :control.` |
`begin :declare.` { *declare* | *start* }* `end :declare.` |
`begin :domain` *domain*`.` {*start*}* `end :domain` *domain*`.` |
`begin :instance.` { *instance-def* | *start* }* `end :instance.` |
`begin :lisp.` {*Common-Lisp-Expression*}* `end :lisp.` |
`begin :template.` { *template-def* | *start* }* `end :template.` |
`begin :type.` { *type-def* | *start* }* `end :type.`

4.1.2 Type Definitions

type-def → *type* { *avm-def* | *subtype-def* } .
type → *identifier*
avm-def → `:=` *body* {`,` *option*}* |
`!=` *nonmonotonic* [`where (` *constraint* {`,` *constraint*}* `)`] {`,` *option*}*
body → *disjunction* [`-->`*list*] [`where (` *constraint* {`,` *constraint*}* `)`]
disjunction → *conjunction* { {`|` | `^`} *conjunction* }*
conjunction → *term* { `&` *term* }*
term → *type* | *atom* | *feature-term* | *diff-list* | *list* | *coreference* |
distributed-disj | *templ-par* | *templ-call* | `~`*term* | `(` *disjunction* `)`
atom → *string* | *integer* | `'`*identifier*
feature-term → `[` [*attr-val* {`,` *attr-val*}*] `]`
attr-val → *attribute* [`:`*restriction*] {`.` *attribute* [`:`*restriction*] [*disjunction*]}*
attribute → *identifier* | *templ-par*
restriction → *conj-restriction* { {`|` | `^`} *conj-restriction* }*
conj-restriction → *basic-restriction* { `&` *basic-restriction* }*
basic-restriction → *type* | `~`*basic-restriction* | *templ-par* | `(` *restriction* `)`
diff-list → `<!` [*disjunction* {`,` *disjunction*}*] `!>` [`:` *type*]
list → `<>` | `<` *nonempty-list* `>` [*list-restriction*]
nonempty-list → [*disjunction* {`,` *disjunction*}* `,`] `...` |
disjunction {`,` *disjunction*}* [`.` *disjunction*]
list-restriction → `:` `(` *restriction* `)` | `:` *type* [`:` `(`*integer*`,` *integer*`)` | `:` *integer*]
coreference → `#`*coref-name* | `~#(` *coref-name* {`,` *coref-name*}* `)`
coref-name → *identifier* | *integer*
distributed-disj → `%`*disj-name* `(` *disjunction* {`,` *disjunction*}+ `)`
disj-name → *identifier* | *integer*
templ-call → `@`*templ-name* `(` [*templ-par* {`,` *templ-par*}*] `)`
templ-name → *identifier*
templ-par → `$`*templ-var* [`=` *disjunction*]
templ-var → *identifier* | *integer*
constraint → `#`*coref-name* `=` { *function-call* | *disjunction* }
function-call → *function-name* `(` *disjunction* {`,` *disjunction*}* `)`
function-name → *identifier*
nonmonotonic → *type* `&` `[` *overwrite-path* {`,` *overwrite-path*}* `]`
overwrite-path → *identifier* { `.` *identifier* }* *disjunction*
subtype-def → { `:<` *type* }+ {`,` *option*}*
option → `status:` *identifier* | `author:` *string* | `date:` *string* | `doc:` *string* |
`expand-control:` *expand-control*

expand-control → ([(:expand { ({*type* | (*type* [*index* [*pred*]])} {*path*}+) }*) |
(:expand-only { ({*type* | (*type* [*index* [*pred*]])} {*path*}+) }*)] |
[(:delay { ({*type* | (*type* [*pred*])} {*path*}+) }*)] |
[(:maxdepth *integer*)] |
[(:ask-disj-preference {t | nil})] |
[(:attribute-preference {*identifier*}*)] |
[(:use-conj-heuristics {t | nil})] |
[(:use-disj-heuristics {t | nil})] |
[(:expand-function {depth | types} -first-expand)] |
[(:resolved-predicate {resolved-p | always-false | ...})] |
[(:ignore-global-control {t | nil})])
path → {*identifier* | *pattern*} {. {*identifier* | *pattern*}}*
pattern → ? | * | + | ?[*identifier*][?|*|+]
pred → eq | subsumes | extends | ...

4.1.3 Instance Definitions

instance-def → *instance avm-def* .
instance → *identifier*

4.1.4 Template Definitions

template-def → *templ-name* ([*templ-par* {, *templ-par*}*]) := *body* {, *option*}* .

4.1.5 Declarations

declaration → *partition* | *incompatible* | *sort-def* | *built-in-def* |
hide-attributes | *hide-values* | *export-symbols*
partition → *type* = *type* { {| | ^} *type* }* .
incompatible → nil = *type* {& *type*}+ .
sort-def → sort[s] : *type* {, *type*}* .
built-in-def → built-in[s] : *type* {, *type*}* .
hide-attributes → hide-attribute[s] : *identifier* {, *identifier*}* .
hide-values → hide-value[s] : *identifier* {, *identifier*}* .
export-symbols → export-symbol[s] : *identifier* {, *identifier*}* .

4.1.6 Statements

statement → `check-welltypedness` [{*type* | *instance* | `:all`} [{`:instances` | `:avms`} [`:domain` *domain*] [`:index` *index*] [`:verbose` {`t` | `nil`}]]] . |
`clear-simplify-memo-tables` [`:domain` *domain*] [`:threshold` *integer*] . |
`compute-approp` [`:domain` *domain*] [`:warn-if-not-unique` {`t` | `nil`}] . |
`defcontrol` { `:global` | *type* | *instance* } *expand-control* [`:index` *index*] . |
`defdomain` *domain* {*defdomain-option*}* . |
`deldomain` *domain* . |
`defreadermacro` *identifier* {*string* | `nil`} [*string*] . |
`delete-all-instances` [*domain*] . |
`delete-instance` [*instance* [`:domain` *domain*] [`:index` *integer*]] . |
`delete-type` [*type* [`:domain` *domain*]] . |
`describe-template` *templ-name* [domain] . |
`do-all-infons` {*infon-keys*}* . |
`do-infon` {*infon-keys*}* . |
`expand-all-instances` {*expand-option*}* . |
`expand-all-types` {*expand-option*}* . |
`expand-instance` [*instance* [`:index` *integer*] {*expand-option*}*] . |
`expand-type` [*type* [`:index` *index*] {*expand-option*}*] . |
`fegramed` . |
{ `fgi` | `fli` } [*instance* {*fegramed-option*}*] . |
{ `fgp` | `flp` } [*type* {*fegramed-option*}*] . |
`get-switch` *identifier* . |
`grapher` . |
`help` [*identifier*] . |
`include` *filename* . |
`ldt` . |
`leval` *Common-Lisp-Expression* . |
{ `lgi` | `lli` } [*instance* {*latex-option*}*] . |
{ `lgp` | `llp` } [*type* {*latex-option*}*] . |
`message` *string* {*Common-Lisp-Expression*}* . |
`load-simplify-memo-table` [`:domain` *domain*] [`:filename` *filename*] . |
{ `pgi` | `pli` } [*instance* {*print-option*}*] . |
{ `pgp` | `plp` } [*type* {*print-option*}*] . |
`print-all-names` {*infon-keys*}* . |
`print-all-statistics` [`:domain` *domain*] [`:stream` *stream*] . |
`print-approp` [`:domain` *domain*] . |
`print-control` { *type* | *instance* | `:global` } . |
`print-domain-statistics` [`:domain` *domain*] [`:stream` *stream*] . |
`print-expand-statistics` [`:domain` *domain*] [`:stream` *stream*] . |
`print-global-statistics` [`:stream` *stream*] . |
`print-recursive-sccs` [`:domain` *domain*] . |
`print-simplify-memo-tables` [`:domain` *domain*] [`:stream` *stream*] [`:threshold` *integer*] . |
`print-simplify-statistics` [`:domain` *domain*] [`:stream` *stream*] . |
`print-switch` *identifier* . |
`print-unified-types` [`:filename` *string*] [`:domain` *domain*] . |
`recompute` . |
`reset-all-instances` [*domain*] . |
`reset-all-protos` [*domain*] . |
`reset-all-statistics` [`:domain` *domain*] . |
`reset-domain-statistics` [`:domain` *domain*] . |

`reset-expand-statistics` [`:domain` *domain*] . |
`reset-global-statistics`. |
`reset-instance` [*instance* [`:domain` *domain*] [`:index` *integer*]] . |
`reset-print-mode`. |
`reset-proto` [*type* [`:domain` *domain*] [`:index` *index*]] . |
`reset-simplify-statistics` [`:domain` *domain*] . |
`restore-print-mode`. |
`save-print-mode`. |
`set-print-mode` [*print-mode*] . |
`set-switch` *identifier Common-Lisp-Expression* . |
`start-collect-unified-types` [`:domain` *domain*] . |
`tune-types` [`:domain` *domain*] [`:threshold` *integer*] [...] . |
`wait`. |
`with-print-mode` *print-mode Common-Lisp-Expression* .

infon-keys → see Section 5.8

print-option → `:domain` *domain* | `:index` *index* | `:stream` {`t` | `nil` | *stream*} |
`:label-sort-list` (*{identifier}**) | `:label-hide-list` (*{identifier}**) |
`:remove-tops` {`t` | `nil`} | `:init-pos` *integer*

latex-option → `:domain` *domain* | `:index` *index* | `:hide-types` {`t` | `nil`} |
`:filename` *filename* | ... (see Section 5.18.3)

fegramed-option → `:domain` *domain* | `:index` *index* |
`:filename` *filename* | `:wait` {`t` | `nil`} | `:file-only` {`t` | `nil`}

defdomain-option → `:hide-attributes` ({*identifier*}*) |
`:hide-values` ({*identifier*}*) |
`:export-symbols` ({*identifier*}*) |
`:documentation` *string* |
`:top` *type* |
`:bottom` *type* |
`:load-built-ins-p` {`t` | `nil`} |
`:errorp` {`t` | `nil`}

expand-option → `:domain` *domain* |
`:expand-control` *expand-control*

domain → `'`*identifier* | `:`*identifier* | `"`*identifier*`"`

print-mode → `:debug` | `:default` | `:exhaustive` | `:fs-nll` | `:hide-all` |
`:hide-types` | `:read-in` | `:tdl2asl` | `:x2morf`

filename → *string*

index → *integer* for instances
integer | *identifier string* for avm types

integer → {`0`|`1`|`2`|`3`|`4`|`5`|`6`|`7`|`8`|`9`}+

identifier → {`a`–`z`|`A`–`Z`|`0`–`9`|`_`|`+`|`-`|`*`|`?`}+

string → `"`{*any character*}*`"`

4.2 Creating and Changing Domains

Domains are sets of type, instance and template definitions. It is possible to define and use several domains at the same time and to have definitions with the same names in different domains. Domains roughly correspond to packages in COMMON LISP (in fact, they are implemented using the package system).
An arbitrary keyword symbol or string may be chosen for *domain* except those which are names of existing COMMON LISP packages, e.g. `TDL`, `COMMON-LISP` or `COMMON-LISP-USER`. All domain names will be normalized into strings containing only uppercase characters.
The name `TDL` is reserved for internal functions and variables. It is possible to specify the domain of the current definition by using the `begin :domain` *domain* and `end :domain` *domain* block delimiters (see Sections 4.3 and 4.4).

- function `defdomain` *domain* [`:hide-attributes` *attribute-list*]
  [`:hide-values` *values-list*]
  [`:export-symbols` *symbol-list*]
  [`:documentation` *doc-string*]
  [`:top` *top-symbol*]
  [`:bottom` *bottom-symbol*]
  [`:load-built-ins-p` {`t` | `nil`}]
  [`:errorp` {`t` | `nil`}]

  creates a new domain *domain* (a symbol or a string). Options:
  values-list is a list of attributes whose values will be hidden at definition time. *attribute-list* is a list of attributes that will be hidden (including their values) at definition time. *symbol-list* is a list of symbols to be exported from the domain package. These three symbol lists can also be declared in the `:declare` part (cf. Section 4.5). If `:load-built-ins-p t` is specified, the standard file of TDL built-in types will be included, otherwise, nothing will be loaded. The default is `t`.
  `:top` and `:bottom` define the name of the top and bottom symbol; the default is the value of the global variables `*TOP-SYMBOL*` and `*BOTTOM-SYMBOL*`. A domain can be given documentation using the `:documentation` keyword; its value must be a string. If `:errorp t` is specified, it will cause error to redefine a domain. If the value of `:errorp` is `nil` (default), only a warning will be given. Example:

  ```
  <TDL> defdomain :MY-DOMAIN :load-built-ins-p nil.
  #<DOMAIN MY-DOMAIN>
  <TDL>
  ```

- function `deldomain` *domain* [`:errorp` {`t` | `nil`}] [`:delete-package-p` {`t` | `nil`}]
  deletes domain *domain* (symbol or string), which includes all type, instance, and template definition as well as the corresponding package with package name *domain*, including all symbols defined in this package. If `:errorp t` is specified, using an undefined domain name will cause an error. If `:errorp nil` is specified (default), a warning will be given and the current domain will not be changed. If `:delete-package-p t` is specified, the corresponding package will be deleted. Otherwise (default), only all domain-specific information (type definitions, global hashtables etc.) will be deleted. Example:

  ```
  <TDL> deldomain :MY-DOMAIN.
  <TDL>
  ```

Definitions from the standard `tdl-built-ins.tdl` file are shown below. They will be included automatically if `:load-built-ins-p t` (which is also the default) is specified in `defdomain`.

```
begin :declare.
  built-in:  fixnum, bignum, integer. ;;; only COMMON LISP types can be
  built-in:  atom, string, symbol.    ;;; declared as built-ins
  sort:  *null*.                      ;;; is the type of the empty list <>
  sort:  *built-in*.                  ;;; the top built-in type
  sort:  *sort*.                      ;;; the top sort type
  sort:  *undef*.                     ;;; make *undef* a sort in order to
                                      ;;; exclude features defined on it
end :declare.

begin :type.
  *avm* := [ ].                       ;;; the top avm type
  atom    :< *built-in*.              ;;; now specify the subtype
  integer :< atom.                    ;;; relation for the built-ins
  fixnum  :< integer.
  bignum  :< integer.
  symbol  :< atom.
```

```
  string  :< atom.
  *null*  :< *built-in*.              ;;; although *null* is not a real
  *cons* := *avm* & [FIRST, REST].    ;;; built-in, make it a subtype of
  *list* := *null* | *cons*.          ;;; *built-in*
  *diff-list* := *avm* & [LIST, LAST].

  dl-append := *avm* & [ARG1 [LIST #first,     ;;; difference list
                              LAST #between],  ;;; version of APPEND
                        ARG2 [LIST #between,
                              LAST #last],
                        RES  [LIST #first,
                              LAST #last]].

  *rule* :=                    ;;; the most general rule type
    [ ]  -->  < ... >,         ;;; use [] instead of *top*, because *top*
    status: RULE.              ;;; is only the default top symbol which
  unary-rule :=                ;;; can be overwritten through DEFDOMAIN
    *rule*  -->  < [ ] >.      ;;; :top <top>
  binary-rule :=               ;;; moreover, use the 'status' keyword to
    *rule*  -->  < [ ], [ ] >. ;;; let Bernie's parser know about the
  ternary-rule :=              ;;; the special role of *rule*
    *rule*  -->  < [ ], [ ], [ ] >.
end :type.
```

4.3 The Structure of TDL Grammars

A TDL grammar may consist of type definitions, sort declarations, template definitions, instance specifications and control information. In addition, it is possible to mix different domains and LISP code.
The structuring feature in TDL grammars is the `begin` and `end` statement, which is comparable to `BEGIN/END` blocks in PASCAL, or the LaTeX environments.
Environments determine syntactic as well as semantic contexts for different purposes.
Some environments provide the necessary preconditions for enclosed definitions, e.g., the domain environment supports definitions of entire type lattices, the necessary context for type definitions. Others such as the control environment are completely optional.
Another constraint is that template definitions precede the type or instance definitions that contain template calls (cf. macros in programming languages).
Environments can be nested freely (the so-called environment stack keeps track of this) and distributed over different grammar files. The loading of files may also be nested (cf. the `include` documentation).
The TDL prompt indicates the current domain and the current environment. Its general output format is <*domain*:*environment*>, e.g.,

```
<MY-DOMAIN:TEMPLATE> _
```

If no domain is active, the prompt is `<TDL>`.
Typically, a TDL grammar starts with the definition of a domain (`defdomain`), changes to this domain (`begin :domain`), declares sorts (`begin`/`end :declare`), defines templates (`begin`/`end :template`), feature types (`begin`/`end :type`), and, finally, instances (`begin`/`end :instance`).

Example:

```
;;; The structure of tdl grammars. An example.

defdomain :grammar.  ;; this includes a default initial type hierarchy
defdomain :junk-domain :load-built-ins-p NIL.

set-switch *verbose-p* nil. ;; set verbosity
```

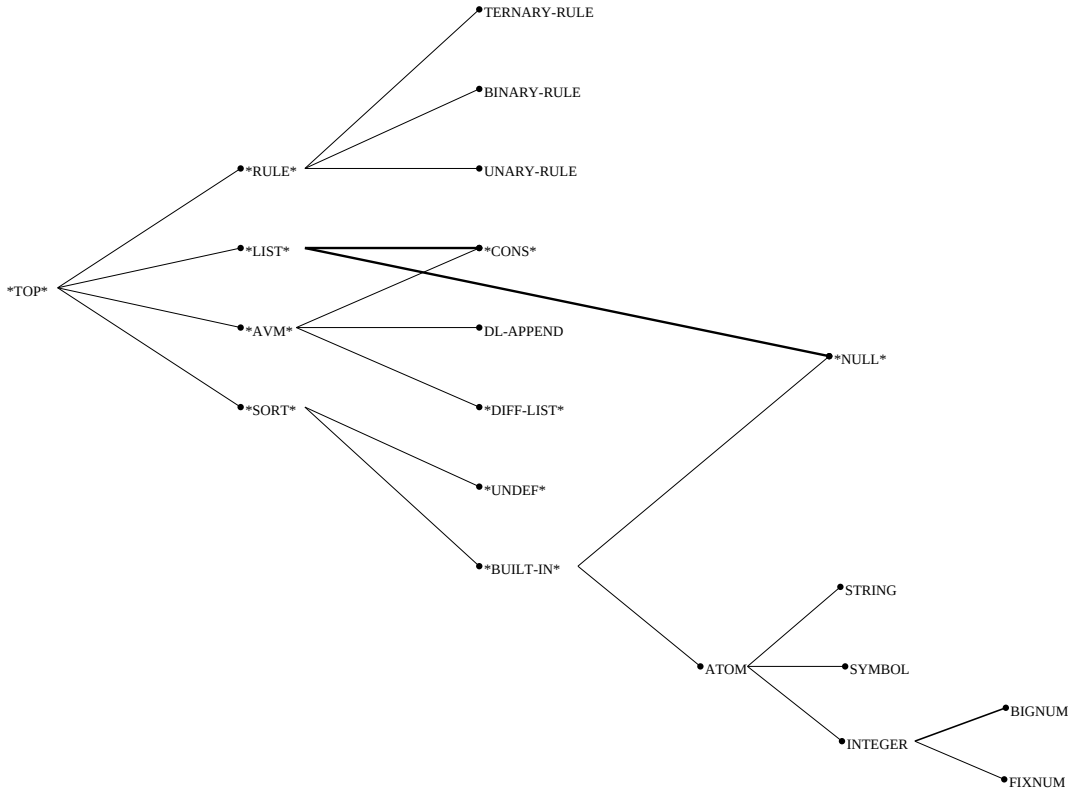


Figure 1: The initial type hierarchy (with `:load-built-ins-p t`)

```
begin :domain :grammar.

;; we start with semantics
  begin :declare.
    include "grammar/semantic-sorts".
    sorts : organism, moveable,nonmoveable,physical,selfmoving,
            nonselfmoving,animated,non-animated,vehicle.
    sign = word ^ phrase.
  end :declare.

  begin :template.  ;; load template definitions
    include "grammar/semantic-templates".
  end :template.

  begin :type.    ;; type definitions
    selfmoving :< moveable :< physical.
    nonmoveable :< physical.
    nonselfmoving :< moveable.
    animated :< moveable.
    non-animated :< moveable.
    organism := selfmoving & animated.
    vehicle := selfmoving & non-animated.
```

```
    include "grammar/semantic-avms".
  end :type.

  begin :instance.
    ;; instance definitions
  end :instance.

;; now we continue with phonology
  begin :declare.
    include "grammar/phonology-declarations".
  end :declare.

  begin :type.
    include "grammar/phonology-avms".
  end :type.

;; now a big syntax package...
  include "grammar/syntax/load-syntax".

;; we finish with bottom declarations
  begin :declare.  ;; bottom declarations
    nil = *undef* & *avm*.
    nil = *undef* & *built-in*.
  end :declare.

;; now let's expand all instances
expand-all-instances.

message "grammar loading done.".

end :domain :grammar.
```

4.4 Domain Environment

A domain environment starts with

`begin :domain` *domain*.

and ends with

`end :domain` *domain*.

domain must be the name of a previously defined domain, i.e., a quoted symbol, a string or a keyword symbol. `begin :domain` pushes *domain* to the global stack `*DOMAIN*`, while `end :domain` pops it. Arbitrary $\mathcal{TDL}$ statements or other environments may be enclosed by the domain environment.
All symbols (sort, type, template, instance names) occurring between `begin :domain` *domain* and `end :domain` *domain* are defined or looked up in *domain*.
All other environments except the `:lisp` environment must be enclosed by at least one domain environment. See Section 4.2 for more details.

