

Trale Milca Environment v. 2.5.0
User's Manual (Draft)

Gerald Penn, Detmar Meurers,
Kordula De Kuthy, Mohammad Haji-Abdolhosseini,
Vanessa Metcalf, Stevan Müller, Holger Wunsch

May 2003

©2003, The Authors

Contents

1	Using the Trale System	3
1.1	Introduction	3
1.2	Running Trale	3
1.3	Signatures	4
1.3.1	Signature specifications	4
1.3.2	Subtype covering	6
1.3.3	Interaction with the signature	7
1.4	Descriptions	8
1.4.1	Logical variable macros	8
1.4.2	Macro hierarchies	10
1.4.3	Automatic generation of macros on different types	12
1.5	Theory specifications	14
1.5.1	Complex antecedent constraints	15
1.5.2	Additional commands	17
1.6	Test sequences	17
1.6.1	Test files	17
1.6.2	Test queries	17
2	Some examples illustrating Trale functionality	19
3	Lexical rule compiler	23
3.1	Introduction	23
3.2	Using the lexical rule compiler	23
3.2.1	Input syntax	24
3.2.2	Interpretation	29
4	Output	32
4.1	Saving of outputs	32
4.2	Grisu interface	32
4.2.1	Unfilling	33
4.2.2	Feature ordering	34
4.2.3	Diff of feature structures	34

5	The Chart Display	35
5.1	Installation and Customization	35
5.2	Working with the Chart Display	36
5.2.1	Debugging	37
5.2.2	Generation	38
6	[incr TSDB()]	39
6.1	Installing [incr TSDB()]	39
6.1.1	Setting up Shell Variables	40
6.1.2	Setting up .tsdbrc	40
6.1.3	Setting up PVM	41
6.1.4	Initializing a CPU	42
6.1.5	Creating a Test Suite	42
7	Programming hooks in Trale	45
7.1	Pretty-printing hooks	45
7.1.1	Portraying feature structures	45
7.1.2	Portraying inequations	47
7.1.3	A sample pretty-printing hook	47

Chapter 1

Using the Trale System

1.1 Introduction

The purpose of this manual is to provide an introduction to the features provided by TRALE that exist above and beyond what is provided by ALE, and documented in the ALE User's Guide. Some of these features exist in TRALE itself, while others exist in ALE on which TRALE is implemented. This manual assumes a familiarity with the ALE User's Guide.¹

TRALE is a system for parsing, logic programming and constraint resolution with typed feature structures in a manner roughly consistent with their use in Head-driven Phrase Structure Grammar (HPSG). It is written in SICStus Prolog 3.8.6, and operates by pre-compiling various built-ins to ALE code that are compiled further to Prolog code by ALE and, ultimately, to lower-level code by the SICStus compiler. TRALE has all of the functionality of ALE plus some extras, which are explained in the following sections. The most apparent difference between ALE and TRALE is the signature specifications. This is discussed in section 1.3. Section 1.5 talks about an extra feature regarding theory specifications. In chapter 2, some linguistic examples that make use of the new features of TRALE are presented. The last section discusses the pretty-printing hooks that have been introduced in ALE. We start out with an overview on how to run TRALE and get started.

1.2 Running Trale

To run the TRALE Milca release, call “trale” or “trale -g” to start it with the graphical user interface Grisu. Calling “trale -h” returns a list of other options

¹ALE User's Guide is available online at <http://www.cs.toronto.edu/~gpenn/ale.html>.

which are available.²

Two files are necessary to declare a TRALE grammar—a *signature file*, which defines type hierarchies, and a *theory file*, which defines lexical items, phrase structure rules, relations, etc. relative to the signature defined in the signature file. These files are discussed in more detail below. To load and compile a theory and its corresponding signature file, type:

```
| ?- compile_gram('<theory_file>').
```

where `<theory_file>` is the name of the theory file. As a shortcut for the compilation of a file called 'theory', the system provides the shortcut

```
| ?- c.
```

The above commands automatically compile the corresponding signature file as well. The name of the signature file is assumed to be 'signature'. If this is not the case, it must be declared in the theory file with a `signature/1` declaration. For example,

```
signature(foo).
```

declares the signature file associated with the theory file that contains this predicate to be `foo`. As in ALE, parsing can be performed with the `rec/1` command. For example, to parse the sentence "Kim read the book yesterday", type

```
| ?- rec([kim, read, the, book, yesterday]).
```

1.3 Signatures

1.3.1 Signature specifications

TRALE signatures are markedly different in format from ALE signatures. When using TRALE, follow the signature format discussed in this section. ALE signatures are not recognized by TRALE.

TRALE signatures are specified using a separate text file with subtyping indicated by indentation as in the following example signature:

²To run the bare TRALE system without the OSU extensions and graphical user interface, set your `TRALE_HOME` environment variable to the location where TRALE lives. After starting SICStus Prolog, type

```
| ?- compile('<trale_dir>/trale').
```

where `<trale_dir>` is the location of `trale.pl`. This command loads and compiles TRALE, which in turn loads and compiles parts of ALE code that are necessary for its operation. A copy of `ale.pl` thus must also be present in the same directory where `trale.pl` is located.

```

type_hierarchy
bot
  a f:bool g:bool
    b f:plus g:minus
    c f:minus g:plus
  bool
    plus
    minus
.

```

The example shows a type hierarchy with a most general element `bot`, which immediately subsumes types `a` and `bool`. Type `a` introduces two features `F` and `G` whose values must be of type `bool`. Type `a` also subsumes two other types `b` and `c`. The `F` feature value of the former is always `plus` and its `G` feature value is always `minus`. The feature values of type `c` are the inverse of type `b`. Finally, `bool` has two subtypes `plus` and `minus`.

As shown in the example, appropriate features are written after the types that introduce them. The type of the value of a feature is separated from the feature by a colon as in `f:bool`, which says the feature `F` takes a value of type `bool`. Note that subtypes are written at a consistent level of increased indentation. This means that if a type is introduced at column C , then all its subtypes must be introduced directly below it at column $C + n$. There are no requirements on the value of n other than it being consistent and greater than zero. However, $n = 2$ is recommended. Inconsistent indentation causes an error. There can only be one type hierarchy in a signature file. If more than one type hierarchy is declared in the same signature file, only the first one is considered by TRALE.