4.5 Declare Environment and Declarations

A declare environment starts with

`begin :declare.`

and ends with

`end :declare.`

It may appear anywhere within a domain environment, and may contain arbitrary declarations, other environments and $\mathcal{TDL}$ statements.
Declare environments declare

- built-in sort symbols: `built-in[s]` : *type* { , *type*}* .
  `built-in` declares a COMMON LISP type to be a sort in $\mathcal{TDL}$, e.g., `integer`, `string`, etc. A `built-in` sort can be unified only with its subsorts or with an atom that has the corresponding COMMON LISP type. An example is shown in section 4.6.2. Note that the standard $\mathcal{TDL}$ type `*built-in*` itself is an ordinary sort but is not declared to be a built-in type. Its only purpose is to be the super-sort of all predefined sorts in $\mathcal{TDL}$ such as `*null*` and the atomic sorts, e.g., `atom`, `string`, etc.

- sort symbols: `sort[s]` : *type* { , *type*}* .
  `sort` declares types to be sorts (singleton sorts in Smolka's terminology). Sorts always live in a closed world, i.e., their unification fails unless they subsume each other or have a greatest lower bound. This declaration is optional. It is equivalent to the definition *type* `:< *sort*.` in the `:type` environment which may be faster at definition time in the current implementation.

- incompatible types: `nil` = *type* { `&` *type*}+ .
  declares the types to be incompatible. This declaration is useful for avm types in an open world (i.e., if `*AND-OPEN-WORLD-REASONING-P*` has value `t`).

- exhaustive partitions: *supertype* = *type* { `|` *type* }* .
  declares an exhaustive partition (cf. [Krieger & Schäfer 94a]).

- disjoint exhaustive partitions: *supertype* = *type* { `^` *type* }* .
  declares an exhaustive disjoint partition (cf. [Krieger & Schäfer 94a]).

All other relations between types (conjunctions, disjunctions) must be defined in the `:type` environment. The type hierarchy for avm types will be inferred from the avm type definitions.
In addition, the following domain specific symbol lists can also be declared in this environment (cf. Section 4.2).

- `hide-value[s]` : *identifier* { , *identifier*}* .
  specifies the attributes whose values are to be hidden at definition time,

- `hide-attribute[s]` : *identifier* { , *identifier*}* .
  specifies the attributes (including their values) to be hidden at definition time,

- `export-symbol[s]` : *identifier* { , *identifier*}* .
  specifies the symbols to be exported from the domain package.

All declarations must be specified directly in a declare environment, and nowhere else.

4.6 Type Environment and Type Definitions

A type environment starts with

```
begin :type.
```

and ends with

```
end :type.
```

It may appear anywhere within a domain environment, and may contain arbitrary type definitions, other environments and $\mathcal{TDL}$ statements. The syntax for subsort and subtype definitions is

type { `:<` *type* }+ { , *option*}*.

Subsort or subtype definitions define the order of sorts or types without feature constraints. They are not necessary if feature constraints are specified for a subtype. Example:

```
*avm* :< *top*.
```

but

```
*cons* := *avm* & [ first, rest ].
```

In both cases, the left hand side is a subtype of the right hand side type.
The general syntax of type definitions[4] is

type := *body* {, *option*}* .

type is a symbol, the name of the type to be defined. The complex BNF syntax of *body* is given in Section 4.1.2. Some examples are presented on the following pages.

4.6.1 Feature Structure Definitions

The $\mathcal{TDL}$ syntax for a feature structure type *person-number-type* with attributes `PERSON` and `NUMBER` is

```
person-number-type := [ PERSON, NUMBER ].
```

The definition results in the structure

$$\begin{bmatrix} \textit{person-number-type} \\ \text{PERSON } [\,] \\ \text{NUMBER } [\,] \end{bmatrix}$$

If no value is specified for an attribute, the empty feature structure with the top type of the type hierarchy will be assumed. Attribute values can be atoms, feature structures, disjunctions, distributed disjunctions, coreferences, lists, functional constraints, template calls, or negated values.

4.6.2 Atoms

In $\mathcal{TDL}$, an atom can be a number, a string or a symbol. Symbols must be quoted with a single quote `'` (otherwise they will be interpreted as sorts or avm types). Atoms can be used as values of attributes or as disjunction elements.
Example: The $\mathcal{TDL}$ type definition

```
pl-3-phon := [ NUMBER 'plural,
               PHON   "-en",
               PERSON 3 ].
```

results in the structure

$$\begin{bmatrix} \textit{pl-3-phon} \\ \text{NUMBER } \texttt{plural} \\ \text{PHON } \texttt{"-en"} \\ \text{PERSON } \texttt{3} \end{bmatrix}$$

An example of atoms as disjunctive elements is shown in Section 4.6.9.
Atoms are not ordered hierarchically (as is the case for sorts). An atom only unifies with itself, the top type of the type hierarchy or, if defined, with a built-in sort of an appropriate data type, i.e., integer atoms unify with the built-in sorts *integer* and *number*, the string atoms unify with the built-in sort *string*, symbolic atoms unify with the built-in sort *symbol*. These three sorts are defined in the standard built-in file `tdl-built-ins.tdl`. Built-in sorts may also be user-defined. One need only define an appropriate COMMON LISP type, e.g.

```
begin :lisp.
  (DEFTYPE Even-Integer () '(AND INTEGER (SATISFIES EVENP)))
end :lisp.
begin :declare.
  built-in : Even-Integer.
end :declare.
```

These lines define a COMMON LISP type `Even-Integer` and declare it as a built-in sort in $\mathcal{TDL}$. This sort unifies only with even integer atoms.

[4] For nonmonotonic definitions see section 4.6.17.

4.6.3 Paths

Paths may be abbreviated using dots between attribute names, e.g.

```
P1 := [ DTRS.HEAD-DTR.CAT.SYN.LOCAL.SUBCAT 'hi ].
```

yields structure

$$\left[\begin{array}{l} \textit{p1} \\ \text{DTRS}\ \left[\text{HEAD-DTR}\ \left[\text{CAT}\ \left[\text{SYN}\ \left[\text{LOCAL}\ \left[\text{SUBCAT}\ \texttt{hi}\right]\right]\right]\right]\right] \end{array}\right]$$

4.6.4 Logical Operators

In $\mathcal{TDL}$, values (atoms, types, feature structures) may be combined by the logical operators `&` (conjunction, unification, inheritance), `|` (disjunction), `^` (exclusive or), and `~` (negation).
These operators may be freely nested, where `~` has highest priority, and `&` binds stronger than `|` and `^`. Parentheses may be used to break this binding or to group operands. Example:

```
l := [a x & (~b | c & [r 1])].
```

Important note for `Emacs` *users*: If you type in the `|` symbol in the emacs lisp mode, you must quote it with a backslash, i.e., `\|`. Otherwise, the `Emacs` lisp mode will wait for another 'closing' `|`. When you are writing grammar file (preferably in $\mathcal{TDL}$ mode, of course), you can omit the backslash.

4.6.5 Type Specification and Inheritance

All conjunctive feature structures can be given a type specification. Type specification at the top level (empty feature path) of a type definition means inheritance from a supertype. The feature definition of the specified type will be unified with the feature term to which it is attached when type expansion takes place. The inheritance relation represents the definitional dependencies of types. Together with multiple inheritance (described in the following section), the inheritance relation can be seen as a directed acyclic graph (DAG).
An example of type specification inside a feature structure definition follows:

```
agr-plural-type := [ AGR person-number-type & [ NUMBER 'plural ] ].
```

Expanding this definition results in the structure

$$\left[\begin{array}{ll} \textit{agr-plural-type} & \\ \text{AGR} & \left[\begin{array}{l} \textit{person-number-type} \\ \text{PERSON}\ [\,] \\ \text{NUMBER}\ \texttt{plural} \end{array}\right] \end{array}\right]$$

Now an example of type inheritance at the top level:

```
pl-type := person-number-type & [ NUMBER 'plural ].
```

Expanding this definition results in the structure

$$\left[\begin{array}{l} \textit{pl-type} \\ \text{PERSON}\ [\,] \\ \text{NUMBER}\ \texttt{plural} \end{array}\right]$$

This feature structure is called the *global prototype* of *pl-type*: an expanded feature structure of a defined type which has (possibly) inherited information from its supertype(s) is called a *global prototype*. A feature

structure consisting only of the local information given by the type definition is called a *local prototype* or *skeleton*. So the *local prototype* of *pl-type* is

$$\begin{bmatrix} \textit{person-number-type} \\ \text{NUMBER } \texttt{plural} \end{bmatrix}$$

Section 5.18 explains how the different prototypes of a defined type can be displayed.
As mentioned above, type specification is optional. If no type is specified, the structure being defined will be assumed to have the top type of the hierarchy.

4.6.6 Multiple Inheritance

Multiple inheritance is possible at any level. A glb (greatest lower bound) type is not required to exist if the global variable `*AND-OPEN-WORLD-REASONING-P*` has value `t`.
Suppose *number-type*, *person-type* and *gender-type* are defined as follows:

```
number-type := [ NUMBER ].
person-type := [ PERSON ].
gender-type := [ GENDER ].
```

Then the $\mathcal{TDL}$ type definition

```
mas-2-type := number-type & person-type & gender-type & [ GENDER 'mas,
                                                          PERSON 2 ].
```

would result in the following structure (after type expansion):

$$\begin{bmatrix} \textit{mas-2-type} \\ \text{GENDER } \texttt{mas} \\ \text{PERSON } 2 \\ \text{NUMBER } [\,] \end{bmatrix}$$

4.6.7 Coreferences

Coreferences indicate information sharing between feature structures. In $\mathcal{TDL}$, coreference symbols may occur anywhere in the value of an attribute. If values are specified, they are attached to the coreference tag by the `&` connector. The order of the elements of such a conjunction does not matter.
A coreference symbol consists of the hash sign `#`, followed by either a number (positive integer) or a symbol. However, in the internal representation and in the printed output of feature structures, the coreference symbols will be normalized to an integer number. Example:

```
share-pn := [ SYN #pn & person-number-type,
              SEM #pn ].
```

results in the following structure (after type expansion):

$$\begin{bmatrix} \textit{share-pn} \\ \text{SYN } \boxed{1} \begin{bmatrix} \textit{person-number-type} \\ \text{PERSON } [\,] \\ \text{NUMBER } [\,] \end{bmatrix} \\ \text{SEM } \boxed{1} \end{bmatrix}$$

4.6.8 Negated Coreferences

Negated coreferences specify that two attributes must not *share* the same value, i.e., they may have the same value, but these values must not be linked to each other by coreferences (they may be type identical but must not be token identical).
The syntax of negated coreferences is

$$\sim\#(a_1, a_2, \ldots a_n)$$

where $a_1, a_2, \ldots a_n$ are coreference symbols, i.e., numbers or symbols, without the hash sign. If $n = 1$, the parentheses can be omitted.
Example: The $\mathcal{TDL}$ definition

```
give := [ RELN give, GIVER ~#(1,2), GIVEN #1, GIVEE #2 ].
```

would result in the following structure:

$$\begin{bmatrix} \textit{give} \\ \text{RELN} \;\; \texttt{give} \\ \text{GIVER} \;\; \neg(\boxed{1}, \boxed{2})[\,] \\ \text{GIVEN} \;\; \boxed{1} \\ \text{GIVEE} \;\; \boxed{2} \end{bmatrix}$$

4.6.9 Simple Disjunctions

Disjunction elements are separated by | (or \| in the `Emacs` interaction mode, cf. Section 4.6.4). Disjunction elements can be atoms, conjunctive feature descriptions, simple disjunctions, distributed disjunctions, lists, template calls or negated values. In simple disjunctions, the alternatives must not contain coreferences to values outside the alternative itself (see [Backofen & Weyers 95] for the reasons).
Distributed disjunctions provide a restricted way to use coreferences to outside disjunction alternatives (Section 4.6.10).
An example of disjunctions in a type definition:

```
person-1-or-2 := [ SYN person-number-type & [ PERSON 1 ] |
                       person-number-type & [ PERSON 2 ] ].
```

The resulting feature structure is

$$\begin{bmatrix} \textit{person-1-or-2} \\ \text{SYN} \left\{ \begin{bmatrix} \textit{person-number-type} \\ \text{PERSON} \;\; 1 \end{bmatrix} \right. \\ \qquad\quad \left. \begin{bmatrix} \textit{person-number-type} \\ \text{PERSON} \;\; 2 \end{bmatrix} \right\} \end{bmatrix}$$

Another more local specification of the same disjunction would be

```
person-1-or-2 := [ SYN person-number-type & [ PERSON 1 | 2 ] ].
```

The resulting feature structure is

$$\begin{bmatrix} \textit{person-1-or-2} \\ \text{SYN} \begin{bmatrix} \textit{person-number-type} \\ \text{PERSON} \left\{ \begin{array}{l} 1 \\ 2 \end{array} \right\} \end{bmatrix} \end{bmatrix}$$

Disjunctions at the top level of a type definition introduce disjunctive types (depicted as bold edges in the $\mathcal{TDL}$ grapher). Arbitrary combinations of sorts, atoms, and feature structure types are allowed. Example:

```
*list* := *null* | *cons*.  ;; where *null* is a sort, *cons* an avm
```

The resulting feature structure (after type expansion) is:

$$\left\{ \begin{array}{l} \left[\begin{array}{l} \textit{*cons*} \\ \text{FIRST } [\,] \\ \text{REST } [\,] \end{array} \right] \\ \textit{*null*} \end{array} \right\}$$

The only case where no disjunctive edges are introduced in the type hierarchy is a disjunction of pure atoms, e.g.,

```
num := 1 | 2 | 3.
```

$$\left\{ \begin{array}{l} \texttt{1} \\ \texttt{2} \\ \texttt{3} \end{array} \right\}$$

^ instead of | means exclusive-or. Disjoint type partitions can be declared in the declare environment (Section 4.5).

4.6.10 Distributed Disjunctions

A very useful feature of $\mathcal{TDL}$, implemented in the underlying unification system $\mathcal{UDiNe}$, is distributed (or named) disjunction [Eisele & Dörre 90]. This kind of disjunction has a specification restricted to a local domain, although it may affect more than one attribute. The main advantage of distributed disjunction is a more succinct representation. Consider the following example:

$$\left[\begin{array}{ll} \textit{season-trigger} & \\ \text{SEASON } \%1 & \left\{ \begin{array}{l} \texttt{"spring"} \\ \texttt{"summer"} \\ \texttt{"fall"} \\ \texttt{"winter"} \end{array} \right\} \\ \text{NUMBER } \%1 & \left\{ \begin{array}{l} \texttt{1} \\ \texttt{2} \\ \texttt{3} \\ \texttt{4} \end{array} \right\} \end{array} \right]$$

This structure has been generated by the following $\mathcal{TDL}$ expression:

```
season-trigger := [ SEASON %1("spring", "summer", "fall", "winter"),
                    NUMBER %1(   1    ,    2    ,   3   ,    4    ) ].
```

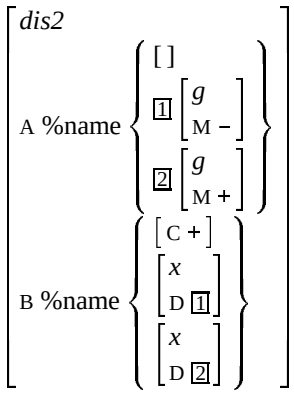
When a structure of type *season-trigger* is unified with the structure `[SEASON "summer" | "fall"]`, the value of attribute `NUMBER` become `2 | 3`, i.e., the value of attribute `SEASON` triggers the value of attribute `NUMBER`, and vice versa.
The syntax of the alternative list in distributed disjunctions is

$$\%i(a_{i_1}, \ldots, a_{i_n})$$

where i is an integer number or a symbol, the disjunction index for each group of distributed disjunctions (`%1` in the example). More than two alternative lists per index are allowed. All alternative lists with the same index must have the same number (n) of alternatives. The disjunction index is local in every type definition and is normalized to a unique index when unification of feature structures takes place.

In general, if alternative a_{i_j} ($1 \leq j \leq n$) does not fail, it selects the corresponding alternative b_{i_j}, c_{i_j}, ... in all other alternative lists with the same disjunction index i.
As in the case of simple disjunctions, disjunction alternatives must not contain coreferences refering to values outside the alternative itself. But for distributed disjunctions, there is an exception to this restriction: disjunction alternatives may contain coreferences to values in another distributed disjunction if both disjunctions have the same disjunction index and the alternative containing the coreference has the same position in the disjunction alternative list.
An example of such a distributed disjunctions with coreferences is:

```
dis2 :=[ a %name( []   , #1              , #2              ),
         b %name( [c +], x&[d #1 g&[m -]], x&[d #2 g&[m +]] ) ].
```

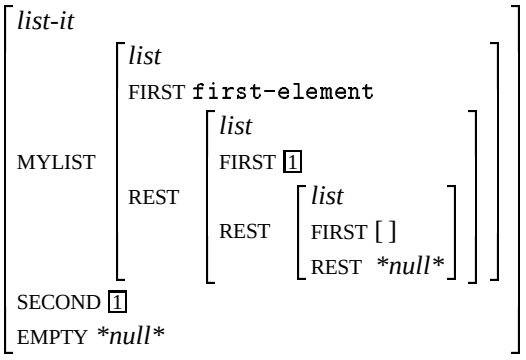


4.6.11 Lists

In $\mathcal{TDL}$, lists are represented as first-rest structures with distinguished attributes `FIRST` and `REST`, where the sort **null** at the last `REST` attribute indicates the end of a list (and, of course, the empty list). The input of lists can be abbreviated by using the `<>` syntax which is only syntactic sugar.

```
list-it := [ MYLIST < first-element, #second, [] >,
             SECOND #second,
             EMPTY  <> ].
```

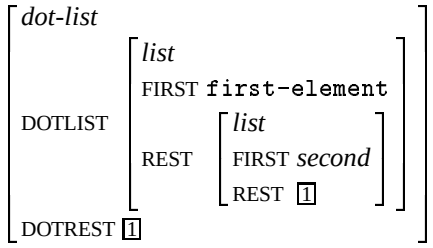
The resulting feature structure is



Dotted pair lists can be defined à la LISP, e.g.

```
dot-list := [ DOTLIST < first-element, second . #rest >,
              DOTREST #rest ].
```

The resulting feature structure is

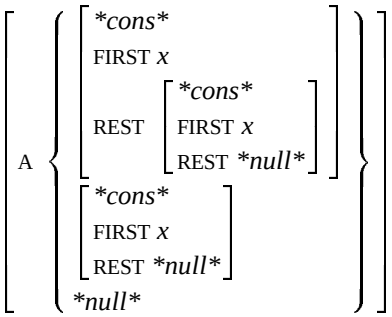


Lists with open end can be defined by using `...` as the last element. The value of the last `REST` attribute will be `[]` (top).
In addition, the `<...>` notation can be combined with type and length restrictions. The general syntax is

`<...>` [`:` (*restriction*) | `:` *type* [`:` (*minlength*, *maxlength*) | `:` *length*]]

The following definition produces a list with element type *x* of length 0, 1 or 2 at the top level attribute `a`.