Types are syntactically Prolog terms, which means that they have to start with a lower-case letter and only consist of letters and numbers (e.g. `bot`, `bool`, `dtr1`). New types are introduced in separate lines. Each informative line must contain at least a type name. A type may never occur more than once as the subtype of the same supertype. It can, however, occur as a subtype of two or more different supertypes, i.e., for multiple inheritance. In this case, it is better to add an ampersand (`&`) to the beginning of the type name in order to prevent unintended multiple inheritance.

There may be zero or more features introduced for each type. As mentioned before, these have the form `feature:value`. All feature-value pairs are separated by white space and they should appear in the same line. Recall that, `feature` is the name of a feature and `value` is the value restriction for that feature. As with the types, a feature name must always start with a lower case letter. If a feature is specified for a type, all its subtypes inherit this feature automatically. As in ALE, in cases of multiple inheritance, the value restriction on any feature that has been inherited from the supertypes is the union of those value restrictions. A single period (`.`) in an otherwise blank line signals the end of a signature declaration.

TRALE signature specifications also allow for `a_/1` atoms as potential value

restrictions. As described in the ALE User's Guide, the `a_/1` atoms let you use Prolog terms as featureless types. For example, this is useful for the value of `phon` features, relieving the user from having to introduce the spelling (or phonology) of each lexical item in the type hierarchy beforehand.

As another example, let us see how the type hierarchy in Figure 1.1 translates into a TRALE signature. As the figure shows, the type `agr`, which is immediately subsumed by \perp , introduces three features `person`, `number` and `gender`. These features are of types `per`, `num` and `gen` respectively. The TRALE translation of this hierarchy is shown below. Note that 1st, 2nd and 3rd are respectively shown as `first`, `second`, and `third` because a Prolog atom has to begin with a lower-case letter.

```
type_hierarchy

bot
  per
    first
    second
    third
  num
    singular
    plural
  gen
    feminine
    masculine
  agr person:per number:num gender:gen
.
```

1.3.2 Subtype covering

TRALE assumes that subtypes exhaustively cover their supertypes, i.e., that every object of a non-maximal type, `t`, is also of one of the maximal types subsumed by `t`. This is only significant when the appropriateness conditions of `t`'s maximal subtypes on the features appropriate to `t` do not cover the same products of values as `t`'s appropriateness conditions. Let us look at the following type hierarchy for example.

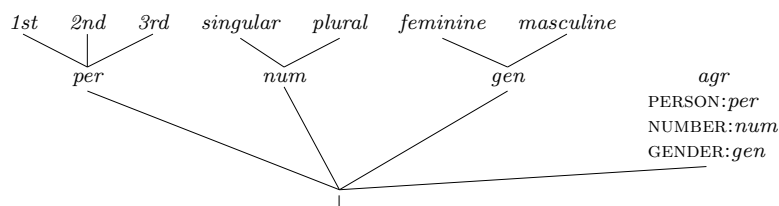
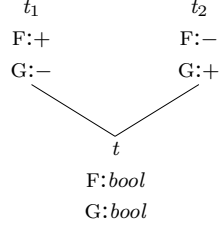


Figure 1.1: A sample type hierarchy



In this hierarchy, there are no \mathbf{t} objects with identically typed or structure-shared F and G values as in the following feature structures:

$$\begin{bmatrix} \mathbf{F} & \boxed{+} \\ \mathbf{G} & \boxed{-} \end{bmatrix} \begin{bmatrix} \mathbf{F} & + \\ \mathbf{G} & + \end{bmatrix} \begin{bmatrix} \mathbf{F} & - \\ \mathbf{G} & - \end{bmatrix}$$

Unlike ALE, TRALE does not accept such undefined combinations of feature values as valid. However, if TRALE detects that only one subtype's product of values is consistent with a feature structure's product of values, it will promote the product to that consistent subtype's product. Thus, in our example, a feature structure:

$$\begin{bmatrix} t \\ \mathbf{F} & + \\ \mathbf{G} & bool \end{bmatrix}$$

will be promoted automatically to the following. Note that the type itself will not be promoted to \mathbf{t}_1 .

$$\begin{bmatrix} t \\ \mathbf{F} & + \\ \mathbf{G} & - \end{bmatrix}$$

1.3.3 Interaction with the signature

- `show_approp(<type>)`. shows the appropriateness conditions of a type
- `show_subtypes(<type>)`. shows a mini typehierarchy with the immediate subtypes of `<type>`
- `show_all_subtypes(<type>)`. shows the complete typehierarchy below `<type>`
- `show_supertypes(<type>)`. shows the immediate supertypes of `<type>`
- `show_all_supertypes(<type>)`. shows the hierarchy below the most general type `bot` and type `<type>`, including only those types which are direct or indirect supertypes of `<type>` (pretty funky when multiple inheritance is involved)

1.4 Descriptions

The following discusses some additions to the ALE description language which are included in TRALE.

1.4.1 Logical variable macros

TRALE's logical variable macros, unlike ALE macros, use logical variables in their definitions rather than true macro variables. Logical variables entail structure-sharing if used more than once in a predicate. For example, the Prolog expression `foo(X,X)` means that the two arguments of `foo` are structure-shared.³ True macro variables, on the other hand, simply serve as place holders and their multiple occurrence does not entail structure sharing. This makes a difference when a formal parameter to a macro occurs more than once in a macro definition, e.g.:

```
foo(X,Y) macro f:X, g:X, h:Y.
```

In this ALE macro (which uses true macro variables), `F`'s and `G`'s values will not be shared in the result. That is, `foo(a,b)` for types, `a` and `b`, will expand to

```
(f:a, g:a, h:b)
```

in which `F` and `G` are not structure-shared unless `a` is extensional.⁴ One way to make the two features' values structure-shared is to substitute a (logical) variable as an actual parameter for `X`, i.e. `foo(A,b)`. Note that the first argument of the macro `foo` here is a variable rather than an atom. This variable is a "logical" variable because it is used as a first-class citizen of ALE's description logic, rather than at the macro level. In this case the macro expands to the following:

```
(f:A, g:A, h:b)
```

TRALE's logical variable macros, on the other hand, automatically interpret macro parameters such as `X` and `Y` as logical variables, and thus implicitly enforce structure-sharing with multiple occurrences. For example:

```
foo(X,Y) := f:X, g:X, h:Y.
```

will automatically structure-share the values of `F` and `G`. The infix operator `:=/2` indicates a logical variable macro.

Guard declarations for macros can optionally be applied to these parameters by appending the guard with a hyphen:

³Recall that Prolog variables start with an upper-case letter.

⁴An extensional type cannot be copied and has to be structure-shared if it occurs more than once in a feature structure. Extensional and intensional types are discussed in ALE User's Guide.

```
foo(X-a, Y-b) := f:X, g:X, h:Y.
```

This declaration says that X must be consistent with type a , and Y must be consistent with type b for this macro clause to apply. If it does, F 's and G 's values are shared. Thus $\text{foo}(a,b)$ expands to the following:

```
(f:(X,a), g:(X,a), h:(Y,b))
```

Note that ALE macros can still be declared (with `macro/2`). As in ALE, `@` is used to call a macro in a description. Let us assume that this signature is defined:

```
type_hierarchy
```

```
bot
  person gender:gen nationality:nat name:name
  gen
    male
    female
  nat
    american
    canadian
  name
    john
    mary
.
```

The following macros can then be defined in the theory file:

```
man(X-name,Y-nat) :=
  (person, name:X, gender:male, nationality:Y).

woman(X-name,Y-nat) :=
  (person, name:X, gender:female, nationality:Y).
```

The above macros can now be called in feature descriptions using `@` as in these lexical entries:

```
john ---> @ man(john,american).
mary ---> @ woman(mary,canadian).
```

The integrity of lexical entries can be checked by `lex/1`. Given the above information for example, `lex john` results in the following output in TRALE:

```
| ?- lex john.
```

```
WORD: john
ENTRY:
person
```

```
GENDER male
NAME john
NATIONALITY american
```

```
ANOTHER? n.
```

```
yes
```

In addition, one may check the integrity of macro definitions by `macro/1`. In this case, `macro woman(X,Y)` produces the following output:

```
| ?- macro woman(X,Y).
```

```
MACRO:
```

```
    woman([0] name,
          [1] nat)
```

```
ABBREVIATES:
```

```
    person
    GENDER female
    NAME [0]
    NATIONALITY [1]
```

```
ANOTHER? n.
```

```
yes
```

1.4.2 Macro hierarchies

Macros can be hierarchically organized by calling one macro in the definition of another. The macro `X` occurring in the definition of a macro `Y` then can be referred to as a supermacro of `X`. And conversely, `Y` is a submacro of macro `X`.

The notions of sub- and supermacro thus in one sense are parallel to the notion of sub- and supertype. But it is important to keep in mind that ontologically macros and types are very different; in particular an object of a type will also be of one of its subtypes, and of exactly one of its most specific subtypes. There is no equivalent to this with macro hierarchies, which are just subsumption hierarchies of some descriptions that were given names. Different from types, macros have no theoretical status; they just serve to write down a theory more compactly.

In terms of the macro hierarchy commands below, note that (parallel to types) the sub- and supermacro relations only include macros on the same level, not those embedded under features.

This file provides the following top-level predicates, where `<(sub/super)macro>` is the macro name (incl. its argument slots). Many of the predicates exist in

two version, one that returns single results and can be backtracked into, and the other (same predicate name, but ending in s) which returns the list of all results. Note that the list returned by the second kind of predicates is sorted though. Also, it is worth noting that the predicates returning a list will always succeed (they return a [] in the case where setof would fail).

- `submacro(<macro>,<submacro>)`.
- `submacros(<macro>,<list(submacros)>)`.
- `supermacro(<macro>,<supermacro>)`.
- `supermacros(<macro>,<list(supermacros)>)`.
- `show_submacros(<macro>)`.
- `show_all_submacros(<macro>)`.
- `show_supermacros(<macro>)`.
- `show_all_supermacros(<macro>)`.
- `show_all_macros`. shows the entire macro hierarchy
- `macro(<macro>)` shows the most general satisfier of the description abbreviated by the macro (predicate provided by core ale.pl)
- `is_macro(<macro>)` returns every macro that's defined (if tracked back into)
- `macros(<list(macro)>)` returns list of macros that are defined
- `most_specific_macro(<macro>)`
- `most_specific_macros(<list(macro)>)`
- `most_general_macro(<macro>)`
- `most_general_macros(<list(macro)>)`
- `isolated_macro(<macro>)`
- `isolated_macros(<list(macro)>)` Isolated macros are those that are most general and most specific at the same time, i.e. they neither occur in other macro definitions nor are they defined in terms of other macros.

1.4.3 Automatic generation of macros on different types

Since HPSG theories usually formulate constraints about different kind of objects, the grammar writer usually has to write a large number of macros to access the same attribute, or to make the same specification, namely one for each type of object which this macro is to apply to. For example, when formulating immediate dominance schemata, one wants to access the VFORM specification of a *sign*. When specifying the valence information one wants to access the VFORM specification of a *synsem* object. And when specifying something about non-local dependencies, one may want to refer to VFORM specifications of *local* objects.

TRALE therefore provides a mechanism which derives definitions of macros describing one type of object on the basis of macros describing another type of object – as long as the linguist tells the system which path of attributes leads from the first type of object to the second.

The path from one type of object to another is specified by including a declarations of the following form in the grammar:

```
access_rule(type1,path,type2).
```

Such a statement is interpreted as: From **type1** objects you get to **type2** objects by following path **path**.

Since only certain macros are supposed to undergo this extension, they are specified using slightly different operators than standard TRALE macros: access macros are specified using the `':=='` instead of the `':'` operator of ordinary macros. The type of the macro is determined on the basis of the access suffix. The typing of each of the arguments (if any) is added using the `-` operator after each argument.