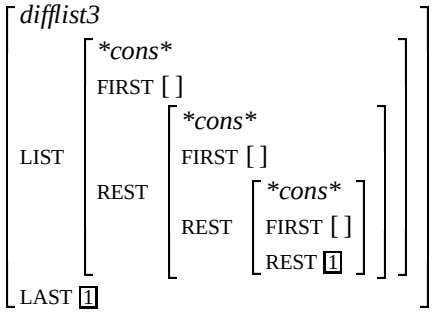
```
list012-of-x :=[a <...>:x:(0,2)].
```



4.6.12 Difference Lists

Difference lists are first-rest structures with distinguished attributes `FIRST` and `REST`, and a special `LAST` attribute at the top level, which shares the value with the last `REST` attribute.
Difference lists permit appending of list structures without requiring an append type or an append relation.
In *TDL*, the elements of difference lists may be enclosed in `<! !>` as an abbreviation. Example:

```
difflist3 := <! [],[],[] !>.
```



4.6.13 Negation

The ~ sign indicates negation. Example:

```
not-mas-type := [ GENDER ~'mas ].
```

The resulting feature structure is

$$\begin{bmatrix} \textit{not-mas-type} \\ \text{GENDER} \neg \texttt{mas} \end{bmatrix}$$

Negation of types will be pushed down to atoms according the schema of [Smolka 88; Smolka 89].
If `*list*` list is defined as in the `tdl-built-ins.tdl` file (page 4.2), the definition

```
notlist := ~ *list*.
```

will result in the following (expanded) structure:

$$\left\{ \begin{array}{l} [\neg \textit{*cons*} \wedge \neg \textit{*null*}] \\ \begin{bmatrix} \neg \textit{*null*} \\ \text{FIRST } \texttt{*undef*} \end{bmatrix} \\ \begin{bmatrix} \neg \textit{*null*} \\ \text{REST } \texttt{*undef*} \end{bmatrix} \end{array} \right\}$$

Here `*undef*` indicates undefined attributes. It is an atom that unifies with nothing else.

4.6.14 External Coreference Constraints

Instead of specifying the values of coreferences within a feature structure, it is also possible to add a list of such constraints at the end of a feature type definition. The syntax is

. . . `where (` *constraint* {`,` *constraint*}* `).`

where *constraint* → `#`*coref-name* `=` {*function-call* | *disjunction*}
Here, '. . .' mean the body of a type, instance or template definition. External coreference constraints are pure syntactic sugar, but may be useful, e.g. for expressing the identity of coreferences in very complex definitions, or as variables, e.g. `where (#8 = #9, #undef = *undef*)`. *function-call* is explained in the following section.

4.6.15 Functional Constraints

Functional constraints define the value of an attribute on the basis of a function which has to be defined and computed outside the $\mathcal{TDL}$ system.
The syntax of functional constraints is similar to that of external coreference constraints, i.e., functional constraints must be specified outside a feature structure, but are connected with it through a coreference tag, cf. last section.

function-call → *function-name* `(` *disjunction* {`,` *disjunction*}* `)`

String concatenation is a nice example of the use of functional constraints:

```
add-prefix := [ WORD   #word,
                PREFIX #prefix,
                WHOLE  #whole ]
              where (#whole = String-Append (#prefix, #word)).
```

The definition of the LISP function `String-Append` is shown in the example in Section 4.11. The usual representation for functional constraints is:

$$\begin{bmatrix} \textit{add-prefix} \\ \text{WORD } \boxed{1} \\ \text{PREFIX } \boxed{2} \\ \text{WHOLE } \boxed{3} \end{bmatrix}$$

Functional Constraints:

$\boxed{3} = \texttt{String-Append}(\boxed{2}, \boxed{1})$

The evaluation of functional constraints will be postponed until all parameters are instantiated (residuation; cf. [Aït-Kaci & Nasr 86; Smolka 91] for theoretical backgrounds). The evaluation can be enforced by using the function `EVAL-CONSTRAINTS` of the `UNIFY` package. Further details are described in [Backofen & Weyers 95].

4.6.16 Template Calls

Templates are pure textual macros which allow specification of (parts of) type or instance definitions by means of some shorthand. The *definition* of templates will be explained in Section 4.8. A template *call* simply means the syntactic replacement of a template name by its definition and possibly given parameters. Thus we restrict templates to be non-recursive.
The syntax of template calls is

`@`*templ-name* `(` [*templ-par* { `,` *templ-par*}*] `)`

where a *templ-par* is a pair consisting of a parameter name (starting with the `$` character), followed by `=`, and a value. All occurrences of the parameter name will be replaced by the value given in the template call or by the default value given in the template definition. See Section 4.8 for further details and examples.

4.6.17 Nonmonotonicity and Value Restrictions

$\mathcal{TDL}$ supports nonmonotonic definitions for avm types and instances, called single link overwriting (SLO). A type can be overwritten by a set of paths with associated overwrite values. The general syntax for nonmonotonic definitions is

identifier `:=` *nonmonotonic* [`where (` *constraint* { `,` *constraint*}* `)`] { `,` *option*}* `.`

where

nonmonotonic → *type* `&` `[` *overwrite-path* { `,` *overwrite-path*}* `]`

and

overwrite-path → *identifier* { `.` *identifier* }* *disjunction*

This feature of $\mathcal{TDL}$ can be used to model defaults. A special extension of typed unification will handle nonmonotonic unification in a future version of $\mathcal{TDL}$ [Krieger 93]. Currently, one has to be careful when using this feature. A suitable application would be lexical types that normally will not be unified with a nonmonotonically defined lexicon entry.
Note that the `[...]` syntax denotes a set of overwrite paths with associated overwrite values. This is different from the `[...]` notation known from avm type or instance definitions, because everything following a path specification *identifier* { `.` *identifier* }* *is* the overwrite value and will replace *all* inherited information at this path.

```
begin :type.
  a := [ person_x : integer, person_y : integer ].
  b := a & [ person_x 1 | 2, person_y 1 | 2 ].
  c != b & [ person_x 3 ].
  d != b & [ person_x "three" ].  ;;; error: restriction violated
end :type.
```

The expanded prototype of *c* is

$$\begin{bmatrix} c \\ \text{PERSON\_X } 3 \\ \text{PERSON\_Y } \left\{ \begin{matrix} 1 \\ 2 \end{matrix} \right\} \end{bmatrix}$$

If TDL has been compiled with the `#+TDL-Restriction` compiler option, the *:restriction* type specification at attributes will be checked before paths are overwritten. If an overwrite value is not equal to or more specialized than the type specified in the definition of the structure to be overwritten, an error will be signaled:

```
Error: Restriction INTEGER is inconsistent with overwrite value
       (:ATOM "three") under path PERSON_X in D
Restart actions (select using :continue):
 0: Continue; overwrite restriction anyway.
```

4.6.18 Rules

Different parsers use different representations for rules. The `-->` syntax allows abstraction from the internal representation of rules as feature structures. A user-definable function is responsible for translating the abstract representation into the desired format. Rules can be defined as types and as instances. A sophisticated representation of rules, e.g., as used in the DISCO system, even allows inheritance from rule types. Rule definition syntax is

identifier `:=` *disjunction* `-->` *list* [`where` `(` *constraint* {`,` *constraint*}* `)`] .

where *disjunction* represents the left hand side of the rule and *list* contains the right hand side in the TDL list syntax. Examples:

```
*rule* :=                              ;;; the most general rule type
  [ ]  -->  < ... >.
binary-rule :=                         ;;; some silly examples to show
  *rule*  -->  < [ ], [ ] >.           ;;; what is possible
np :=
  binary-rule  -->  <Det, Noun>.       ;;; rule inheritance
xp :=
  yp & zp  -->  < Cat1, Cat2, ... >.
ap :=
  (bp & cp) | ~dp  -->  < #1 & Cat1,
                          Cat2,
                          #1 >.
tp := sp & [attr #a & foo]  --> < fee,
                                  fum & [rtta #a & #b],
                                  fuu & #b >.
```

We show two kinds of representation of the rules here, taking the `np` type from above.

$$np \Rightarrow \left[\begin{array}{l} \textit{binary-rule} \\ \text{ARGS} \left[\begin{array}{l} \textit{*cons*} \\ \text{FIRST } \textit{det} \\ \text{REST} \left[\begin{array}{l} \textit{*cons*} \\ \text{FIRST } \textit{noun} \\ \text{REST } \textit{*null*} \end{array}\right] \end{array}\right] \end{array}\right]$$

internal representation of the DISCO parser

$$np \Rightarrow \left[\begin{array}{l} \textit{*cons*} \\ \text{FIRST } \textit{binary-rule} \\ \text{REST} \left[\begin{array}{l} \textit{*cons*} \\ \text{FIRST } \textit{det} \\ \text{REST} \left[\begin{array}{l} \textit{*cons*} \\ \text{FIRST } \textit{noun} \\ \text{REST } \textit{*null*} \end{array}\right] \end{array}\right] \end{array}\right]$$

internal representation of another parser

The name of the function that generates features structures from the rule syntax can be set in the global variable `*WHICH-PARSER*`, its default value is the symbol `TDL-PARSE::CONSTRUCT-BERNIE` for the DISCO parser.

4.7 Optional Keywords in Definitions

For external use, *TDL* provides a number of optional specifications which are basically irrelevant to the grammar (except for controlled expansion). If the optional keywords are not specified, default values will be assumed by the *TDL* control system. Optional keywords are `author:`, `doc:`, `date:`, `status:`, and `expand-control:`. If a keyword is given, it must be followed by a value.
The values of `author:`, `doc:` and `date:` must be strings. The default value of `author:` is defined in the global variable `*DEFAULT-AUTHOR*`. The default value of `doc:` is defined in the global variable `*DEFAULT-DOCUMENTATION*` (see Section 5). The value of `date:` is a string containing the current time and date. If not specified, this string will be automatically generated by the system.
The `status:` information is necessary if the grammar is to be processed by the DISCO parser. It distinguishes between different categories of types and type instances, e.g., lexical entries, rules or root nodes. If the `status:` keyword is given, the status value of the type will become the specified one. If no status option is given, the status will be inherited from the supertype, or be `:unknown`, if the supertype is the top type of the type hierarchy.
The `expand-control:` keyword can be used to specify control information for type expansion. It has the same effects as the `defcontrol` statement for *type* with index `nil`, see Section 4.10.

4.8 Template Environment and Template Definitions

A template environment starts with

```
begin :template.
```

and ends with

```
end :template.
```

It may appear anywhere within a domain environment, and may contain arbitrary template definitions, environments and *TDL* statements.

Templates in *TDL* are what parametrized macros in programming languages are: syntactic replacement of a template name by its definition and (possibly) replacement of given parameters in the definition. In addition, the specification of default values for template parameters is possible in the template definition. Templates are very useful in writing grammars that are modular; they can also keep definitions independent (as far as possible) from specific grammar theories.
Note that template definitions must not be recursive. Recursive definitions are only allowed for avm types.

The general syntax of a *TDL* template definition is

templ-name ([*templ-par* { , *templ-par*}*]) := *body* { , *option*}* .

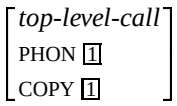
where *templ-par* is a pair consisting of a parameter name (starting with the `$` character), followed by `=`, and a default value. All occurrences of the parameter name will be replaced by the value given in the template call or by the default value given in the template definition. *body* can be a complex description as in type definitions.
Example: The template definition

```
a-template ($inherit = *avm*, $attrib = PHON, $value) :=
            $inherit & [ $attrib #1 & $value,
                         COPY    #1 ].
```

makes it possible to generate the following types using template calls:

```
top-level-call := @a-template ().
```

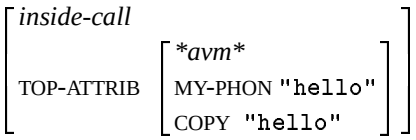
is a top-level template call which will result in the feature structure:



while

```
inside-call := [ top-attrib @a-template ($value = "hello",
                                         $attrib = MY-PHON) ].
```

is a template call inside a feature type definition which will result in the feature structure:



Disjunction and coreference names in template definitions are local to each template expansion. In this sense, templates are similar to COMMON LISP macros.
{*options*}* in template definitions are the optional keywords `author:`, `date:` and `doc:`. If used, a keyword must be followed by a string. The default value for the `author:` string is defined in the global variable `*DEFAULT-AUTHOR*`. The default value for the `doc:` string is defined in the global variable `*DEFAULT-DOCUMENTATION*` (see Section 5). The default value for `date:` is a string containing the current time and date.
Section 5.17 describes the function `describe-template` which prints information about template definitions.

4.9 Instance Environment and Instance Definitions

A type environment starts with

```
begin :instance.
```

and ends with

```
end :instance.
```

It may appear anywhere within a domain environment, and may contain arbitrary instance definitions, environments and TDL statements.
An instance definition is similar to a type definition, but instances are not part of the type hierarchy although they can inherit from types. For instance, each lexical entry will typically be an instance of a more general type, e.g., *intransitive-verb-type* with additional specific graphemic and semantic information. The idea is to keep the type lattice as small as possible. The distinction between types and instances is similar to that of classes and instances in object oriented programming languages, e.g., CLOS.
Instances are not inserted into the TDL type hierarchy. In general, instances are objects (feature structures) which can be used by the parser. It is possible to create several instances of the same type with different or the same instance-specific information.
The general syntax of a TDL instance definition[5] is

instance-name := *body* {, *option*}* .

body can be a complex description as in type definitions. *option*s in instance definitions are the optional keywords `author:`, `doc:`, `date:`, and `status:`.
If the same name is given more than once for an instance of the same type, the old instances will not be destroyed and the parser is responsible for the access to all instances. This behavior can be controlled by the global variable `*ACCUMULATE-INSTANCE-DEFINITIONS*`.

[5] For nonmonotonic definitions see section 4.6.17.

If the `status:` keyword is given, the status value of the instance will become the specified one. If no status option is given, the status will be inherited from the top level types.
The values of `author:`, `doc:` and `date:` must be strings. The default value of `author:` is defined in the global variable `*DEFAULT-AUTHOR*`. The default value of `doc:` is defined in the global variable `*DEFAULT-DOCUMENTATION*` (see Section 5). The default of `date:` is the current time and date.

4.10 Control Environment

A control environment starts with

```
begin :control.
```

and ends with

```
end :control.
```

It may appear anywhere within a domain environment, and must be enclosed directly by either an instance or a type environment. It may contain arbitrary control definitions, other environments and $\mathcal{TDL}$ statements. The control environment is supported only for the sake of clarity in order to structure a $\mathcal{TDL}$ grammar. The environment itself is completely syntactic sugar. Control information can be given either in a type or instance definition by the optional `:expand-control` keyword, or through the `defcontrol` statement in a type or instance environment. The control environment additionally allows specification of control information separately from the type or instance definitions, e.g., in a separate file.
Note that the control environment needs to be enclosed by a domain environment *and* either a type or an instance environment, depending on what kind of definitions are to be expanded
The macro

`defcontrol` { *type* | *instance* | `:global` } *expand-control* [`:index` *number*] .

defines control information for the expansion of a *type* or an *instance*. For further details see section 5.4.

4.11 Lisp Environment

A LISP environment starts with

```
begin :lisp.
```

and ends with

```
end :lisp.
```

The LISP environment allows insertion arbitrary LISP code into $\mathcal{TDL}$ grammars. Example:

```
begin :lisp.
  (DEFUN String-Append (&rest args)
     (APPLY #'CONCATENATE 'STRING args))
end :lisp.
```

This `DEFUN` defines the function `String-Append` used in the example of Section 4.6.15.
There is also a short notation for evaluating LISP expressions from $\mathcal{TDL}$: The macro

`leval` *Common Lisp Expression* .

evaluates *Common Lisp Expression* in any environment. For the sake of clarity, we recommend using this statement only in the interactive mode. Example:

```
leval (LOAD-SYSTEM "my-parser").
```

4.12 Comments

; after an arbitrary token or at the beginning of a line inserts a comment which will be ignored by the $\mathcal{TDL}$ reader until end of line. A comment associated with a specific type, template or instance definition should be given in the `doc:` string at the end of the definition.
`#|` and `|#` can be used to comment regions (as in COMMON LISP).

5 Useful Functions, Switches, and Variables

The following functions and global variables are defined in the package `TDL` and are made public to all user-defined domains (implemented by COMMON LISP packages) via `use-package`. This is done automatically in the function `defdomain`.

5.1 Global Switches and Variables

The following global LISP variables can be set by the user. Switches are set to `t` for ON or `nil` for OFF.

- Global variable `*AND-OPEN-WORLD-REASONING-P*` *default value*: `t`
  possible values: `t` or `nil`
  This variable controls whether avm types live in an open or in closed world. Cf. [Krieger & Schäfer 94a].

- Global variable `*SIGNAL-BOTTOM-P*` *default value*: `t`
  possible values: `t` or `nil`
  If `t`, an error is signaled if the conjunction of two types is bottom.

- Global variable `*IGNORE-BOTTOM-P*` *default value*: `nil`
  possible values: `t` or `nil`
  If `t`, typed unification skips over bottom. The result of an inconsistent type conjunction will be the bottom type, and feature unification will be continued as if the conjunction would be consistent. This is useful to debug a grammar.

- Global variable `*WARN-IF-TYPE-DOES-NOT-EXIST*` *default value*: `t`
  possible values: `t` or `nil`
  This variable controls whether a warning will be given if a type definition contains the name of an undefined type in its body.

- Global variable `*WARN-IF-REDEFINE-TYPE*` *default value*: `t`
  possible values: `t` or `nil`
  This variable controls whether a warning will be signaled if a type already exists and is about to be redefined.

- Global variable `*ACCUMULATE-INSTANCE-DEFINITIONS*` *default value*: `nil`
  possible values: `t` or `nil`
  If `t`, redefining an instance will push the new definition onto a stack. Otherwise, new definitions will replace older ones.

- Global variable `*DEFAULT-AUTHOR*` *default value*: `""`
  possible values: *string*
  This variable should contain the name of the grammar author or lexicon writer. It will be used as default value for the optional keyword `author:` in type, template and instance definitions.

- Global variable `*DEFAULT-DOCUMENTATION*` *default value*: `""`
  possible values: *string*
  This parameter specifies the default documentation string for type, template and instance definitions. It will be used as default value for the optional keyword `doc:` in type, template and instance definitions.

- Global variable `*VERBOSE-P*` *default value*: `nil`
  possible values: `t` or `nil`
  This parameter specifies the verbosity behavior during processing of type definitions. If the value is `t`, a verbose output will be generated. If the value is `nil`, only the name of the (successfully) defined type will be printed in brackets, e.g., `#Avm<VERB-TYPE>`.

- Global variable `*VERBOSE-READER-P*` *default value*: `nil`
  possible values: `t` or `nil`
  This parameter specifies the verbosity behavior of the *TDL* reader. If the value is `nil`, the *TDL* reader does not print values that are returned from function calls and type, instance, template definitions. Otherwise, the first return value will be printed.

- Global variable `*VERBOSE-EXPANSION-P*` *default value*: `nil`
  possible values: `t` or `nil`
  This parameter specifies the verbosity behavior when type expansion takes place. If the value is `nil`, *TDL* type expansion will only print messages when types are not defined or inconsistent. Otherise, a verbose trace of the expansion will be printed.

- Global variable `*TRACE-P*` *default value*: `nil`
  possible values: `t` or `nil`
  If `t`, verbose trace information is printed by the *TDL* parser, the definition functions, and the expansion algorithm.