To distinguish the macro names for different type of objects, a naming convention for macros is needed. All macros on objects of a certain type therefore have the same suffix, e.g., `"_s"` for all macros describing *signs*. The type-suffix pairing chosen by the linguist is specified by including declarations of the following form in the grammar:

```
access_suffix(type,suffix).
```

Such a statement declares that the names of macros describing objects of type **type** end in **suffix**.

So the extend access mechanism reduces the work of the linguist to providing

- macros describing the 'most basic' type of object, and
- `access_suffix` and `access_rule` declarations.

Access macros are not compiled directly. Instead the access macros must be translated to ordinary TRALE macros at some point before compiling a grammar using a call to `extend_access(<FileList>,<OutFileName>)`, where `<FileList>` is a Prolog list of Filenames containing access macro declarations

and <OutFileName> is a single file containing the ordinary TRALE macros. Note that this resulting file needs to be explicitly loaded as part of the theory file that one compiles (as usual, using `compile_gram/1`) in order for those macros to be compiled as part of the grammar.

A small example As an example, say we want to have abbreviations to access the VFORM of a *sign*, a *synsem*, *local*, *cat*, and a *head* object. Then we need to define a macro accessing the most basic object having a VFORM, namely *head*:

```
vform_h(X-vform) ::= vform:X.
```

Second, (once per grammar) `access_suffix` and `access_rule` declarations for the grammar need to be provided. The former define a naming convention for the generated macros by pairing types with macro name suffixes. The latter define the rules to be used by the mechanism by specifying the relevant paths from one type of object to another.

```
access_suffix(head,"_h").
access_suffix(cat,"_c").
access_suffix(loc,"_l").
access_suffix(synsem,"_s").
access_suffix(sign,"what_a_great_suffix").

access_rule(cat,head,head).
access_rule(loc,cat,cat).
access_rule(synsem,loc,loc).
access_rule(sign,synsem,synsem).
```

This results in the following macros to be generated:

```
vform_h(X)           := vform:X.
vform_c(X)           := head:vform_h(X).
vform_l(X)           := cat:vform_c(X).
vform_s(X)           := loc:vform_l(X).
vformwhat_a_great_suffix(X) := synsem:vform_y(X).
```

If we were only interested in a `vform` macro for certain objects, say those of type *sign* and *synsem*, it would suffice to specify access rules for those types instead of the access rules specified above. The following specifications would do the job:

```
access_suffix(head,"_h").
access_suffix(synsem,"_s").
access_suffix(sign,"what_a_great_suffix").

access_rule(synsem,loc:cat:head,head).
access_rule(sign,synsem:loc:cat:head,head).
```

The result would then be:

```

vform_h(X)                :=  vform:X.
vform_s(X)                :=  loc:cat:head:vform_h(X).
vformwhat_a_great_suffix(X) :=  synsem:loc:cat:head:vform_h(X).

```

Warnings

Several kinds of warnings can appear on user output. Access expansion continues.

1. A TRALE macro already defined always has priority over a derived macro, regardless of whether
 - (a) the derived macro is the direct translation of an access macro defined by the user or
 - (b) the derived macro is the result of `access_rule` applications.
2. If a TRALE macro has already been derived by translation of an access macro with or without `access_rule` application, an access macro occurring later in the grammar which would derive the same macro is not translated and no further rules are applied to the later access macro. Currently this is also the case if the two predicates differ in arity.

Errors

Several types of errors can be detected and a message is printed on user output. Access expansion then aborts.

1. A type occurring in an `access_rule` is not allowed to have
 - (a) multiple suffixes defined for it
 - (b) no suffixes defined for it
2. Two suffixes defined must not
 - (a) be identical
 - (b) have a common ending

1.5 Theory specifications

TRALE theories can use all of the declarations available to ALE. These include relations, lexical entries, lexical rules, extended phrase structure rules, and Prolog-like definite clauses over typed feature structures. They also include one extra, complex antecedent constraints, which is discussed in the following section.

1.5.1 Complex antecedent constraints

ALE has a restricted variety of type constraints. That is to say, the antecedent (left-hand side) of these constraints can only be a type. ALE constraints have the following forms:

```
t cons Desc.
```

or

```
t cons Desc goal Goal.
```

where the antecedent, `t`, is a type and the consequent (right-hand side), `Desc`, is the description of the constraint. These constraints apply their consequents to all feature structures of type `t`, which is to say that they are universally quantified over all feature structures and are triggered based on subsumption, i.e., `Desc` and `Goal` are not necessarily applied to feature structures consistent with `t`, but rather to those that are subsumed by the most general satisfier of `t`, as given by a constraint-free signature. For example, the constraint:

```
a cons (f:X,g:=\=X)
```

states that the values of the `F` and `G` features of any object of type `a` or a type subsumed by `a` must not be structure-shared. If a goal is specified in a constraint, the constraint is satisfied only if the goal succeeds.

TRALE generalizes this to allow for antecedents with arbitrary function-free, inequation-free antecedents. TRALE constraints are defined using the infix operator, `*>/2`, e.g.:

```
(f:minus, g:plus) *> X goal foo(X).
```

This constraint executes `foo/1` on feature structures with `F` value `minus` and `G` value `plus`. These are also universally quantified, and they are also triggered based on subsumption by the antecedent, not unification. For example, in the above constraint, if a feature structure does not have an `F` value, `minus`, and a `G` value, `plus`, yet, but is not inconsistent with having them, then TRALE will suspend consideration of the constraint until such a time as it acquires the values or becomes inconsistent with having them. These constraints are thus consistent with a classical view of implication in that the inferences they witness are sound with respect to classical implication, but they are not complete. On the other hand, they operate passively in the sense that the situation can arise in which several constraints may each be waiting for the other for their consequents to apply. This is called *deadlock*. An alternative to this approach would be to use unification to decide when to apply consequents, or some built-in search mechanism that would avoid deadlock but risk non-termination. Of the two, deadlock is preferable. Additional (constraint) logic programs can be written to search the space of possible solutions in a way suited to the individual case if there are deadlocked or suspended constraints in a solution.