- Global variable `*LAST-TYPE*` *default value*: *undefined*
  possible values: a *type-symbol*
  This variable contains the name of the last type defined. It is used by the print functions `pgp`, `plp`, `lgp`, `llp`, `fgp`, `flp`, and by `expand-type`, `delete-type`, and `reset-proto` when no type name is specified. The value of this variable can be changed by the user.

- Global variable `*LAST-INSTANCE*` *default value*: *undefined*
  possible values: an *instance-symbol*
  This variable contains the name of the last instance defined. It is used by the print functions `pgi`, `pli`, `lgi`, `lli`, `fgi`, `fli`, and by `expand-instance`, `delete-instance`, and `reset-instance` when no instance name is specified. The value of this variable can be changed by the user.

- Global variable `*USE-MEMOIZATION-P*` *default value*: `t`
  possible values: `t` or `nil`
  If `nil`, no memoization of simplified type expression will take place. Otherwise, the domain-specific hash tables will be used.

- Global variable `*EXPAND-TYPE-P*` *default value*: `nil`
  possible values: `t` or `nil`
  If `nil`, feature structures, i.e., avm types and instances, will not be expanded at definition time. This saves time and space at definition time. If `t`, expansion will run on the prototypes with the control information known so far.

- Global variable `*SIMPLIFY-FS-P*` *default value*: `t`
  possible values: `t` or `nil`
  If not `nil`, feature structure simplification will be performed at the end of type or instance expansion. Feature structure simplification may remove unnecessary fails in disjunctions, and hence may speed up subsequent unifications.

- Global variable `*BUILD-INTERMEDIATE-TYPES-P*` *default value*: `nil`
  possible values: `t` or `nil`
  This global variable controls whether *TDL* introduces intermediate types for certain complex formulae recognized during the parsing of type definitions which, however, are not specified by the user, i.e., these types will not occur on the left side of a type definition. If the value is `t`, intermediate types will always be created (at any level of a feature structure). If `nil`, intermediate types are not created, except for the top level of a type definition in order to classify the new type correctly.

- Global variable `*USE-INTERMEDIATE-TYPES-P*` *default value*: `t`
  possible values: `t` or `nil`
  This global variable controls whether intermediate types generated at definition or at run time will be

used as abbreviations during typing, If `nil`, intermediate type will not be used. This variable will be used in type definitions as well as in instance definitions.

- Global variable `*CREATE-LEXICAL-TYPES-P*` *default value*: `t`
  possible values: `t` or `nil`
  If `t`, $\mathcal{TDL}$ will be forced to introduce an intermediate type at the top level of an instance definition (if necessary). At all other levels of an instance definition, the variables `*BUILD-INTERMEDIATE-TYPES-P*` and `*USE-INTERMEDIATE-TYPES-P*` control the behavior of intermediate type generation.

- Global variable `*WARN-UNIFICATION-P*` *default value*: `nil`
  possible values: `t` or `nil`
  Normally, no unification takes place at definition time. But there are some infrequent cases, e.g., if the grammar writer specifies a conjunction of two feature structures (`[a [b x]] & [b y]`), which make unification necessary. If `*WARN-UNIFICATION-P*` is `nil`, no warning will be given when unification is performed.

- Global variable `*SOURCE-GRAMMAR*` *default value*: user's home directory pathname
  possible values: a pathname
  This variable contains the default prefix for grammar files, if no absolute pathname is specified for *filename* in the `include` statement.

- Global variable `*LOAD-BUILT-INS-P*` *default value*: `t`
  possible values: `t` or `nil`
  This variable contains the default value for the `:load-built-ins-p` keyword in the `include` statement.

- Global variable `*WARN-NORMAL-FORM-P*` *default value*: `nil`
  possible values: `t` or `nil`
  This variable determines whether a warning is given if a $\mathcal{TDL}$ expression is not in normal form (only at definition time). If `nil`, no such warning will be given.

- Global variable `*UPDATE-GRAPHER-OUTPUT-P*` *default value*: `nil`
  possible values: `t` or `nil`
  This variable controls whether an automatic redraw is performed on the grapher when a type is (re)defined. If `nil`, no automatic redraw will be done.

- Global variable `*NORMALFORM-OPERATOR-SYMBOL*` *default value*: `:and`
  possible values: `:and` or `:or`
  This variable contains the operator for the normal form of type expressions. Either disjunctive or conjunctive normal form is possible.

- Global variable `*TOP-SYMBOL*` *default value*: `*TOP*`
  possible values: a symbol
  This variable contains the name for the top type of type hierarchies. This is the default for the `:top` keyword in the `defdomain` function.

- Global variable `*BOTTOM-SYMBOL*` *default value*: `*BOTTOM*`
  possible values: a symbol
  This variable contains the name for the bottom type of type hierarchies. This is the default for the `:top` keyword in the `defdomain` function. It is also used for the generation of symbol names for bottom types.

- Global variable `*TOP-SORT*` *default value*: `*SORT*`
  possible values: a symbol
  This variable contains the name for the top sort of type hierarchies. This is the default for the declaration of sorts if no super-sort is specified.

- Global variable `*LIST-TYPE-SYMBOL*` *default value*: `*LIST*`
  possible values: a symbol
  This variable contains the name for the first/rest list type.
- Global variable `*CONS-TYPE-SYMBOL*` *default value*: `*CONS*`
  possible values: a symbol
  This variable contains the name for the first/rest cons type.
- Global variable `*DIFF-LIST-TYPE-SYMBOL*` *default value*: `*DIFF-LIST*`
  possible values: a symbol
  This variable contains the name for the difference list type.
- Global variable `*END-OF-LIST*` *default value*: `*NULL*`
  possible values: a symbol
  This variable contains the name for the end-of-list type (sort).
- Global variable `*FIRST-IN-LIST*` *default value*: `FIRST`
  possible values: a symbol
  This variable contains the name for the `FIRST` attribute in first/rest lists.
- Global variable `*REST-IN-LIST*` *default value*: `REST`
  possible values: a symbol
  This variable contains the name for the `REST` attribute in first/rest lists.
- Global variable `*LAST-IN-LIST*` *default value*: `LAST`
  possible values: a symbol
  This variable contains the name for the `LAST` attribute in difference lists.
- Global variable `*LIST-IN-LIST*` *default value*: `LIST`
  possible values: a symbol
  This variable contains the name for the `LIST` attribute in difference lists.

5.2 Setting Switches and Global Variables

- macro `set-switch` *identifier Common-Lisp-Expression* .
  This macro sets the value of a global value with name *identifier* (cf. Section 5.1). Example:
  ```
  <MY-DOMAIN:TYPE> set-switch *WARN-IF-TYPE-DOES-NOT-EXIST* NIL.
  ```
- function `print-switch` *identifier* .
  This function prints the value of a global variable. Example:
  ```
  <MY-DOMAIN:TYPE> print-switch *AUTHOR*.
  ""
  ```

5.3 Including Grammar Files

The function

`include` *filename* .

includes *TDL* grammar files. If no `begin :domain` is specified at the beginning of the file, the definitions are loaded in the current domain. `include` files may be arbitrarily nested.
filename should be a string containing a filename or a path. If no absolute *filename* path is specified, the default path of variable `*SOURCE-GRAMMAR*` is taken.
TDL filenames must have the `.tdl` extension. If no such extension is specified, it will be appended automatically.
Example:

```
<MY-DOMAIN:DECLARE> include "my-declarations".
```

is equivalent to

```
<MY-DOMAIN:DECLARE> include "my-declarations.tdl".
```

5.4 Expanding Types and Instances

Type expansion means replacing the type names in typed feature structures by their definitions. Partial expansion can be done according to the control information given by the `defcontrol` statements or the `expand-control` keywords. Default is full expansion of all types.
All expand functions store the expanded structures in the *global prototype* slot of the type or instance infon (cf. Section 5.8). The *local prototype* (skeleton) always remains unchanged.

5.4.1 Defining control information: `defcontrol`

The control information for the expansion algorithm may be specified globally and/or locally, either in a separate file or mixed with the type and instance definitions.
The `begin :control. ... end :control.` environment can be used to indicate control information, but this is not necessary.
The syntax of macro `defcontrol` is:

`defcontrol` { *type* | *instance* | `:global` } *expand-control* [`:index` *index*] .

The first parameter in the `defcontrol` statement is a symbol, either the name of a type or the name of an instance (this depends on the surrounding environment), or `:global` which indicates global control information. A `defcontrol` can be anywhere in a grammar file, even before the corresponding type definitions. A newer `defcontrol` declaration (with the same *type* and *index*) will replace an older one (this is also true for global control).

5.4.2 Expanding Types and Instances: `expand-type` and `expand-instance`

The syntax is given by:

`expand-type` *type* [`:index` *index*] [`:expand-control` *expand-control*] .
`expand-instance` *instance* [`:index` *index*] [`:expand-control` *expand-control*] .
`expand-all-types` [`:index` *index*] [`:expand-control` *expand-control*] .
`expand-all-instances` [`:index` *index*] [`:expand-control` *expand-control*] .

Additional internal functions such as `expand-fs` exist in order to destructively expand anonymous feature structure or parts of it, e.g., from within a parser, etc.
The *index* parameter may be used to define different prototypes of the same type that are (possibly) only partially expanded. Each prototype needs its own `defcontrol`.
The indexed prototypes of a type can be 'spliced' into a feature structure through type expansion using the `:expand-only` or `:expand` slot of the control information.
Instance indices (only integers are allowed) can be used to define different levels of expanded lexicon entries, etc.
The default index is `nil` which is the standard prototype. If no special control information is given (locally or globally), the `nil` index specifies a fully expanded prototype.
The `:skeleton` index may be useful at the `:expand-only` or `:expand` slot. It denotes the unexpanded definition of a type (its skeleton). `:skeleton` cannot be used as an argument for the defcontrol keyword `:index`, because a skeleton is always unexpanded and expansion is permitted.
`expand-type` will generate a new prototype with index *index* from a copy of the `:skeleton` of type *type* if this index does not exist. If it exists, and is not already fully expanded, it will be expanded again.

5.4.3 The Syntax of *expand-control*

If *expand-control* is specified for `expand-instance` or `expand-type`, the values of slots that are omitted will be inherited from global control. Control information which has been defined for the type or instance with the same index will be ignored.
If some slots in `defcontrol :global` are omitted, they will be taken from global variables with corresponding names: `*MAXDEPTH*`, `*ATTRIBUTE-PREFERENCE*`, `*EXPAND-FUNCTION*`, `*RESOLVED-PREDICATE*`, `*IGNORE-GLOBAL-CONTROL*`, `*ASK-DISJ-PREFERENCE*`, `*USE-DISJ-HEURISTICS*`, or

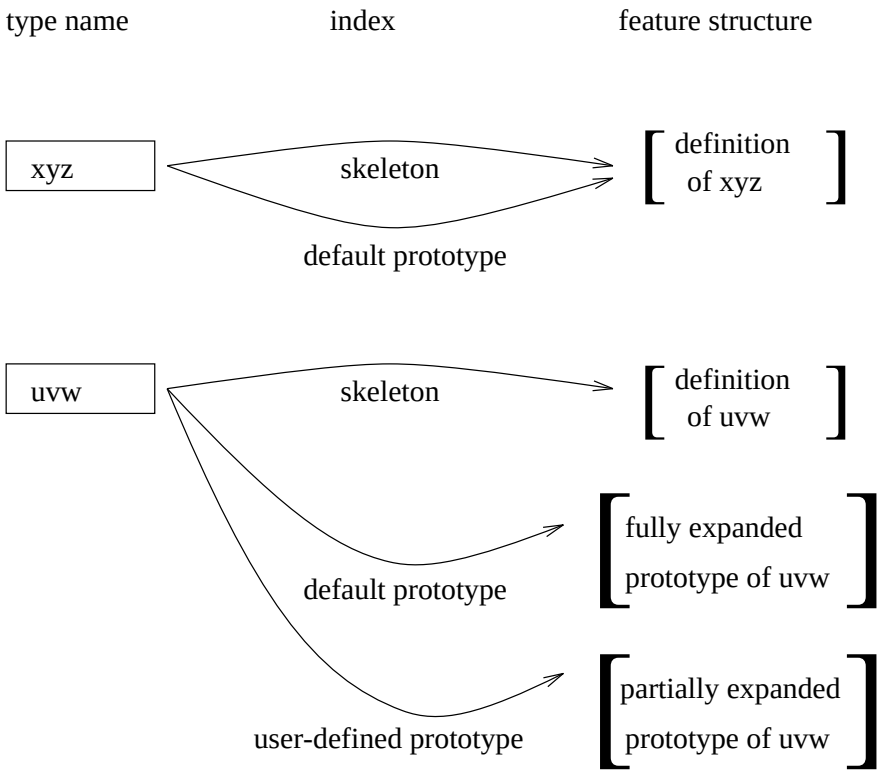


Figure 2: *Types, skeletons, prototypes and indices: Type xyz's prototype is either unexpanded or contains no avm types. Thus, its prototypical feature structure is identical with its definition (skeleton). Type uvw has a (fully) expanded prototype and a user-defined prototype which are both (possibly partially) expanded copies of uvw's skeleton feature structure.*

`*USE-CONJ-HEURISTICS*`. Their value can be set with `set-switch`. The global switch `*VERBOSE-EXPANSION-P*` can be set to `t` for verbose trace of type expansion. Default value is `nil` (quiet).
If some slots in local *expand-control* are omitted, they will be inferred from global *expand-control*.
The syntax of *expand-control* is as follows.

expand-control → `(` [`(:expand` { `(` {*type* | `(`*type* [*index* [*pred*]]`)`} {*path*}$^+$ `)` }* `)` |
`(:expand-only` { `(` {*type* | `(`*type* [*index* [*pred*]]`)`} {*path*}$^+$ `)` }* `)`] |
[`(:delay` { `(` {*type* | `(`*type* [*pred*]`)`} {*path*}$^+$ `)` }* `)`] |
[`(:maxdepth` *integer* `)`] |
[`(:ask-disj-preference` {`t` | `nil`} `)`] |
[`(:attribute-preference` {*identifier*}* `)`] |
[`(:use-conj-heuristics` {`t` | `nil`} `)`] |
[`(:use-disj-heuristics` {`t` | `nil`} `)`] |
[`(:expand-function` {`depth` | `types`} `-first-expand` `)`] |
[`(:resolved-predicate` {`resolved-p` | `always-false` | ...} `)`] |
[`(:ignore-global-control` {`t` | `nil`} `)`]
`)`

path → {*identifier* | *pattern*} {`.` {*identifier* | *pattern*}}*

pattern → `?` | `*` | `+` | `?`[*identifier*][`?`|`*`|`+`]

pred → `eq` | `subsumes` | `extends` | ...

index → *integer* for instances
integer | *identifier* | *string* for avm types

Now we describe the *expand-control* slots.

- `:expand-function`

  This slot specifies the basic expansion algorithm. The default expansion algorithm is `depth-first-expand` with prototype memoization and a special treatment of recursive types (a combination of breadth first for recursive and depth first for non-recursive types).

  The alternative is a combined 'types-first' algorithm for non-recursive types and breadth first for recursive types. This 'types-first' algorithm is advantageous only if feature structures with many delayed types are to be fully expanded (e.g., at run time). The behavior for recursive types is the same as with the proper depth first algorithm. (`:expand-function types-first-expand`) selects the 'types-first' algorithm.

- `:delay`

  The delay slot specifies a list of types whose expansion is deferred. For each type, a comparison predicate *pred* (`eq`, `subsumes`, `extends`, or user-defined, default is `eq`) and a list of paths or path patterns can be defined.

  Path patterns can facilitate path specifications. `*` denotes zero or more features, `+` one or more features, `?` exactly one feature. In each case, the prefix `?`*identifier* can be used to define variables for features or path segments. The variables are local to each path pattern. `?`*identifier* without a `*`, `+`, or `?` suffix is the same as `?`*identifier*`?`, i.e., one feature variable. Example:

```
defcontrol mytype ((:delay (vtype syn.loc.* sem.?x.head.?x)
                           ((ntype subsumes) *)))
                  :index 42.
```

  Here, expansion of the type `vtype` will be delayed under all paths which start with `syn.loc` and all paths which start with `sem`, then an arbitrary feature (bound to variable `x`), then `head`, then the second feature again (constraint by variable `x`). Expansion of the type `ntype` and all its subtypes will be delayed under all paths.

- `:expand-only` and `:expand`

  There are two mutually exclusive type expansion modes. If the `:expand-only` list is specified, only types in this list will be expanded, all others will be delayed. If the `:expand` list is specified, all types will be expanded. Types not mentioned in the list will be expanded using the default prototype index `nil`, i.e., fully, if not specified otherwise.

  In both cases, the types in the `:delay` list will be delayed anyway.

  index specifies the index of the prototype to be spliced in. *pred* is as described in the paragraph before (`:delay`).

- `:maxdepth`

  If (`:maxdepth` *integer*) is specified, all types at paths longer than *integer* will be delayed anyway. This feature may be used as a brute force method to stop infinite expansion.

- `:attribute-preference`

  This slot defines a partial order on attributes. The sub-feature structures at the leftmost attributes will be expanded first. This may speed up expansion if no numerical preference data is available. Example:

```
defcontrol :global ((:attribute-preference first rest last head-dtr
                                           comp-dtrs front back)).
```

- `:ask-disj-preference`

  If this flag is set to `t`, the expansion algorithm interactively asks for the order in which disjunction alternatives should be expanded. Example:

```
Ask-Disj-Preference in G under path X
The following disjunctions are unexpanded:
Alternative 1:
  (:Type A :Expanded NIL) []
Alternative 2:
  (:Type B :Expanded NIL) []

Which alternative in G under path X should be expanded next (1, 2, or 0 to
leave them unexpanded, or :all to expand all alternatives in this order,
or :quiet to continue without asking again in G) ? _
```

- `:use-conj-heuristics` and `:use-disj-heuristics`

  [Uszkoreit 91] suggested that exploitation of numerical preference information for features and disjunctions would speed up unification. These slots control the use of this information in conjunctive and disjunctive structures respectively.

- `:resolved-predicate`

  This slot specifies a user definable predicate that may be used to stop recursion. The description of such predicates is be rather complex and is omitted here. The default predicate is `always-false` which will make the expansion algorithm complete (if no delay or maxdepth restriction is given, of course).

- `:ignore-global-control`

  If this flag has value `t`, the values of the three globally specified lists `:expand-only`, `:expand`, `:delay` will be ignored. If `nil`, locally and globally specified lists will be taken into account.

5.4.4 Printing Control Information

The $\mathcal{TDL}$ statement (macro)

`print-control` { *type* | *instance* | `:global` } .

prints the control information in an internal format with path patterns replaced by a special syntax.

function `print-recursive-sccs` [`:domain` *domain*] .

prints the stronlgy connected components of the recursive dependency graph computed so far. It contains recursive types recognized so far (by type expansion). Example:

```
print-recursive-sccs.
((*CONS* *LIST*) (APPEND APPEND1))
```

5.4.5 How to Stop Recursion

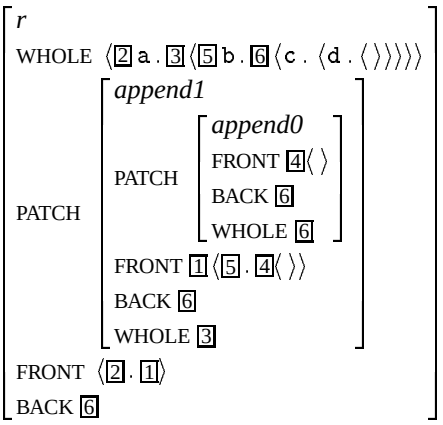
Type expansion with recursive type definition is undecidable in general, i.e., there is no complete algorithm that halts on arbitrary input (type definitions) and decides whether a description is satisfiable or not. However, there are several ways to stop infinite expansion.

- The first method is part of the expansion algorithm. If a recursive type occurs in a typed feature structure that is to be expanded, and this type has been expanded under a subpath, and no features or other types are specified at this node, then this type will be delayed, since it would expand forever (this is called lazy expansion). An example of a recursion that stops like this is the recursive version of the `list` type (see below). A counter example, i.e., a type that will not stop without a finite input (using the default resolved predicate `always-false` and no delay pattern), is Aït-Kaci's `append` type [Aït-Kaci 86]. That's life.

  Expanding `append` with finite input will stop, of course; an example of this is the last type definition in the code below.

```
defdomain :append :load-built-ins-p NIL.
begin :domain :append.
begin :declare.
  sort:  *null*.  ;;; the empty list
end :declare.
begin :type.
  *avm* := [ ].        ;;; the top avm type
  *list* := *null* | *cons*.
  *cons* := *avm* & [FIRST,REST *list*].

;;; Ait-Kaci's version of APPEND

  append0 := *avm* & [FRONT < >,
                      BACK  #1 & *list*,
                      WHOLE #1].
  append1 := *avm* & [FRONT <#first . #rest1>,
                      BACK  #back & *list*,
                      WHOLE <#first . #rest2>,
                      PATCH append & [FRONT #rest1,
                                      BACK  #back,
                                      WHOLE #rest2]].
  append := append0 | append1.

  r:=append & [FRONT <'a,'b>,
               BACK  <'c,'d>].

  expand-type 'r.
```

Full expansion of `r` results in the following structure.



- The second way is brute force: use the `:maxdepth` slot to cut expansion at a suitable path depth.
- The third method is to define `:delay` patterns or to select the `:expand-only` mode.
- The fourth method may work in some cases (Prolog hackers may like it): Use the `:attribute-preference` list to define the 'right' order for expansion.
- The last method is to define a suitable `:resolved-predicate` for a class of recursive types. For further details, see [Schäfer 95].

5.5 Checking Welltypedness/Appropriateness

$\mathcal{TDL}$ supports optional welltypedness checks at run time as well as at definition time. The appropriateness specification for a feature is inferred by the type definition of the most general type that introduces this feature. This is done by the function

`compute-approp` [`:domain` *domain*] [`:warn-if-not-unique` {`t` | `nil`}].

Its optional keyword `:warn-if-not-unique` determines whether a warning is given if there is more than one most general type that introduces a feature[6]. The function is called by the two functions described below if necessary.

The function

`print-approp` [`:domain` *domain*].

prints the current appropriateness table of a domain. This table is comparable to the *Approp* function in [Carpenter 93, Chapter 6]. But there, it is defined *Approp* : $\mathcal{F} \times \mathcal{T} \mapsto \mathcal{T}$, i.e., for all features *and* types, while $\mathcal{TDL}$ stores *Approp* : $\mathcal{F} \mapsto \mathcal{T} \times \mathcal{T}$ only once for each feature and infers the admissable value types by a (cheap) lookup at the prototypical feature structure of the (sub)type of the type which introduces the feature.

A feature structure is welltyped if each feature has an appropriate type and if the type of its *value* is equal to or more specific than the value type of its appropriateness specification.
The welltypedness check can be done

1. at definition time. The global variable `*CHECK-WELLTYPEDNESS-P*` (values: `t` or `nil`) controls whether this check is done (`t`) or not (`nil`). This check enforces expansion at definition time.

2. at run time. The global variable `*CHECK-UNIFICATION-WELLTYPEDNESS-P*` (values: `t` or `nil`) controls whether this check is done (`t`) or not (`nil`). The global variable `*RETURN-FAIL-IF-NOT-WELLTYPED-P*` (values: `t` or `nil`) controls whether a unification failure is triggered if the unified nodes are not welltyped (`t`).

3. for a specific type or instance. The function
   `check-welltypedness` [*type* | *instance* | `:all` [`:instances` | `:avms`
   [`:domain` *domain*] [`:index` *index*] [`:verbose` {`t` | `nil`}]]].
   provides such a check for a single type or instance as well as for all types or instances with the specified *index*.

The global variable `*VERBOSE-WELLTYPEDNESS-CHECK-P*` controls whether a warning is given if a welltypedness check is negative (`t`).
Below we show a brief example output of `print-approp`.

```
Feature       ((Intro-Type . Value-Type)*)
-----------------------------------------
          QUE  ((NON-LOCAL-TYPE . *TOP*))
        SLADJ  ((NON-LOCAL-TYPE . *TOP*))
        SLASH  ((NON-LOCAL-TYPE . *TOP*))
         HOUR  ((TIME-VALUE . *TOP*))
      NON-LOC  ((NON-LOCAL . NON-LOCAL-TYPE))
      SUBJ-SC  ((SUBJ-SUBCAT-TYPE . *TOP*))
         LIST  ((*DIFF-LIST* . *TOP*))
     SEM-MOOD  ((QUESTION-SEMANTICS . SYMBOL))
       SUBCAT  ((SUBCAT-TYPE . *TOP*))
   FILLER-DTR  ((FILLER-DTR-TYPE . MAX-SIGN-TYPE))
```

[6] [Carpenter 93, Chapter 6] calls such an appropriateness condition unacceptable and stipulates that there exists exactly one most general type which introduces a feature. $\mathcal{TDL}$ is not so restrictive, but the warnings can be employed to write grammars that do not make use of such 'unacceptable' appropriateness conditions. Our treatment is comparable to *polyfeatures* in CUF [Dörre & Dorna 93].

```
  PFORM  ((PFORM-TYPE . *TOP*))
    FEM  ((GENDER-VAL . *TOP*))
    MAS  ((GENDER-VAL . *TOP*))
    RES  ((DL-APPEND . *TOP*))
   ARG2  ((DL-APPEND . *TOP*))
   ARG1  ((DL-APPEND . *TOP*))
...
```

5.6 Deleting Types and Instance Definitions

- function `delete-type` [*type* [`:domain` *domain*]] .
  deletes a type (avm or sort). It removes *type* from the avm/sort hashtable in domain *domain* and from the type hierarchy. Example:
  `<MY-DOMAIN:INSTANCE> delete-type 'my-type.`
- function `delete-instance` [*instance* [`:domain` *domain*] [`:index` *number*]] .
  removes *instance* with index *number* (default: 0) from the instance hashtable in domain *domain*. Example:
  `<MY-DOMAIN:INSTANCE> delete-instance 'root-node :index 0.`
- function `delete-all-instances` [*domain*] .
  removes all instances from the instance hashtable in domain *domain* (default: current domain). Example:
  `<MY-DOMAIN:INSTANCE> delete-all-instances.`

5.7 Resetting Prototypes of Types and Instances

A global prototype is a (possibly partially) expanded feature structure of an avm type or of an instance. If a type or an instance is not expanded at all, or if its definition is already fully expanded, then the global prototype is the same as its local one (its definition or *skeleton*), i.e., they are identical.

- function `reset-proto` [*type* [`:domain` *domain*] [`:index` *index*]] .
  resets the prototype of an avm type to its skeleton.
- function `reset-all-protos` [*domain*] .
  resets all prototypes of all avm types in *domain*.
- function `reset-instance` [*instance* [`:domain` *domain*] [`:index` *number*]] .
  resets the prototype of an instance to its skeleton.
- function `reset-all-instances` [*domain*] .
  resets the prototypes of all instances in *domain*.

5.8 Accessing Internal Information (Infons)

The following functions apply a functional argument *function*, a COMMON LISP function, e.g., a print function, collector, etc., to the slots of the internal representation (infon structures) of avms, sorts, instances and templates.
domain specifies the domain (default: current domain).
name must be the name of a sort, avm, template or instance.
table may be one of `:avms` (the default) `:sorts`, `:templates`, `:instances`.
accessor may be one of the following slot accessor functions: `name` (the default), `surface`, `domain`, `intermediate`, `comment`, `author`, `date`, `value-types`, `restriction-types`, `atomic-symbols`, `attributes`, `expand-control`, `skeleton`, `prototype`, `creation-index`, `monotonic`, `overwrite-values`, `overwrite-paths`.
There is an additional accessor function `parameters` which can be applied only to template infons.
The additional accessors `class-info` and `mixed?` can only be applied to type infons.

- function `do-infon` [`:name` *name*] [`:table` *table*] [`:accessor #'`*accessor*] [`:function` *function*] [`:domain` *domain*] .
  applies a function to infon of *name* in *table* and *domain*. Example:

```
<MY-DOMAIN:TYPE> do-infon :name 'my-instance
                          :table :instances
                          :accessor #'author.
```

- function `do-all-infons` [`:table` *table*] [`:accessor #'`*accessor*] [`:function` *function*] [`:domain` *domain*] .
  applies a function to all infons in one table (sorts, avms, templates, instances) in one domain. Example:
  `<MY-DOMAIN:TYPE> do-all-infons :table :avms :accessor #'surface.`

- `print-all-names` [*table* [*domain*]] .
  prints all names in one table in one domain, it is just a special case of `do-all-infons`. Example:
  `<MY-DOMAIN:TEMPLATE> print-all-names :templates.`

5.9 Collecting and Printing Statistical Information

The $\mathcal{TDL}$ system can be compiled with or without the statistics module. If the system is compiled with statistics, the following functions are defined:

- function `print-all-statistics` [`:domain` *domain*] [`:stream` *stream*] .
  prints all statistical information that is available. If *domain* is not specified, this will be done for *all* domains.

- function `print-domain-statistics` [`:domain` *domain*] [`:stream` *stream*] .
  prints all statistical information that are domain specific. If *domain* is not specified, the current domain is assumed.

- function `print-expand-statistics` [`:domain` *domain*] [`:stream` *stream*] .
  prints expansion statistics. If *domain* is not specified, the current domain is assumed.

- function `print-global-statistics` [`:stream` *stream*] .
  prints all statistical information that is domain independent.

- function `print-simplify-statistics` [`:domain` *domain*] [`:stream` *stream*] .
  prints type simplification statistics. If *domain* is not specified, the current domain is assumed.

- function `reset-all-statistics` [`:domain` *domain*] .
  resets all statistical information. If *domain* is not specified, this will be done for *all* domains.

- function `reset-domain-statistics` [`:domain` *domain*] .
  resets all statistical information that is domain specific. If *domain* is not specified, the current domain is assumed.

- function `reset-expand-statistics` [`:domain` *domain*] .
  reset expansion statistics. If *domain* is not specified, the current domain is assumed.

- function `reset-global-statistics` .
  resets all statistical information that is domain independent.

- function `reset-simplify-statistics` [`:domain` *domain*] .
  resets type simplification statistics.

- function `count-nodes` {*type* | *instance* | `:all`}
  [`:table` {`:avms` | `:instances`}]
  [`:expand-p` {`t` | `nil`}]
  [`:verbose` {`t` | `nil`}]
  [`:domain` *domain*]
  [`:index` *index*]
  [`:stream` *stream*]
  [`:filename` {`nil` | *filename*}].
  counts the number of nodes in an avm type or instance with the specified index (default is `nil` for types and `0` for instances). Instead of a name, the `:all` keyword can be specified to count all nodes in all instances or types with *index*. In this case, `:verbose t` will output the number of nodes for each type or instance. Otherwise, only the total will be printed.

  The `:filename` or `:stream` argument can be used to redirect the output to a file or a stream (default: standard output). `:expand-p t` will expand structures before counting if necessary (default is `nil`). When called from LISP, the function returns 9 values (integers) in the order as below. Here is an example output:

```
Total number of nodes in all instances:
# of conj avm nodes: 13868
# of atomic nodes:   5564
# of sortal nodes:   3697
# of attributes:     24717
# of disj nodes:     644
# of disj elements:  1606
# of fail nodes:     0
# of undef nodes:    0
# of shared nodes:   2763
total # of nodes:    23773
```

If *domain* is not specified, the current domain is assumed.

5.10 Memoization

At definition time as well as at run time, type expressions are simplified (syntactically and semantically) and stored in memoization hashtables. In each domain, there are four memo tables: for conjunctive and disjunctive normal form and with and without exploiting information from the type hierarchy.

- function `clear-simplify-memo-tables` [`:domain` *domain*] [`:threshold` *integer*] .
  clears the simplification memo tables. If the `:threshold` number is specified, only entries that have been used less than or equal to *integer* times will be removed from the memo tables. If *integer* is `nil`, all entries will be removed (default). The `:threshold` keyword is only supplied with the statistics module.

- function `print-simplify-memo-tables` [`:domain` *domain*] [`:threshold` *integer*] .
  prints the contents of the simplification memo tables. If the `:threshold` number is specified, only entries that have been used more than *integer* times will be printed. If *integer* is `nil`, all entries will be printed (default). The `:threshold` keyword is only supplied with the statistics module.

- function `save-simplify-memo-table` [`:domain` *domain*] [`:filename` *string*]
  [`:threshold` *integer*] .
  saves type simplification memoization table to a file. The `:threshold` keyword is only supplied with the statistics module. All entries occurring less than *integer* times will not be saved.

- function `load-simplify-memo-table` [`:domain` *domain*] [`:filename` *string*] .
  loads type simplification memoization table from a file (written with `tune-types` or `save-simplify-memo-table`). This may speed up subsequent unifications.

5.11 Tuning up Unification: Training Sessions

In this section, some tools will be described that may be used to speed up unification at run time. A training session is necessary

1. to extract type definitions for GLB types if the result of the unification of their expanded definitions is consistent,
2. to generate a table of sets of types that are inconsistent (or consistent) with other types (as a result of their feature constraints).

Such a training session consists of the following steps

1. load (and expand) a grammar
2. call `Start-Collect-Unified-Types`.
3. do train parses
4. call `tune-types`.

To work with the tuned types later on, simply type

1. `include "glb-types". ;;; load the additional GLB type definitions` (optional)
2. `load-simplify-memo-table :filename "cnf-memo-table".`

before run-time. Of course, the user is responsible for updates of the files if the type hierarchy as changed.

- function `start-collect-unified-types` [`:domain` *domain*] .
  This function enables a training session, resets some variables, and clears some tables.
- function `load-simplify-memo-table` [`:domain` *domain*] [`:filename` *string*] .
  loads type simplification memoization table from a file (written with `tune-types` or `save-simplify-memo-table`).
- function `print-unified-types` [`:filename` *string*] [`:domain` *domain*] .
  prints contents of the global hashtable :unified-types to screen (or to file if filename string is given).
- function `tune-types` [`:domain` *domain*]
  [`:threshold` *integer*]
  [`:unify-input-file` {`nil` | *string*}]
  [`:create-glbs` {`nil` | `t`}]
  [`:hashtable` *hashtable*]
  [`:assume-consistency` {`nil` | `t`}]
  [`:memo-output-file` *string*]
  [`:glb-output-file` *string*] .

  Main function. Either takes the current unify table (default) or loads one from file `:unify-input-file` that has been written with `print-unified-types`.

  Tune-Types creates a `:memo-output-file` (default name `"cnf-memo-table"`) as well as a `:glb-output-file` (default name `"glb-types.tdl"`). The first file can be loaded at run time with `load-simplify-memo-table`, the second one with `include`.

  If `:create-glbs nil` is specified, no glb types will be introduced (default: `t`) and no glb output file will be created.

  `:threshold` *integer* specifies a threshold for the entries in the table of unified types to be considered. Only entries that have occurred at least *integer* times will be considered (default: 0=all entries).

  `:assume-consistency t` is a sensible default because it assumes that all type expressions that occur as an argument of an entry in the unify table are consistent. Otherwise it would unify (expand) *all* arguments.

  `:hashtable` is one of `:simplify-cnf-hierarchy` (default), `:simplify-cnf`, `:simplify-dnf-hierarchy`, or `:simplify-dnf` and specifies the corresponding type memoization hashtable.

5.12 Defining Reader Macros

The `alias` facility allows extension of the *TDL* syntax by adding new macros that may abbreviate *TDL* syntax or integrate other modules like parsers or other user shells.

macro `alias` *identifier* {*definition-string* | `nil`} [*help-string*] .

defines a user macro with name *name* (string or symbol) and definition *definition-string*. *definition-string* must start with a COMMON LISP function or macro name (without surrounding parentheses), followed by arbitrary arguments.
Arguments specified with a *TDL* reader macro call will be passed to the COMMON LISP function or macro by simply appending them at the end of the *definition-string*. If *definition-string* is `nil`, then *name* will be defined to call a function or macro with the same name. In this case, the corresponding symbol must be exported from the `TDL` or `COMMON-LISP` package.
help-string should contain a string with a brief description of the reader macro. It will be printed with the `help` command (see below). Example: The `message` command described in the following paragraph is defined as a reader macro as follows.

```
alias "MESSAGE" "FORMAT T" "print a message (Lisp's FORMAT syntax)".
```

5.13 Printing Messages

During parsing the grammar files, the function

`message` *string* {*Common Lisp Expression*}* .

can be used to print messages. The args may be variable names or LISP function calls as in the COMMON LISP `FORMAT` function. Example:

```
message "Default author is ~A" *DEFAULT-AUTHOR*.
```

5.14 Help

`help` [*statement* | `:all`] .

`help :all` (default) prints a list of all statements (readermacros) that are defined. If a *statement* name is specified, a brief description associated with the readermacro will be printed. Example:

```
<DISCO:TYPE> help begin.
Help for begin: begin a TDL definition block.
```

5.15 Wait

`wait.`

waits until the return key is pressed on COMMON LISP's `*TERMINAL-IO*` (useful for demos etc.).

5.16 Exit *TDL*

`ldt.`

quits the *TDL* syntax reader and returns to COMMON LISP.

5.17 Getting Information about Defined Templates

function `describe-template` *template-name* .

prints a short information text about a template definition. Example:

```
<MY-DOMAIN:TEMPLATE> describe-template 'a-template.
The template A-TEMPLATE has the following definition:
  a-template ($inherit = *TOP*, $attrib = PHON, $value) :=
             $inherit & [$attrib #1 & $value,
                         COPY #1].
The template A-TEMPLATE has been defined on 03/15/1994 at 17:12:23.
The author is: tdl-info.
The following documentation is associated with A-TEMPLATE:
```

5.18 Printing Feature Structures

For debugging and documentation purposes, it is possible to print prototypes of the defined feature types and instances. This can be done by using the following functions. For all kinds of representation (ASCII, FEGRAMED or LaTeX), the print modes described in section 7 will be considered.

5.18.1 Printing to the Interactive Screen or to Streams (ASCII)

The following four functions call the print function `PRINT-FS` of the *UDiNe* system which is defined in package `UNIFY`. It prints feature structures either to the standard output (default) or to streams, e.g., text files. For internal details we refer to the *UDiNe* documentation. The output format of the *TDL* type entries is described in this manual in section 7.

- function `plp` [*type* {*print-option*}*] .
  `plp` prints the *local prototype* of the feature structure with name *type*. If no type name is specified, `plp` prints the prototype of the *last* type defined before evaluating `plp`. The *local prototype* (or skeleton) contains only the *local* information given in the definition of *type*. Example:
  ```
  <MY-DOMAIN:TYPE> plp 'mas-sg-agr :init-pos 12 :hide-types T.
              [GENDER : [FEM : -
                         MAS : +]
               NUM    : SG]
  ```
- function `pgp` [*type* {*print-option*}*] .
  `pgp` prints the *global prototype* of the feature structure with name *type*. If no type name is specified, `pgp` prints the prototype of the *last* type defined before evaluating `pgp`. The *global prototype* contains *all* information that has been inferred for type *type* by type expansion so far. Example:
  ```
  <MY-DOMAIN:TYPE> pgp 'mas-sg-agr.
  (:TYPE MAS-SG-AGR) [GENDER : GENDER-VAL [FEM : -
                                          MAS : +]
                      CASE   : []
                      NUM    : SG]
  ```
- function `pli` [*instance* {*print-option*}*] .
  `pli` prints the *local prototype* of the instance with name *instance*. If no instance name is specified, `pli` prints the prototype of the *last* instance defined before evaluating `pli`. The *local prototype* (or skeleton) contains only the *local* information given in the definition of *instance*.
- function `pgi` [*instance* {*print-option*}*] .
  `pgi` prints the *global prototype* of the instance with name *instance*. If no instance name is specified, `pgi` prints the prototype of the *last* instance defined before evaluating `pgi`. The *global prototype* contains *all* information that has been inferred for *instance* by expansion so far.