Variables in `*>` constraints are implicitly existentially quantified within the antecedent. Thus:


```
(f:X, g:X) *> Y goal foo(Y).
```

applies the consequent when F's and G's values are structure-shared. In other words, it applies the consequent if there exists an X such that F's and G's values are both X. In addition, the consequent of the above-mentioned constraint implicitly applies only to feature structures for which F and G are both appropriate. Path equations can be used in antecedents to explicitly request structure-sharing as well. The following constraint is equivalent to the one above:

```
([f]==[g]) *> Y goal foo(Y).
```

A singleton variable in the antecedent results in no delaying itself apart from the implicit appropriateness conditions. Variables occurring in the consequent are in fact bound with scope that extends over the consequent and relational attachments. Thus, in the following example:

```
(f:X, g:X) *> W goal foo(X, W).
```

the first argument passed to `foo/2` is the very X that is the value of both F and G. This use of variables on both sides of the implication is a loose interpretation consistent with common practice in linguistics. With a classical interpretation of implication, it is always true that:

$$p \rightarrow q \quad \text{iff} \quad p \rightarrow (p \wedge q)$$

Thus:

$$(\exists x_1, \dots, \exists x_n. p) \rightarrow q \quad \text{iff} \quad (\exists x_1, \dots, \exists x_n. p) \rightarrow ((\exists x_1, \dots, \exists x_n. p) \wedge q)$$

Note that, according to the classical interpretation, q is not in the scope of the existential quantifiers. TRALE, however, bends this rule taking the latter to be equivalent to:

$$(\exists x_1, \dots, \exists x_n. p) \rightarrow \exists x_1, \dots, \exists x_n. (p \wedge q)$$

Here, q is in the scope of the $\exists x_1, \dots, \exists x_n$. Consequently, if the genuine equivalence is desired, one must ensure that x_1, \dots, x_n do not occur in q , in which case $(\exists x_1, \dots, \exists x_n. p) \wedge q$ and $\exists x_1, \dots, \exists x_n. (p \wedge q)$ are equivalent. Requiring this extra variable hygiene is the price of permitting this non-equivalent use of implication and quantification as the default, rather than what is logically valid. An example of such a relaxed use of such rules in linguistics is provided below:

```
spec_dtr:(head:noun,
          index:Ind)
*> head_dtr:(head:verb,
            index:Ind).
```

The above constraint is formulated so as to assure subject-verb agreement by enforcing structure-sharing between the INDEX feature of the subject and that of the verb. In the strict interpretation, the second instance of the variable `Ind` would have broad scope (existentially quantified over the entire clause), and thus be possibly different from the `Ind` in the antecedent. TRALE’s interpretation of this, however, assumes they are the same. As mentioned above, if the strict interpretation is desired, a different variable name must be used in the consequent of this constraint.

1.5.2 Additional commands

- `lex_desc(<word>,<desc>)`. shows all lexical entries having the form provided as first argument and compatible with the description provided as second argument. Underspecifying the first argument, i.e., calling `lex_desc(_,<desc>)`, is possible to search for all lexical entries matching the description.

1.6 Test sequences

1.6.1 Test files

Test items are encoded as t/5 facts:

```
t(Nr,‘‘Test Item’’,Desc,ExpSols,‘Comment’).
```

- `Nr`: test item ID number
- `Test Item`: test string, must be enclosed in double-quotes
- `Desc`: optional start category description, leave uninstantiated to get all possible parses
- `ExpSols`: expected number of solutions
- `Comment`: optional comment, enclosed in single-quotes

1.6.2 Test queries

Basic test queries

- with pop-up structures
`test(Nr).`
`test([From,To]).`
`test(all).`
- without structures
`testt(Nr).`
`testt([From,To]).`
`testt(all).`

Testing with descriptions

- with pop-up structures
 `test(Nr,Desc).`
 `test([From,To],Desc).`
 `test(all,Desc).`
- without structures
 `testt(Nr,Desc).`
 `testt([From,To],Desc).`
 `testt(all,Desc).`

The value of `Desc` overrides any description given in `t/5`. If `Desc` is a variable (or bot or sign) all parses are returned. The expected number of solutions given in `t/5` is ignored.

Chapter 2

Some examples illustrating Trale functionality

This section presents some linguistic examples that take advantage of the new features in `TRALE`. In HPSG, English verbs are typically assumed to have the following two features in order to distinguish auxiliary verbs from main verbs and also to show whether a subject-auxiliary inversion has taken place.

$$\begin{bmatrix} verb \\ AUX \quad bool \\ INV \quad bool \end{bmatrix}$$

The values for the `AUX` and `INV` features are taken to be of type `bool`. However, note that there cannot be any verbal type with the following combination of feature values:

$$\begin{bmatrix} AUX \quad - \\ INV \quad + \end{bmatrix}$$

That is, there are no verbs in English that can occur before the subject and not be auxiliaries. Thus, using `TRALE`'s interpretation of sub-typing, we can prevent this undesirable combination with the following type hierarchy:

```
type_hierarchy
bot
  bool
    plus
    minus
  verb aux:bool inv:bool
    aux_verb aux:plus inv:bool
    main_verb aux:minus inv:minus
.
```

Whenever there is an object of type `main_verb`, its AUX and INV feature values must be set to `minus`. In the case of auxiliaries, their AUX feature has to be `plus` but their INV feature could be either `plus` or `minus`.

The following example shows a TRALE logical variable macro. This macro assumes subject verb agreement holds.

```
vp(Ind) :=
  synsem:local:(content:index:Ind,
                 cat:subcat:[synsem:local:content:index:Ind]
  ).
```

As mentioned in subsection 1.4.1, TRALE treats variables used in TRALE macro definitions (`:=`) as logical variables and therefore, assumes structure-sharing between multiple occurrences of such variables. Using a TRALE logical variable macro, we ensure that the values of the INDEX feature of the verb phrase and of the subject are structure-shared. Therefore,

```
vp((person:third, number:singular))
```

is equivalent to:

```
synsem:local:(content:index:(Ind,
                             person:third,
                             number:singular),
               cat:subcat:[synsem:local:content:index:Ind])
```

In the above feature structure, the values of both INDEX features are structure-shared. Had we used a regular ALE macro (using `macro/1`), we would have reached a similar result but the values of the INDEX features would simply have been structure-*identical*.