*print-option*s are the following optional keywords:

- `:remove-tops` *flag* *default value:* `nil`
  possible values: {`t`|`nil`}
  If *flag* is `t`, attributes with empty values (i.e., values that unify with everything, i.e., the top type of the

hierarchy `[]`) will not be printed. If *flag* is `nil`, all attributes (except those in `label-hide-list`) will be printed.

- `:label-hide-list` ({*identifier*}*) *default value:* `()`
  possible values: a list of symbols (attribute names)
  Attributes in the list and their values will not be printed.

- `:label-sort-list` ({*identifier*}*) *default value:* the value of `*LABEL-SORT-LIST*`
  possible values: a list of symbols (attribute names)
  the list defines an order for attributes to be printed. Attributes of the feature structure will be printed first-to-last according to their left-to-right position in the list. All remaining attributes which are not member of the list will be printed at the end.

- `:stream` *stream* *default value:* `t`
  possible values: {`t` | `nil` | a COMMON LISP stream}
  If *stream* is `t`, the feature structure will be printed to standard output or to the interactive screen. If *stream* is `nil`, the feature structure will be printed to a string. In all other cases the feature structure will be printed to the LISP stream *stream*.

- `:init-pos` *number* *default value:* 0
  possible values: a positive integer number
  number defines the left margin offset (space characters) for the feature structure to be printed.

- `:read-in-mode` *flag* *default value:* `nil`
  possible values: {`t`|`nil`}
  If `t`, the feature structure is printed in a way such that the output could be used by *UDiNe*'s input function `build-fs`. Otherwise a pretty print is done. To be read in, feature structures have to be printed with print mode `:read-in` (see section 7). Otherwise, type information may be incomplete.

5.18.2 FEGRAMED

FEGRAMED is a feature structure editor [Kiefer & Fettig 94]. It can be started from *TDL* through the function

`fegramed`.

Feature structures from *TDL* can be passed to FEGRAMED using the following commands.

- function `flp` [*type* {*fegramed-option*}*] .
  `flp` starts FEGRAMED with the *local prototype* of the feature structure with name *type*. If no type name is specified, `flp` takes the prototype of the *last* type defined before evaluating `flp`. The *local prototype* (or skeleton) contains only the *local* information given in the definition of type *type*. Example:
  ```
  <MY-DOMAIN:TYPE> flp 'mytype.
  ```

- function `fgp` [*type* {*fegramed-option*}*] .
  `fgp` starts FEGRAMED with the *global prototype* of the feature structure with name *type*. If no type name is specified, `fgp` takes the prototype of the *last* type defined before evaluating `fgp`. The *global prototype* contains *all* information that has been inferred for type *type* by type expansion so far. Example:
  ```
  <MY-DOMAIN:TYPE> fgp 'mas-sg-agr :wait t :hide-types t.
  ```

- function `fli` [*instance* {*fegramed-option*}*] .
  `fli` starts FEGRAMED with the *local prototype* of instance *instance*. If no instance name is specified, `fli` takes the prototype of the *last* instance defined before evaluating `fli`. The *local prototype* (or skeleton) contains only the *local* information given in the definition of *instance*. Example:
  ```
  <MY-DOMAIN:INSTANCE> fli 'agr-en-type.
  ```

- function `fgi` [*instance* {*fegramed-option*}*] .
  `fgi` starts FEGRAMED with the *global prototype* of instance *instance*. If no instance name is specified, `fgi` takes the prototype of the *last* instance defined before evaluating `fgi`. The *global prototype* contains *all* information that has been inferred for instance *instance* by expansion so far.

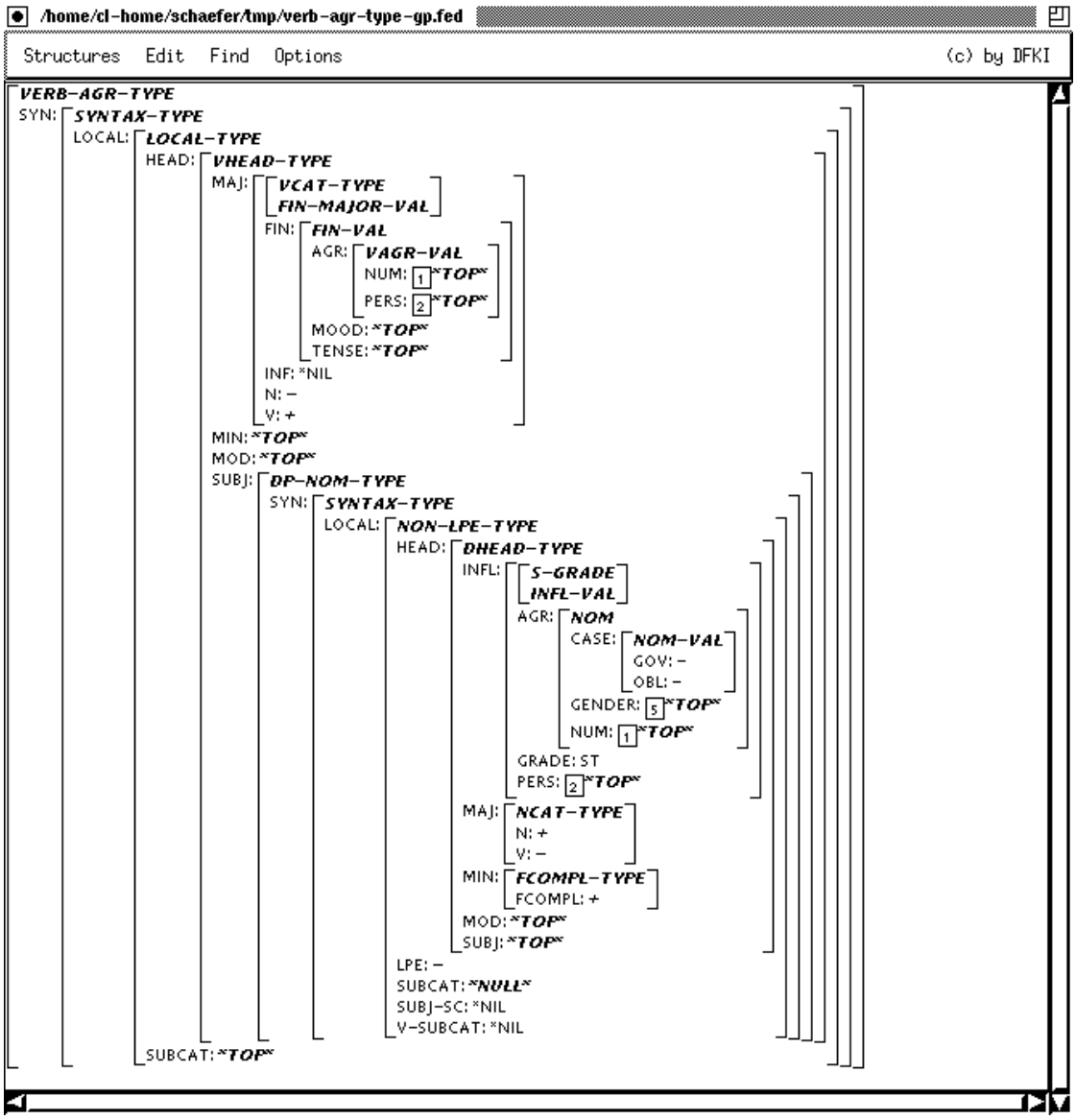


Figure 3: A feature structure type in FEGRAMED

*fegramed-option*s are the following optional keywords:

- `:filename` *filename*
  default value: "*type*-`gp`i`.fed`", "*type*-`lp.fed`", "*instance*-`li`i`.fed`", or "*instance*-`gi`i`.fed`"
  possible values: a string or a LISP path name
  Unless *filename* is specified, a filename will be 'computed' from the type or instance name and the index i of the instance or the global prototype. The file will be created by the $\mathcal{TDL}$-FEGRAMED interface in order to communicate the feature structure information.

- `:wait` *flag* *default value:* `nil`
  possible values: {`t`|`nil`}
  If *flag* is `t`, FEGRAMED will wait until the user chooses the return options. If *flag* is `nil`, FEGRAMED will not wait.

- `:file-only` *flag* *default value:* `nil`
  possible values: {`t`|`nil`}
  If *flag* is `t`, the FEGRAMED interface function will only generate an output file, but not execute the FEGRAMED program on it. If *flag* is `nil`, the file will be generated *and* FEGRAMED will be called.

Further details are described in [Kiefer & Fettig 94]. An example screen dump of a feature structure in FEGRAMED is shown in Figure 3.

5.18.3 $\mathcal{TDL}$2LaTeX

$\mathcal{TDL}$2LaTeX is a tool which generates LaTeX compatible high-quality output of $\mathcal{TDL}$ feature structure types [Lamport 86; Goossens et al. 94].

$\mathcal{TDL}$ Interface Functions to $\mathcal{TDL}$2LaTeX

- function `llp` [*type* {*latex-option*}*].
  `llp` starts $\mathcal{TDL}$2LaTeX with the *local* prototype (skeleton) of the feature structure with name *type*. If no type name is specified, `llp` takes the prototype of the *last* type used before evaluating `llp`. The *local* prototype (LP) contains only the *local* information given in the definition of type *type*. Example:

```
<MY-DOMAIN:TYPE> llp 'agr-en-type :fontsize "small"
                     :doc-header "\\documentstyle[a4,times]{article}".
```

- function `lgp` [*type* {*latex-option*}*].
  `lgp` starts $\mathcal{TDL}$2LaTeX with the *global* prototype of the feature structure with name *type*. If no type name is specified, `lgp` takes the prototype of the *last* type used before evaluating `lgp`. The *global* prototype (GP) contains *all* information that has been inferred for type *type* by type expansion so far. Example:

```
<MY-DOMAIN:TYPE> lgp 'agr-en-type :mathmode "equation".
```

- function `lli` [*instance* {*latex-option*}*].
  function `lgi` [*instance* {*latex-option*}*].
  `lli` and `lgi` start $\mathcal{TDL}$2LaTeX with the feature structure of instance *instance*. The *local* instances (LI) contain only the *local* information given in the definition of *instance* (skeleton). The *global* instances (GI) contain *all* information that has been inferred for instance *instance* by expansion so far. Example:

```
<MY-DOMAIN:INSTANCE> lli 'head-initial-rule :index 0.
<MY-DOMAIN:INSTANCE> lgi 'head-initial-rule :index 0.
```

The optional keywords *latex-option*s are described in section 5.18.3.
There is also a function `latex-fs` which operates on feature structures analogously to $\mathcal{UDiNe}$'s `print-fs`. It roughly takes the same arguments as `lgp` etc.
An example of a complex feature structure generated by $\mathcal{TDL}$2LaTeX is shown in figure 4.

```
<MY-DOMAIN:TYPE> lgp 'count-noun-sem-type :label-sort-list '(first rest)
                                          :align-attributes-p nil
                                          :coreftable '((1 . "Sem")).
```

Optional Keyword Arguments

*latex-option*s are the following optional keywords:

- `:filename` *filename*
  default value: "*type*-gp$i$", "*type*-lp", "*instance*-gi$i$", or "*instance*-li$i$"
  possible values: *string*
  Unless *filename* is specified, a filename will be 'computed' from the type or instance name and the index i of the instance or global prototype. The filename will be used to generate the LaTeX output file.

- `:filepath` *pathname* *default value:* value of variable `*FILEPATH*`
  possible values: a string or a COMMON LISP path name
  pathname sets the directory in which the LaTeX output file will be created and the shell command *command* will be executed. The default for *pathname* is the `tmp` directory in the user's home directory.

- `:hide-types` *flag* *default value:* value of variable `*HIDE-TYPES*` = `nil`
  possible values: {`t`|`nil`}
  If *flag* is `nil`, types will be printed at the top of feature structures (the top type will not be printed). If *flag* is `t`, types will not be printed. The print mode options are described in section 7.

- `:remove-tops` *flag* *default value:* value of `*REMOVE-TOPS*` = `nil`
  possible values: {`t`|`nil`}
  If *flag* is `t`, attributes with empty values (i.e., values that unify with any value) will not be printed. If *flag* is `nil`, all attributes (except those in `label-hide-list`) will be printed.

- `:label-hide-list` ({*identifier*}*) *default value:* value of `*LABEL-HIDE-LIST*` = `()`
  possible values: a list of symbols (attribute names)
  Attributes in the list will not be printed.

- `:label-sort-list` ({*identifier*}*) *default value:* value of variable `*LABEL-SORT-LIST*` = `()`
  possible values: a list of symbols (attribute names)
  The list defines an order for attributes to be printed. Attributes of the feature structure will be printed first-to-last according to their left-to-right position in the list. All remaining attributes which are not member of the list will be printed at the end.

- `:shell-command` *command* *default value:* value of `*SHELL-COMMAND*` = `"tdl2latex"`
  possible values: {`nil`|*string*}
  If *command* it `nil`, only the LaTeX file will be created and $\mathcal{TDL}$2LaTeX will return. If *command* is a string, $\mathcal{TDL}$2LaTeX will start a shell process and execute *command* with parameter *filename*. An example for *command* is the following shell script with name `tdl2ps` which starts LaTeX with the output file of $\mathcal{TDL}$2LaTeX and generates a PostScript™ file using [Rokicki 93]'s DVIPS.

```
#!/bin/sh
#tdl2ps generates PostScript file
latex $1
dvips $1 -o $1.ps
```

  The following script `tdl2epsf` generates an encapsulated PostScript™ file (EPSF). When generated with a PostScript™ font (such as option `times` in the document header), the EPSF file can be used to scale a feature structure in order to fit into an arbitrary box (e.g., in TeX documents using `\epsfbox`, see [Rokicki 93]). To achieve this, the output file of $\mathcal{TDL}$2LaTeX must consist of exactly one page. Large feature structure may lead to 2 or 3 pages of output. In this case, add `\textheight80cm\textwidth40cm` or so to the file header generated by $\mathcal{TDL}$2LaTeX. Then LaTeX should generate one-page output that can be scaled arbitrarily. If TeX stack size is too small to process large feature structures, recompilation of TeX with increased stack size will help.

```
#!/bin/sh
#tdl2epsf generates encapsulated PostScript file (EPSF)
latex $1
dvips $1 -E -o $1.epsf
```

`tdl2x`, generates a `dvi` file and runs `xdvi` on it.

```
#!/bin/sh
#tdl2x generates a dvi file and starts xdvi
latex $1
xdvi $1
```

- `:wait` *flag* *default value:* value of variable `*WAIT*` = `nil`
  possible values: {`t`|`nil`}
  If *flag* is `nil` and *command* is not `nil`, the shell command *command* will be started as a background process. Otherwise, *TDL*2LaTeX will wait for *command* to be terminated.

- `:latex-header-p` *flag* *default value:* value of `*LATEX-HEADER-P*` = `t`
  possible values: {`t`|`nil`}
  If *flag* is `t`, a complete LaTeX file with `\documentstyle`, etc. will be generated. If *flag* is `nil`, only the LaTeX code of the feature structure enclosed in `\begin{featurestruct}` and `\end{featurestruct}` will be written to the output file. This is useful for inserting LaTeX feature structures into LaTeX documents for papers, books, etc.

- `:align-attributes-p` *flag* *default value:* value of `*ALIGN-ATTRIBUTES-P*` = `nil`
  possible values: {`t`|`nil`}
  If *flag* is `t`, attribute names and values will be aligned. If *flag* is `nil`, no alignment will take place.

- `:fontsize` *size* *default value:* value of `*FONTSIZE*` = `"normalsize"`
  possible values: a string
  This parameter sets the size of the LaTeX feature structures. It must be a string consisting of a valid LaTeX font size name, e.g., `"tiny"`, `"scriptsize"`, `"footnotesize"`, `"small"`, `"normalsize"`, `"large"`, `"Large"`, `"LARGE"`, `"huge"` or `"Huge"`.

- `:corefsize` *size* *default value:* value of variable `*COREFSIZE*` = `nil`
  possible values: {`nil`|*string*}
  This parameter sets the font size for coreference symbols. If *size* is `nil`, the size for the coreference symbol font will be computed from the value of the `:fontsize` keyword. A font one magnification step smaller than given in `:fontsize` will be taken. If *size* is a string, it must contain a valid LaTeX font size as in `:fontsize`.

- `:coreffont` *string* *default value:* value of variable `*COREFFONT*` = `"rm"`
  This parameter sets the LaTeX font name for printing coreference symbols. *string* must contain a valid LaTeX or user defined font name, e.g., `tt`, `bf`, `it`, etc.

- `:coreftable` *a-list* *default value:* value of variable `*COREFTABLE*` = `()`
  This parameter defines a translation table for coreferences and corresponding full names (strings or numbers), e.g., `((1 . "subcat") (2 . "phon") (3 . 1) (4 . 2))`. All coreference numbers at the left side of each element in *a-list* will be replaced by the right side. All other coreferences will be left unchanged.

- `:arraystretch` *number* *default value:* value of variable `*ARRAYSTRETCH*` = 1.1
  This parameter sets the vertical distance between attribute names or disjunction alternatives. *number* is a factor which will be multiplied with the standard character height.

- `:arraycolsep` *string* *default value:* value of `*ARRAYCOLSEP*` = `"0.3ex"`
  This parameter sets the left and right space between braces or brackets and attribute names or values. *string* must contain a LaTeX length expression.

- `:doc-header` *string* *default value:* value of `*DOC-HEADER*`
  This parameter sets the LaTeX `\documentstyle` or `\documentclass` header if `:latex-header-p` is `t`. Default value is `"\\documentstyle{article}"`. It could be replaced by a document style with additional options such as `"a4"`, `"times"`, etc., or, for new LaTeX [Goossens et al. 94], by
  `"\\documentclass{article}`
  `\\usepackage{times}"`

- `:mathmode` *string* *default value:* value of `*MATHMODE*` = `"displaymath"`
  This parameter sets the LaTeX display mode for feature structures. It must be a string consisting of the name of a LaTeX or user defined math mode environment name, e.g., `"math"`, `"displaymath"` or `"equation"`.

- `:typestyle` *style* *default value:* value of variable `*TYPESTYLE*` = `:infix`
  possible values: { `:infix` | `:prefix` }
  If *style* has value `:infix`, complex type entries will be printed in infix notation (e.g., $a \wedge b \wedge c$). If *style* has value `:prefix`, complex type entries will be printed in prefix (LISP like) notation (e.g., (`:AND` a b c)).

- `:print-title-p` *flag* *default value:* value of variable `*PRINT-TITLE-P*` = `nil`
  possible values: {`t`|`nil`}
  If *flag* is `t`, a title with *type* or *instance* will be printed at the bottom of the feature structure. If *flag* is `nil`, no title will be printed.

- `:domain` *domain* *default value:* value of variable `*DOMAIN*`
  possible values: name of a valid domain, only in $\mathcal{TDL}$.

- `:poster` *flag* *default value:* value of variable `*POSTER*` = `nil`
  If `t`, [van Zandt 93]'s poster macros are used to print large feature structures on as many sheets as are needed. This variable only inserts `\input poster` and `\begin{Poster}` ... `\end{Poster}` and forces `"math"` math mode.

- `:pprint-lists` *flag* *default value:* value of variable `*PPRINT-LISTS*` = `t`
  possible values: {`t`|`nil`}
  If *flag* is `t`, lists will we printed using the $\langle\,\rangle$ notation. If `nil`, the internal FIRST /REST encoding will be used.

- `:title` *title* *default value:* `""`
  possible values: { `nil` | *string* }
  prints a title at the bottom of a feature-structure.

- `:index` *number* *default value:* `0`
  This keyword is valid only for $\mathcal{TDL}$ statements `llp` and `lgp`. Its purpose is to select the index of a $\mathcal{TDL}$ instance.

Example: Modifying the Output Style

The following settings can be used for an output style as it is used in [Carpenter 93].

```
<MY-DOMAIN:TYPE> set-switch *ATOM-COMMAND* "\\newcommand{\\atom}[1]
                                              {\\mbox{[{\\bf #1}]}}".
<MY-DOMAIN:TYPE> set-switch *ATTRIB-COMMAND* "\\newcommand{\\attrib}[1]
                                            {\\mbox{\\sc\\lowercase{#1}:\\ }}".
<MY-DOMAIN:TYPE> set-switch *TYPE-COMMAND* "\\newcommand{\\type}[1]
                                             {\\mbox{\\bf #1\\/}}".
```

Example: Printing Huge Structures

A simple way to get huge feature structures on one page is to use a small font and to hide unimportant attributes e.g.

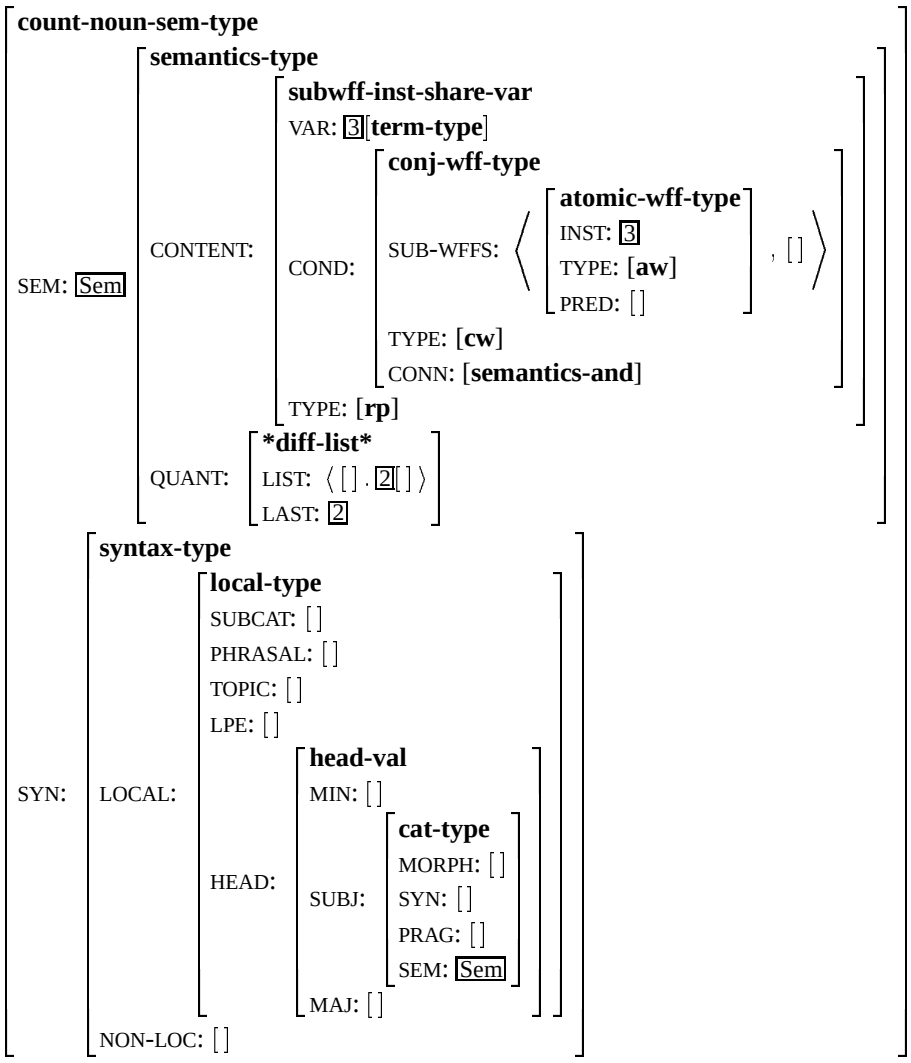


Figure 4: A feature structure generated by $\mathcal{TDL}$2LaTeX

```
lgp 'ethn :fontsize "footnotesize" :remove-tops t :label-hide-list '(SYN).
```

Example: Printing Structures Hugely

For slides, posters, etc. one may choose big fonts:

```
set-switch *doc-header* "\\documentstyle[a4wide,times]{article}
\\textwidth30cm\\textheigth60cm".
lgp 'speaker-sem :fontsize "LARGE".
```

Global Variables for $\mathcal{TDL}$2LaTeX

Most of the following global variables serve as default for the keywords in the $\mathcal{TDL}$2LaTeX print functions. Others are definitions for LaTeX macros for printing attribute names, types, etc. They may be changed for user purposes.

- Global variable `*FILEPATH*` *default value*: `~/tmp/`
  possible values: a pathname or pathname string
  specifies the path where `.tex`, `.dvi` and other files go.

- Global variable `*SHELL-COMMAND*` *default value*: `"tdl2latex"`
  possible values: `nil` or a string containing a shell command name
  specifies a shell command to run on output file, e.g., 'latex'. If `nil`, no shell process will be started.

- Global variable `*LATEX-HEADER-P*` *default value*: `t`
  possible values: `t` or `nil`
  if `nil`, no LaTeX header (`documentstyle`..., etc.) will be written to output file.

- Global variable `*POSTER*` *default value*: `nil`
  possible values: `t` or `nil`
  If `t`, [van Zandt 93]'s poster macros are used to print feature structures on as many sheets as are needed. This variable only inserts `\input poster` and `\begin{Poster}` ... `\end{Poster}` and forces `"math"` math mode.

- Global variable `*PPRINT-LISTS*` *default value*: `t`
  possible values: `t` or `nil`
  If `t`, lists will we printed using the $\langle\,\rangle$ notation. If `nil`, the internal FIRST: /REST: encoding will be used.

- Global variable `*PRINT-TITLE-P*` *default value*: `nil`
  possible values: `t` or `nil`
  if `nil`, no title (default: *type* or *instance*) will be printed.

- Global variable `*ALIGN-ATTRIBUTES-P*` *default value*: `nil`
  possible values: `t` or `nil`
  if `nil`, attributes and values will not be aligned.

- Global variable `*FONTSIZE*` *default value*: `"normalsize"`
  possible values: font size string
  LaTeX size for feature structures, i.e., one of `tiny`, `scriptsize`, `footnotesize`, `normalsize`, `large`, `Large`, `LARGE`, `huge`, `Huge`.

- Global variable `*COREFSIZE*` *default value*: `nil`
  possible values: `nil` or a string
  if `nil`, the size for the coreference symbol font will be computed from `*FONTSIZE*` or the `:fontsize` keyword. If it is a string, it must be a valid LaTeX font size, e.g., `tiny`, `scriptsize`, `footnotesize`, `normalsize`, `large`, `Large`, `LARGE`, `huge`, `Huge`.

- Global variable `*COREFFONT*` *default value*: `"rm"`
  possible values: string
  LaTeX font name for printing coreferences.

- Global variable `*COREFTABLE*` *default value*: `()`
  possible values: assoc list
  Translation table for coreference numbers and corresponding full names (strings/numbers), e.g. `((1 . "subcat") (2 . "phon") (3 . 1) (4 . 2))`.

- Global variable `*DOC-HEADER*` *default value*: `"documentstylearticle"`
  possible values: string
  LaTeX document style header.

- Global variable `*MATHMODE*` *default value*: `"displaymath"`
  possible values: string
  LaTeX math mode for feature structures, one of `math`, `displaymath`, `equation`.

- Global variable `*TYPESTYLE*` *default value*: `:infix`
  possible values: `:infix` or `:prefix`
  style for complex types, infix or Lisp-like prefix.

- Global variable `*REMOVE-TOPS*` *default value*: `nil`
  possible values: `t` or `nil`
  If `t`, attributes with empty values and top type will be removed. If `nil`, top type attributes will not be removed.

- Global variable `*TITLE*` *default value*: `nil`
  possible values: `nil` or string
  If string: title of feature structure. If `nil`, no title will be printed.

- Global variable `*WAIT*` *default value*: `nil`
  possible values: `t` or `nil`
  If `t`, $\mathcal{TDL}$2LaTeX will wait for `shell-command` to be terminated, if `nil`, $\mathcal{TDL}$2LaTeX will not wait.

- Global variable `*LABEL-HIDE-LIST*` *default value*: `()`
  possible values: list of symbols
  List of attribute symbols to be hidden.

- Global variable `*HIDE-TYPES*` *default value*: `nil`
  possible values: `t` or `nil`
  If `nil`, types will be printed, if `t`, types will be hidden.

- Global variable `*ARRAYCOLSEP*` *default value*: `"0.3ex"`
  possible values: string
  Distance (a LaTeX length value) between braces resp. brackets and attribute names and their values.

- Global variable `*ARRAYSTRETCH*` *default value*: 1.1
  possible values: number
  factor for distance between attributes in conjunctions or values in disjunctions.

- Global variable `*ATOM-COMMAND*`
  default value: `"\\newcommand{\\atom}[1]{\\mbox{\\tt #1}}"`
  possible values: string
  LaTeX command for printing atoms.

- Global variable `*ATTRIB-COMMAND*`
  default value: `"\\newcommand{\\attrib}[1]{\\mbox{\\tt #1\\ }}"`
  possible values: string
  LaTeX command for printing attribute names.

- Global variable `*TYPE-COMMAND*`
  default value: `"\\newcommand{\\type}[1]{\\mbox{\\it #1\\/}}"`
  possible values: string
  LaTeX command for printing types.

- Global variable `*COREF-COMMAND*`
  default value: `"\\newcommand{\\coref}[1]{{\\setlength{\\fboxsep}{0.1ex}%`
  `\\fbox{\\corefsize\\coreffont #1}}}"`
  possible values: string
  LaTeX command for printing coreferences.

- Global variable `*EMPTYNODE-COMMAND*`
  default value: `"\\newcommand{\\emptynode}[0]{\\mbox{$[\\,]$}}"`
  possible values: string
  LaTeX command for printing an empty feature structure `[]`.

- Global variable `*TITLE-COMMAND*`
  default value:
  `"\\newcommand{\\featuretitle}[1]{\\centerline{\\it #1\\/}\\smallskip}"`

possible values: string
LaTeX command for printing title.

- Global variable `*LATEX-SIZE-TRANSLATION*`
  default value:

```
'(("tiny"         . 0.5)    ("scriptsize" . 0.7)
  ("footnotesize" . 0.8)    ("small"      . 0.9)
  ("normalsize"   . 1.0)    ("large"      . 1.2)
  ("Large"        . 1.44)   ("LARGE"      . 1.728)
  ("huge"         . 2.074)  ("Huge"       . 2.488))
```

  An assoc list for magnification factors fontsize $\mapsto$ magstep.

6 TDL Grapher

It is possible to display the TDL type hierarchy using the TDL grapher. The TDL grapher has been implemented first in CLIM 1.2 and is now ported to CLIM 2.0 [McKay et al. 92].
Start: either type `(load-system "tdl-grapher")` instead of `(load-system "tdl")` at the beginning or with the function

`grapher`.

from the TDL reader.
An example screen dump of a TDL grapher session is shown in Figure 5. The grapher layout consists of three screen areas: the menu bar with the buttons described below, the grapher display, and a output window with command history.

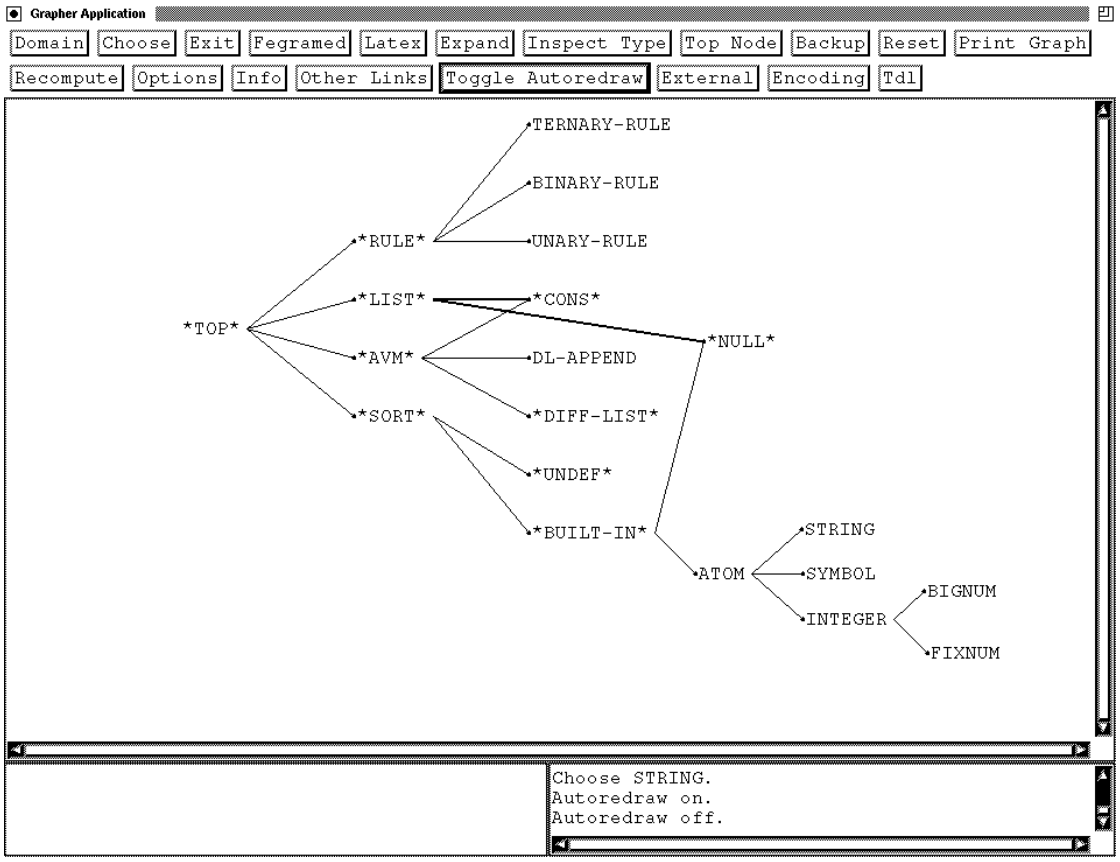


Figure 5: TDL grapher

Buttons:

- `Domain`: Select a domain out of a list of domain names.
- `Choose`: Choose a new node (type) out of a list of alphabetically sorted types. This is the same a clicking the second mouse button at a highlighted type in the graph display. The chosen node is called ‘current node’ in the following lines.
- `Exit`: Exit the Grapher process.
- `Fegramed`: Call FEGRAMED with the global prototype of the current node.
- `Latex`: Call TDL2LaTeXwith the global prototype of the current node.

- `Expand`: Call `expand-type` on the global prototype of the current node.
- `Inspect Type`: Call the Inspector with the type info structure of the current node.
- `Top Node`: Redraw the graph with the current node as the new top node. This is the same as pressing the Shift key and clicking the second mouse button.
- `Backup`: Redraw the graph with one of the super types of the current node as the new top node.
- `Reset`: Redraw the graph with the top node of the type hierarchy as the new top node.
- `Print Graph`: Print the graph to a PostScript™ file `tdl-graph.ps`.
- `Recompute`: Recompute and redraw the graph, e.g. after definition of new types. This can also be done while processing a grammar file by simply inserting the `recompute.` statement into the file.
- `Options`: Menu for setting the output style, e.g., horizontal and vertical space between nodes, maximal depth, etc.
- `Info`: Print information about the current node.
- `Other Links`: Toggle between showing/hiding dependency arcs in the type hierarchy.
- `Toggle Autoredraw`: Toggle the autoredraw mode. If this mode is on, the graph will be redrawn automatically when a type is (re)defined. If autoredraw mode is off (which is the default), the user must press the `recompute` bottom for an update of the graph. This button toggles the value of the global variable `*UPDATE-GRAPHER-OUTPUT-P*` (see documentation on page 30).
- `External`: Print information about lubs and glbs of the current node.
- `Encoding`: Print information about the encoding of the current node.
- `Tdl`: Set useful *TDL* switches.

7 Print/Read Syntax for TDL Type Entries

The output style of the print functions for TDL's typed feature structures as described in section 5.18 can be controlled in a way such that different flags are printed, feature are hidden, or types are omitted.
In this section, we describe the syntax of type entries (mainly for the ascii printing) and how the output behavior can be changed.

7.1 Print Modes

The type entry printer/reader is configurable and supports different modes ('print modes') for dumping/transforming typed feature structures to files or other modules of a NL system.
The easiest way to change the print mode is to use the following functions/macros.

- Macro `with-print-mode` *mode lisp-body*.
  Temporarily sets print mode to *mode* and executes *lisp-body*.

- Function `save-print-mode`.
  Saves print mode to stack `*PRINT-VAR-STACK*`.

- Function `restore-print-mode`.
  Restores print mode from stack `*PRINT-VAR-STACK*`.

- Function `set-print-mode` [*mode*].
  Sets print mode *mode*. Default for *mode* is `:default`.

The default global print mode is `:default`, it may be changed by the user for debugging purposes etc. Possible modes are `:debug`, `:default`, `:exhaustive`, `:fs-nll`, `:hide-all`, `:hide-types`, `:read-in`, `:tdl2asl`, `:x2morf`.
Additional user modes can be defined by extending the global variable `*PRINT-PROFILE-LIST*`.
Examples:

```
Save-Print-Mode.          ;; saves print mode
Set-Print-Mode :debug.    ;; changes print mode
<debugging>
Restore-Print-Mode.       ;; restores print mode

With-Print-Mode :X2MORF  ...(print-fs-calls)...
;; can be used in the X2MORF grammar dumping function

With-Print-Mode :FS-NLL  ...(print-fs-calls)...
;;; for FS-to-NLL translations.
```

The print mode functions/macro change the following four global variables:

- `*PRINT-SLOT-LIST*`

- `*PRINT-CATEGORY-LIST*`

- `*PRINT-SORTS-AS-ATOMS*`, † in the table below (column 4)

- `*PRINT-ONLY-NON-DEFAULTS*`, $\star$ in the table below (column 5)

print mode	*PRINT-SLOT-LIST*	*PRINT-CATEGORY-LIST*	†	⋆
:debug	(:sort-p :expanded :delta)	(:avms :sorts :atoms)	nil	t
:default	(:expanded)	(:avms :sorts :atoms)	t	t
:exhaustive	(:sort-p :delta :restriction :expanded)	(:avms :sorts :atoms)	nil	nil
:tdl2asl	()	(:avms :sorts :atoms)	nil	t
:fs-nll	()	(:avms :sorts :atoms)	t	t
:hide-all	()	()	nil	t
:hide-types	()	(:atoms)	nil	t
:read-in	(:sort-p :delta :restriction :expanded)	(:avms :sorts :atoms)	nil	t
:x2morf	(:expanded :sort-p)	(:sorts :atoms)	nil	t

7.2 Global Variables

The following global variables are defined in package TDL:

- *PRINT-SLOT-LIST* *default value*: (:sort-p :expanded)
  possible values: list of :complete, :delta, :expanded, :restriction, :sort-p
  used in: ascii printing, TDL2LaTeX, FEGRAMED
  type slots to be printed. The :type slot is always printed.

- *PRINT-CATEGORY-LIST* default-value: (:atoms :avms :sorts)
  possible values: list of :atoms, :avms, :sorts
  used in: ascii printing, FEGRAMED
  List of tdl type categories to be printed.

- *PRINT-ONLY-NON-DEFAULTS* *default value*: t
  possible values: t, nil
  used in: ascii printing, TDL2LaTeX, FEGRAMED
  If nil, all slots in *PRINT-SLOT-LIST* are printed. If not nil, only slots with non-default values that are member of *PRINT-SLOT-LIST* are printed. The default values are:
  :complete t, :delta nil, :expanded t, :restriction *TOP*, :sort-p nil
  If *PRINT-ONLY-NON-DEFAULTS* is t and these 4 slots have default value and :type value is the top type of the current domain, then no type entry is printed at all. In all other cases, the value of the :type slot will be printed anyway.

- *HIDE-TYPES* *default value*: nil
  possible values: t, nil
  used in: ascii printing, TDL2LaTeX, FEGRAMED
  If not nil, only true UDiNe atoms (like *fail* and *undef*) will be printed. TDL atoms, sorts and types will not be printed.

- *PRINT-SORTS-AS-ATOMS* *default value*: nil
  possible values: t, nil
  used in: ascii printing, TDL2LaTeX, FEGRAMED
  If not nil, sort symbols will be printed the same way atoms are printed. If nil, sort symbols will be printed like type symbols (:type sort). Conjunctions or Disjunctions of Sorts are *always* printed with (:type (:and/:or ...)).