We can also use the type guard declaration of TRALE macros to make sure that `Ind` is consistent with the type `ind`. This can be achieved by adding the guard to the head of the macro definition as follows:

```
vp(Ind-ind) :=
  synsem:local:(content:index:Ind,
                 cat:subcat:[synsem:local:content:index:Ind]).
```

In some languages, the form of the verb depends on the type of eventuality denoted by the sentence. In Czech, for example, it is generally the case that if an event is total (i.e. completed as opposed to simply terminated), the verb that denotes that event surfaces in the perfective form. This rule can be enforced as the following constraint in the grammar. Note that since the constraint applies to a type rather than a particular description, we could use an ALE constraint (`cons/2`), too.

```
(sentence,event:total) *>
  synsem:(local:(cat:(head:(vform:perf))))).
```

This constraint applies its consequent to all feature structures of type **sentence** with the required **EVENT** value.

Another example of a complex-antecedent constraint can be found in HPSG's Binding Theory, which refers to the notions of o-binding and o-commanding. O-binding is defined as follows (see Pollard and Sag 1994, p. 253–54):

“Y (*locally*) *o-binds* Z just in case Y and Z are coindexed and Y (*locally*) o-commands Z. If Z is not (*locally*) o-bound, then it is said to be (*locally*) *o-free*.”

Pollard and Sag define o-commanding as follows:

“Let Y and Z be *synsem* objects with distinct **LOCAL** values, Y referential. Then Y *locally o-commands* Z just in case Y is less oblique than Z. . .

“Let Y and Z be *synsem* objects with distinct **LOCAL** values, Y referential. Then Y *o-commands* Z just in case Y locally o-commands X dominating Z.”

Based on these notions, HPSG's Binding Theory is phrased as the following three principles (ibid):

HPSG Binding Theory:

Principle A. A locally o-commanded anaphor must be locally o-bound.

Principle B. A personal pronoun must be locally o-free.

Principle C. A nonpronoun must be o-free.

A simplified version of Principle A can be written as a constraint over all head-complement structures (**head_comp_struct**) as follows:

```
% BINDING THEORY
% PRINCIPLE A
head_comp_struct *> (spec_dtr:(synsem:content:
                        (X,
                         index:IndX)),
                    comp_dtr:(synsem:content:
                        (Y,ana,
                         index:IndY)))
goal (local_o_command(X,Y) ->
      IndX = IndY; true).

(X = X) if true.
```

The above ALE constraint makes sure that for all **head_comp_struct** type objects, if the complement daughter is anaphoric and locally o-commanded by the specifier, then the two daughters must be coindexed. The definition “(X = X) if

true” is provided because ALE does not come with a built-in equality relation defined over descriptions. We leave the definitions of `local_o_command/2` and `o_command/2` to the reader.

An alternative is to formulate the constraint in the following manner:

```
% BINDING THEORY
% PRINCIPLE A (Alternate formulation):
(spec_dtr:(synsem:content:(X,index:IndX)),
 comp_dtr:(synsem:content:(Y,ana,index:IndY)))
*> bot
goal (local_o_command(X,Y) -> IndX = IndY; true).

(X = X) if true.
```

The above constraint applies to any description subsumed by the antecedent. If the first daughter’s index locally o-commands the second’s, then they should be coindexed. Bot results in no additional description be added. Alternatively, one could use an anonymous variable, “_”.

Let us now see how Principle B can be written as a TRALE complex antecedent constraint:

```
% Binding Theory
% PRINCIPLE B:
(spec_dtr:(synsem:content:(X,index:Ind)),
 comp_dtr:(synsem:content:(Y,ppro,index:Ind)))
*> bot
goal (local_o_command(X,Y) -> fail; true).
```

This constraint states that for all descriptions with specifier and complement daughters, if the latter is a personal pronoun and locally o-commanded by the former, then the two daughters must not be coindexed.

Analogously, Principle C can be encoded as follows:

```
% BINDING THEORY
% PRINCIPLE C:
(spec_dtr:(synsem:content:(X,index:Ind)),
 comp_dtr:(synsem:content:(Y,npro,index:Ind)))
*> bot
goal (o_command(X,Y) -> fail; true).
```

This last constraint states that for all descriptions with specifier and complement daughters, if the second one is a nonpronoun (`npro`), then it must not be o-commanded by the first and coindexed with it.

Chapter 3

Lexical rule compiler

3.1 Introduction

In the framework of Head-Driven Phrase Structure Grammar (HPSG, Pollard and Sag 1994) and other current linguistic architectures, linguistic generalizations are often conceptualized at the lexical level. Among the mechanisms for expressing such generalizations, so-called *lexical rules* are used for expressing so-called horizontal generalizations (cf. Meurers 2001, and references cited therein).

Reflecting the two ways of conceptualizing lexical rules, on a meta-level or on the same level as the rest of the grammar, the TRALE system offers two mechanisms for implementing lexical rules. The meta-level approach at compile-time computes the transitive closure of the lexicon under lexical rule application. It is described in the ALE manual.

The description-level approach is implemented in the lexical rule compiler described in this chapter. It encodes the treatment of lexical rules proposed in Meurers and Minnen (1997). This chapter focuses on how to use the lexical rule compiler. A discussion of this approach to lexical rules can be found in the Reference Manual of the Lexical Rule compiler and the original paper.

3.2 Using the lexical rule compiler

The lexical rule compiler is automatically loaded with the main TRALE system. If the grammar contains lexical rules using the syntax described in the following section, one can call the lexical rule compiler with `compile_lrs(<file(s)>,<outfile>).`, where `<files>` is either a single file or a list of files containing the part of the theory defining the base lexical entries and the lexical rules. The output of the lexical rule compiler is written to the file `<outfile>`. If only the first argument is provided, the system writes the output to the file `lr_compiler_output.pl`. After compilation the user can then access visual representations of both the global finite-state automaton and the word class automata.