- *PRINT-SLOT-LENGTH* *default value*: 16
  possible values: nil or a number
  used in: ascii printing only
  If a slot is longer than 16 characters, a newline character will be printed (nil = no limit).

- *PRINT-NEWLINE* *default value*: nil
  possible values: t, nil
  used in: ascii printing only
  Prints a newline after each type entry (except before empty label lists).

7.3 BNF

The BNF for typed feature structures (input and output for ascii) is:

node → *atom* |
[*type-info*] `[` {(*identifier node*)}* `]` |
[*type-info*] { *node* {^*node*}+ } |
...

type-info → `(` `:type` *type-expr*
[`:complete` {`t` | `nil`}]
[`:delta` {`nil` | ({*type-expr*}+)}]
[`:expanded` {`t` | `nil`}]
[`:restriction` *type-expr*]
[`:sort-p` {`t` | `nil`}] `)`

type-expr → *identifier* |
(`:and` {*type-expr*}+`)` |
(`:or` {*type-expr*}+`)` |
(`:not` *type-expr*`)` |
(`:atom` *atom*`)`

atom → *identifier* | *integer* | *string*

8 Emacs TDL Mode

TDL mode for `Emacs` supports comfortable editing facilities for TDL grammar files. It indicates matching parentheses (`()[]{}<>`, as in `Emacs` LISP or TEX mode), performs indentation of label lists, and, important for grammar development and debugging, establishes a connection to the TDL system and COMMON LISP. Currently, the TDL mode is implemented for ALLEGRO COMMON LISP.

8.1 Installation

The following installation steps let `Emacs` know about TDL mode.

1. copy the file `tdl-mode.el` from the TDL system distribution into your `Emacs` load path.
2. if it doesn't already exist, create a directory for auto-include files, e.g. `~/.autoinclude`
3. copy the file `header.tdl` from the TDL system distribution into this directory. You can modify this file, but the first line should be `;;; -*- Mode: TDL -*-`.
4. add the following lines to your `Emacs` init file (`~/.emacs` by default)

```
(load "tdl-mode" nil t)
(push '("\\.tdl$" . tdl-mode) auto-mode-alist)
(load "autoinclude" nil t)
(push '("\\.tdl$" . "header.tdl") auto-include-alist)
(setq auto-include-directory "~/.autoinclude")
```

After this, the header file will be included when a new file with extension `.tdl` is created in `Emacs` and TDL mode will be switched on when a file's first line is `;;; -*- Mode: TDL -*-`.

8.2 Key Bindings

The following key bindings are defined for the TDL mode:

- key `TAB` is bound to function `tdl-indent-command`
  indents one line
- key `ESC C-\` is bound to function `tdl-indent-region`
  indents a whole marked region, e.g. one or more type definitions at once, or the whole buffer
- key `ESC C-x` is bound to function `eval-tdl-expression`
  evaluates the whole definition where the cursor is in (up to a terminating dot at the end of a line)
- key `C-c C-s` is bound to function `eval-current-tdl-expression`
  is currently the same as `ESC C-x`
- key `C-c C-r` is bound to function `eval-tdl-region`
  evaluates the whole marked region, e.g. one or more type definitions at once, or the whole buffer
- key `C-c r` is bound to function `eval-tdl-region-and-go`
  evaluates the marked region and switches to the inferior COMMON LISP buffer
- key `C-c C-b` is bound to function `eval-tdl-file`
  performs a TDL `include` of the whole file associated with the current buffer
- key `C-c C-e` is bound to function `goto-end-of-tdl-expression`
  moves the cursor to the end of a TDL definition or statement
- key `C-c C-a` is bound to function `goto-begin-of-tdl-expression`
  moves the cursor to the beginning of TDL definition or statement

TDL mode can also be switched on 'by hand' with `M-x tdl-mode`.

9 Top Level Abbreviations (ALLEGRO COMMON LISP Only)

In the ALLEGRO COMMON LISP [Fra 92] version of $\mathcal{TDL}$, some often used commands are also available as top level abbreviations. The top level command `:alias` prints a list of available abbreviations:

```
Alias        Description
-----        -----------
composer     start allegro composer
fegramed     initialize fegramed
fgi          fegramed global instance
fgp          fegramed global prototype
fli          fegramed local instance
flp          fegramed local prototype
grapher      start grapher [system]
lgi          LaTeX global instance
lgp          LaTeX global prototype
lli          LaTeX local instance
llp          LaTeX local prototype
pgi          print global instance
pgp          print global prototype
pli          print local instance
plp          print local prototype
recompute    recompute grapher
tdl          start tdl reader
```

`:composer`, `:recompute` and `:fegramed` may also be abbreviated by `:com`, `:rec` and `:feg`.
All top level commands take the same parameters as the corresponding $\mathcal{TDL}$-LISP functions described in the sections before. For compatibility reasons, we recommend that top level commands be used in the interactive mode only but not in the $\mathcal{TDL}$ grammar files.
Important Note: Parameters of top level commands should not be quoted. Example:
`<MY-DOMAIN:TYPE> pgp 'agr-en-type :label-hide-list '(GOV OBL).`
but
`MY-DOMAIN(49): :PGP agr-en-type :label-hide-list (GOV OBL)`
`:tdl`, `:composer` and `:fegramed` don't take any parameter.
In addition to these $\mathcal{TDL}$ specific commands, the user may define its own abbreviations. Details are described in the ALLEGRO COMMON LISP manual [Fra 92].

10 Sample Session

```
;;; -*- Mode: TDL -*-
;;; ---------------------------------------------------------------------------
;;; Parametrized Type Expansion in TDL. Demo file
;;; ---------------------------------------------------------------------------

defdomain "DEMO".  ;;; built-in types will be loaded automatically
begin :domain "DEMO".
  set-switch *WARN-IF-REDEFINE-TYPE* NIL.       ;;; switch off warnings
  set-switch *WARN-IF-TYPE-DOES-NOT-EXIST* NIL. ;;; dto
  set-switch *PRINT-SORTS-AS-ATOMS* T.          ;;; for fegramed/pgp
  set-switch *VERBOSE-EXPANSION-P* T.           ;;; verbose expansion
  set-switch *PRINT-SLOT-LIST* (CONS :DELTA *PRINT-SLOT-LIST*). ;;; show :delta
  set-switch *LABEL-SORT-LIST* '(FIRST REST LAST INPUT EDGE NEXT  ;;; for output
                                 WHOLE FRONT BACK A B C D X Y Z). ;;; only
  fegramed.     ;;; start Feature Editor
  set-switch FEGRAMED:*DEF-FILENAME* "/tmp/".
  grapher.      ;;; start Type Grapher
  begin :type.

;;; ---------------------------------------------------------------------------
;;; Parametrized Expansion: expand-only for type d
;;; ---------------------------------------------------------------------------

    a1 := [a 1].
    b2 := [b 2].
    c  := [c  ].
    zz := [z  ].
    d  := zz & [x a1,
                y b2,
                z c & [c 3]].

    defcontrol d ((:expand-only ((c 1 EQ) z.*) ((a1) x))
                  (:attribute-preference z x y)).
    wait.
    expand-type 'd.
    fgp 'd.
    wait.

;;; ---------------------------------------------------------------------------
;;; Parametrized Expansion with delay and prototype index 1
;;; ---------------------------------------------------------------------------

    defcontrol d ((:delay (c *))
                  (:attribute-preference z x y)
                  (:expand-function types-first-expand))
              :index 1.
    expand-type 'd :index 1.
    fgp 'd :index 1.
    wait.

;;; ---------------------------------------------------------------------------
```

```
;;; Interactively ask for disjunct order
;;; ------------------------------------------------------------------------

    inter := [disj  a1 | b2 | c,
              disj2 b2 | d  | 42].

    defcontrol inter ((:ask-disj-preference t)).
    expand-type 'inter.
    fgp 'inter.
    wait.

;;; ------------------------------------------------------------------------
;;; Negation `a la [Smolka 89]
;;; ------------------------------------------------------------------------

    xn := [a 1, b 2, c 3].
    nx := [n ~xn].

    expand-type 'nx.
    fgp 'nx.
    wait.

;;; ------------------------------------------------------------------------
;;; Nonmonotonicity (single link overwriting)
;;; ------------------------------------------------------------------------

    a := [ person_x:INTEGER,
           person_y:INTEGER ].

    b := a & [ person_x  1 | 2 ].

    px3 != b & [ person_x 3 ].

    expand-type 'px3.
    fgp 'px3.
    wait.

    pxs != b & [ person_y "string" ].

    expand-type 'pxs.
    fgp 'pxs.
    wait.

;;; ------------------------------------------------------------------------
;;; Welltypedness Check for an instance at definition time:
;;; ------------------------------------------------------------------------

    set-switch *VERBOSE-EXPANSION-P* NIL.
    set-switch *CHECK-WELLTYPEDNESS-P* T.
    ;;; now expand-instance will be done automatically!
    begin :instance.
       zi := zz & [z c & [c 3],
                   x a1        ].
       fgi 'zi.
```

```
      wait.
    end :instance.
    set-switch *CHECK-WELLTYPEDNESS-P* NIL.

;;; ---------------------------------------------------------------------------
;;; Automata - Basic Configurations
;;; ---------------------------------------------------------------------------

  proto-config := *avm* &
    [EDGE, NEXT, INPUT].

  non-final-config := proto-config &
    [EDGE  #first,
     NEXT.INPUT  #rest,
     INPUT  <#first . #rest>].

  final-config := proto-config &
    [INPUT  < >,
     EDGE  *undef*,
     NEXT  *undef*].

  config := non-final-config | final-config.

;;; ---------------------------------------------------------------------------
;;; consider the two regular expressions U=(a+b)^*c and X=a(b^+)(c^*):
;;; ---------------------------------------------------------------------------

  U := non-final-config &
         [EDGE  %covary('a | 'b, 'c),
          NEXT  %covary(    U    ,  V)].

  V :< final-config.

  X := non-final-config &
         [EDGE  'a,
          NEXT   Y].

  Y := non-final-config &
         [EDGE  'b,
          NEXT  Y | Z].

  Z := config &
         [EDGE  %covary( 'c, *undef*),
          NEXT  %covary(  Z, *undef*)].

;;; ---------------------------------------------------------------------------
;;; now we intersect the two automata U and X  --> a(b^+)c
;;; ---------------------------------------------------------------------------

  UX := U & X.

  test1 := UX & [INPUT <'a,'b,'c>].      ;;; accepted
  test2 := UX & [INPUT <'a,'b,'b,'c>].   ;;; accepted
  test3 := UX & [INPUT <'b,'c>].         ;;; is inconsistent
```

```
  test4 := UX & [INPUT <'a,'b,'c,'d>].   ;;; is inconsistent

  set-switch *VERBOSE-EXPANSION-P* NIL.      ;;; silent expansion
  set-switch *PRINT-SLOT-LIST* (REMOVE :DELTA *print-slot-list*).
                                             ;;; don't print delta list

  expand-type 'test1.
  fgp 'test1.
  wait.
  expand-type 'test2.
  fgp 'test2.
  wait.
  expand-type 'test3.
  expand-type 'test4.
  wait.

;;; ---------------------------------------------------------------------------
;;; Ait-Kaci's version of APPEND
;;; ---------------------------------------------------------------------------

  set-switch *VERBOSE-EXPANSION-P* T.

  *cons* := *avm* & [FIRST,REST *list*].  ;;; redefine *LIST* recursively

  append0 := *avm* & [FRONT < >,
                      BACK  #1 & *list*,
                      WHOLE #1].
  append1 := *avm* & [FRONT <#first . #rest1>,
                      BACK  #back & *list*,
                      WHOLE <#first . #rest2>,
                      PATCH append & [FRONT #rest1,
                                      BACK  #back,
                                      WHOLE #rest2]].
  append := append0 | append1.

  r:=append & [FRONT <'a,'b>,
               BACK  <'c,'d>].    ;;; result will be in WHOLE

  expand-type 'r.
  wait.
  lgp 'r.  ;;; generate LaTeX code
  wait.

  set-switch *VERBOSE-EXPANSION-P* NIL.

  q:=append & [WHOLE <'a,'b,'c>].   ;;; compute possible inputs
  expand-type 'q.
  fgp 'q.
  wait.

;;; ---------------------------------------------------------------------------
;;; Print Recursive Types (SCCs)
;;; ---------------------------------------------------------------------------
```

```
  message "~%~%List of recursive sccs:".
  print-recursive-sccs.

;;; -----------------------------------------------------------------------
;;; Print Appropriateness table
;;; -----------------------------------------------------------------------

  message "~%Computing appropriateness table~%".
  compute-approp :warn-if-not-unique T.
  print-approp.
```

Index

References

[Aït-Kaci & Nasr 86] Hassan Aït-Kaci and Roger Nasr. *Residuation: A Paradigm for Integrating Logic and Functional Programming*. Technical Report AI-359-86, MCC, Austin, TX, 1986.

[Aït-Kaci 86] Hassan Aït-Kaci. *An Algebraic Semantics Approach to the Effective Resolution of Type Equations*. Theoretical Computer Science, 45:293–351, 1986.

[Backofen & Weyers 95] Rolf Backofen and Christoph Weyers. *UDiNe—A Feature Constraint Solver with Distributed Disjunction and Classical Negation*. Technical report, Deutsches Forschungszentrum für Künstliche Intelligenz, Saarbrücken, Germany, 1995. Forthcoming.

[Carpenter 93] Bob Carpenter. *The Logic of Typed Feature Structures*. Tracts in Theoretical Computer Science. Cambridge: Cambridge University Press, 1993.

[Dörre & Dorna 93] Jochen Dörre and Michael Dorna. *CUF—A Formalism for Linguistic Knowledge Representation*. In: Jochen Dörre (ed.), Computational Aspects of Constraint-Based Linguistic Description I, pp. 1–22. ILLC/Department of Philosophy, University of Amsterdam, 1993. DYANA-2 Deliverable R1.2.A.

[Eisele & Dörre 90] Andreas Eisele and Jochen Dörre. *Disjunctive Unification*. IWBS Report 124, IWBS–IBM Germany, Stuttgart, 1990.

[Fra 92] *Allegro CL User Guide*. Technical report, Berkeley, CA, March 1992. 2 volumes.

[Goossens et al. 94] Michel Goossens, Frank Mittelbach, and Alexander Samarin. *The* LaTeX *Companion*. Reading, MA: Addison Wesley, 1994.

[Jameson et al. 94] Anthony Jameson, Bernhard Kipper, Alassane Ndiaye, Ralph Schäfer, Joep Simons, Thomas Weis, and Detlev Zimmermann. *Cooperating to be Noncooperative: The Dialog System PRACMA*. Technical report, Universität des Saarlandes, SFB 314, KI – Wissensbasierte Systeme, Saarbrücken, Germany, 1994.

[Kantrowitz 91] Mark Kantrowitz. *Portable Utilities for Common Lisp*. Technical Report CMU-CS-91-143, School of Computer Science, Carnegie Mellon University, Pittsburgh, PA, 1991.

[Kiefer & Fettig 94] Bernd Kiefer and Thomas Fettig. *FEGRAMED—An Interactive Graphics Editor for Feature Structures*. Technical report, Deutsches Forschungszentrum für Künstliche Intelligenz, Saarbrücken, Germany, 1994. Forthcoming.

[Krieger & Schäfer 93a] Hans-Ulrich Krieger and Ulrich Schäfer. *TDL – A Type Description Language for Unification-Based Grammars*. In: Proceedings Neuere Entwicklungen der deklarativen KI-Programmierung, pp. 67–82, Saarbrücken, Germany, September 1993. Deutsches Forschungszentrum für Künstliche Intelligenz. DFKI Research Report RR-93-35.

[Krieger & Schäfer 93b] Hans-Ulrich Krieger and Ulrich Schäfer. *TDL ExtraLight User's Guide*. Technical report, Deutsches Forschungszentrum für Künstliche Intelligenz, Saarbrücken, Germany, 1993. DFKI Document D-93-09.

[Krieger & Schäfer 94a] Hans-Ulrich Krieger and Ulrich Schäfer. *TDL—A Type Description Language for HPSG. Part 1: Overview*. Technical report, Deutsches Forschungszentrum für Künstliche Intelligenz, Saarbrücken, Germany, 1994. DFKI Research Report RR-94-37.

[Krieger & Schäfer 94b] Hans-Ulrich Krieger and Ulrich Schäfer. *TDL—A Type Description Language for Constraint-Based Grammars*. In: Proceedings of the 15^{th} International Conference on Computational Linguistics (COLING), pp. 893–899, Kyoto, Japan, 1994.

[Krieger 93] Hans-Ulrich Krieger. *Single Link Overwriting—A Conservative Non-Monotonic Extension of Unification-Based Inheritance Networks*. Technical report, Deutsches Forschungszentrum für Künstliche Intelligenz, Saarbrücken, Germany, 1993. Draft version.

[Krieger 95] Hans-Ulrich Krieger. *TDL—A Type Description Language for Constraint-Based Grammars. Foundations, Implementation, and Applications.* PhD thesis, Universität des Saarlandes, Department of Computer Science, Saarbrücken, Germany, 1995. Forthcoming.

[Lamport 86] Leslie Lamport. LaTeX *User's Guide & Reference Manual. A document preparation system*. Reading, Massachusetts: Addison-Wesley, 1986.

[McKay et al. 92] Scott McKay, William York, John Aspinall, Dennis Doughty, Charles Hornig, Richard Lamson, David Linden, David Moon, and Ramana Rao. *Common Lisp Interface Manager*, May 1992.

[Pollard & Sag 87] Carl Pollard and Ivan Sag. *Information-Based Syntax and Semantics. Vol. I: Fundamentals*. CSLI Lecture Notes, Number 13. Stanford: Center for the Study of Language and Information, 1987.

[Pollard & Sag 94] Carl Pollard and Ivan A. Sag. *Head-Driven Phrase Structure Grammar*. Studies in Contemporary Linguistics. Chicago: University of Chicago Press, 1994.

[Rokicki 93] Tomas Rokicki. *DVIPS: A TeX driver*, 1993. Documentation included in the DVIPS distribution, ftpable from most TeX sites.

[Schäfer 95] Ulrich Schäfer. *Parametrizable Type Expansion for TDL*. Master's thesis, Universität des Saarlandes, Department of Computer Science, Saarbrücken, Germany, 1995. Forthcoming.

[Smolka 88] Gert Smolka. *A Feature Logic with Subsorts*. LILOG Report 33, WT LILOG–IBM Germany, Stuttgart, Mai 1988.

[Smolka 89] Gert Smolka. *Feature Constraint Logic for Unification Grammars*. IWBS Report 93, IWBS–IBM Germany, Stuttgart, November 1989.

[Smolka 91] Gert Smolka. *Residuation and Guarded Rules for Constraint-Logic Programming*. Research Report RR-91-13, DFKI, Saarbrücken, 1991.

[Steele 90] Guy L. Steele. *Common Lisp: The Language*. Bedford, MA: Digital Press, 2nd edition, 1990.

[Uszkoreit et al. 94] Hans Uszkoreit, Rolf Backofen, Stephan Busemann, Abdel Kader Diagne, Elizabeth A. Hinkelman, Walter Kasper, Bernd Kiefer, Hans-Ulrich Krieger, Klaus Netter, Günter Neumann, Stephan Oepen, and Stephen P. Spackman. *DISCO–An HPSG-based NLP System and its Application for Appointment Scheduling*. In: Proceedings of the 15^{th} International Conference on Computational Linguistics (COLING), Kyoto, Japan, 1994. also as DFKI Research Report RR-94-38.

[Uszkoreit 91] Hans Uszkoreit. *Adding Control Information to Declarative Grammars*. In: Proceedings of the 29^{th} Annual Meeting of the Association for Computational Linguistics (ACL), pp. 237–245, Berkeley, CA, 1991.

[van Zandt 93] Timothy van Zandt. *Documentation for poster.tex/poster.sty, Posters and banners with generic TeX*, May 1993. Documentation included in the poster distribution, ftpable from most TeX sites.