The command for viewing the global automaton is `lr_show_global`. The automata for the different classes of lexical entries are shown using the command `lr_show_automata`. Both commands are useful for checking that the expected sequences of lexical rule applications are actually possible for the grammar that was compiled. An example is included at the end of section 3.2.1.

The visualization assumes that the graph visualization tool VCG is installed on your system and in your execution path.¹

In order to parse using the output of the lexical rule compiler, one must compile the grammar, without the base lexicon and lexical rules, but including the file generated by the lexical rule compiler. For example, if the grammar without the base lexicon and lexical rules is in the file `theory.pl` and the lexical rule compiler output is in the file `lr_compiler_output.pl` one would call `?- compiler_gram([theory,lr_compiler_output])`.

3.2.1 Input syntax

The format of lexical rule specifications for the lexical rule compiler is shown in figure 3.1. Note that this syntax is different from the lexical rule syntax of ALE, which also is provided by the TRALE system. As described in the ALE manual, lexical rules specified using the ALE lexical rule syntax result in expanding out the lexicon at compile time.

```
<lex_rule_name> ==  
    <input description>  
lex_rule  
    <output description>.
```

Figure 3.1: Lexical rule input syntax

A lexical rule consists of a lexical rule name, followed by the infix operator `==`, followed by an input feature description, followed by the infix operator `lex_rule`, followed by an output feature description and ending with a period.

Input and output feature descriptions are ordinary descriptions as defined in the TRALE manual. The lexical compiler currently handles all kinds of descriptions except for path inequalities. Path equalities can be specified within the input or output descriptions, and also between the input and output descriptions.

We illustrate the syntax with the small example grammar from Meurers and Minnen (1997), which is also included with the TRALE system in the subdirectory `lr_compiler/examples`. The signature of this example is shown in figure 3.2; to illustrate this TRALE signature syntax, figure 3.3 shows the type hierarchy in the common graphical notation.

Based on this signature, figure 3.4 shows a set of four lexical rules exemplifying the lexical rule syntax used as input to the lexical rule compiler.

To complete the example grammar, we include three examples for base lexical entries in figure 3.5. These lexical entries can be found in the file `lexicon.pl`.

¹The tool is freely available from <http://rw4.cs.uni-sb.de/users/sander/html/gsvcg1.html>.

```

type_hierarchy
bot
  t w:bool x:bool y:bool
    t1
    t2 z:list
  word a:val b:bool c:t
  list
  bool
  val
  list
    e_list
    ne_list hd:val tl:list
  bool
    plus
    minus
  val
    a
    b
.

```

Figure 3.2: An example signature

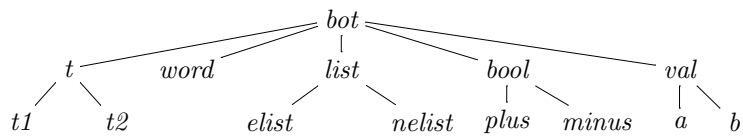


Figure 3.3: A graphical representation of the example type hierarchy

```

lr_one ===
  (b:minus,
   c:y:minus)
lex_rule
  (a:b,
   c:(x:plus,y:plus)).

lr_two ===
  (a:b,
   b:minus,
   c:w:minus)
lex_rule
  (c:w:plus).

lr_three ===
  (c:(t2,
   w:plus,
   x:plus,
   z:t1:One))
lex_rule
  (c:(y:plus,
   z:One)).

lr_four ===
  (b:minus,
   c:(t2,
   w:plus,
   x:plus,
   z:e_list))
lex_rule
  (b:plus,
   c:x:minus).

```

Figure 3.4: An example set of four lexical rule

```

foo ---> (a:b,
          b:minus,
          c:(t2,
              w:minus,
              x:minus,
              y:minus,
              z:(hd:a,
                  tl:(hd:b,
                      tl:e_list))))).

bar ---> (a:b,
          b:minus,
          c:(t2,
              w:minus,
              x:minus,
              y:minus,
              z:(hd:a,
                  tl:e_list))))).

tup ---> (a:b,
          b:minus,
          c:(t1,
              w:minus,
              x:minus,
              y:minus))).

```

Figure 3.5: An example set of base lexical entries

The user is encouraged to look at this grammar, run the compiler on it, and make sure that the resulting output is consistent with the user's understanding. Visualizing the lexical rule interaction generally is a good way to check whether the intended lexical rule applications do in fact result from by the lexical rules that were specified in the grammar. The visualization obtained by calling `lr_show_global/0` for the example grammar is shown in figure 3.6.

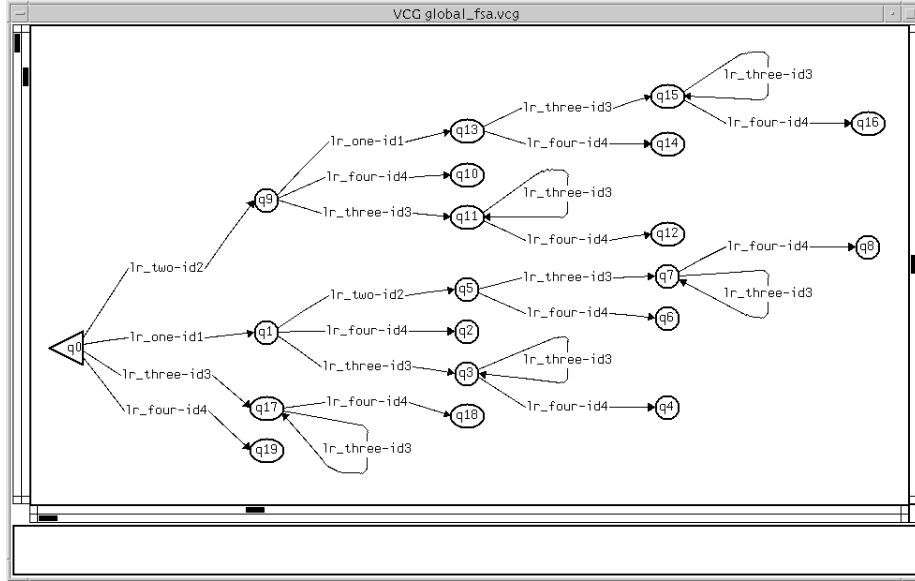


Figure 3.6: Global interaction visualization for the example grammar

The lexical rule interaction which is permitted by a particular lexical class can also be visualized. To view the automaton of an entry with the phonology `Phon` one calls `lr_show_automaton(Phon)`. To view all such automata, the predicate to call is `lr_show_automata/0`. In figure 3.7 we see the visualization obtained for the lexical entry “foo” of our example grammar by calling `show_automaton(foo)`.

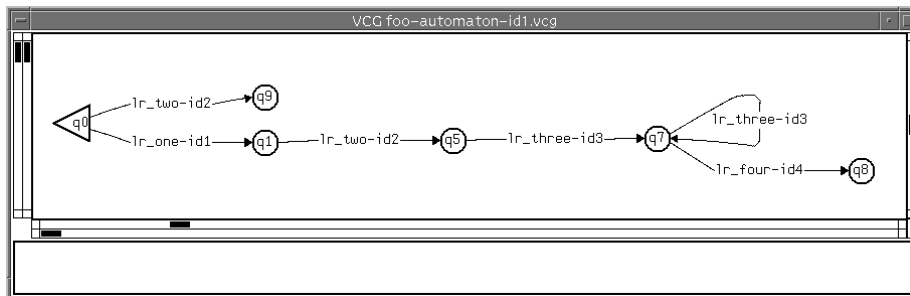


Figure 3.7: Interaction visualization for the entry “foo”

3.2.2 Interpretation

While the basic interpretation of lexical rules is straightforward, it turns out to be more difficult to answer the question how exactly the intuition should be spelled out that properties which are not changed by the output of a lexical rule are carried over unchanged, the so-called framing. A detailed discussion of the interpretation of lexical rules and the motivation for this particular interpretation can be found in Meurers (2001); we focus here on the essential ideas needed to sensibly use the lexical rule compiler.

A lexical rule can apply to a variety of lexical entities. While each of these lexical entities must be described by the input of the lexical rule in order for the rule to apply, other properties not specified by the lexical rule can and will vary between lexical entries. Feature structures corresponding to lexical entities undergoing the lexical rule therefore may differ in terms of type value and appropriate features. Frames carrying over properties not changed by the lexical rule need to take into account different feature geometries. Since framing utilizes structure sharing between input and output, we only need to be concerned with the different kinds of objects that can undergo a lexical rule with regard to the paths and subpaths mentioned in the output description. Specifically, when the objects undergoing lexical rule application differ with regard to type value along some path mentioned in the output description, we may need to take into account additional appropriate attributes in framing. Each such possibility will demand its own frame.

The lexical rule compiler provides a truthful procedural realization of the formal interpretation of lexical rules defined in Meurers (2001). Generally speaking, the input description of a lexical rule specifies enough information to capture

the class of lexical entries intended by the user to serve as inputs. The output description, on the other hand, specifies what should change in the derivation. All other specifications of the input are supposed to stay the same in the output.

In the spirit of preserving as much information as possible from input to output, we generate frames on the basis of species (= most specific type) pairs; that is, we generate a frame (an IN-OUT pair) on the basis of a maximally specific input type, and a maximally specific output type, subtypes of those specified in, or inferred from, the lexical rule description. In this way we maintain tight control over which derivations we license, and we guarantee that all possible information is transferred, since the appropriate feature list we use is that of a maximally specific type. We create a pair of skeleton feature structures for the species pair, and it is to this pair of feature structures that we add path equalities. We determine the appropriate list of species pairs on the basis of the types of the input and output descriptions.

The first step in this process is determining the types of the input and output of the lexical rule. We then obtain the list of species of the input type, and the list of species of the output type. We refer to these as the input species list, and the output species list, and their members as input and output species. At this point it will be helpful to have an example to work with. Consider the type hierarchy in figure 3.8.

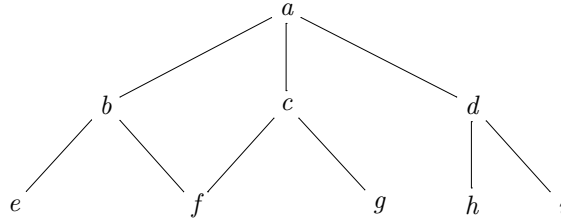


Figure 3.8: An example hierarchy for illustrating the interpretation

We can couch the relationship between the input and output types in terms of type unification, or in terms of species set relations. In terms of unification, there are four possibilities: the result of unification may be the input type, the output type, something else, or unification may fail. In the first case the input type is at least as or more specific, and the input species species will be a subset of the output species. In the second case the output is more specific and the output species will be a subset of the input species. In the third case the input and output types have a common subtype, and the intersection of input and output species is nonempty. In the fourth case the input and output types are incompatible, and the intersection of their species sets is empty.

If a (maximally specific) type value can be maintained in the output, it is. Otherwise, we map that input species to all output species. In terms of set membership, given a set of input species X , a set of output species Y , the set of species pairs P thus can be defined as:

$$P = \{\langle x, x \rangle \mid x \in X \wedge x \in Y\} \cup \\ \{\langle x, y \rangle \mid x \in X, x \notin Y \wedge y \in Y\}$$

Given in figure 3.9 are examples of all four cases, using the example signature,

	Case 1	Case 2	Case 3	Case 4
Input type	c	a	b	c
Output type	a	c	c	d
Unify to	c	c	f	fail
Input species	f, g	e, f, g, h, i	e, f	f, g
Output species	e, f, g, h, i	$f, g,$	f, g	h, i
Species pairs	$f\text{-}f, g\text{-}g$	$e\text{-}f, e\text{-}g, f\text{-}f,$ $g\text{-}g, h\text{-}f, h\text{-}g,$ $i\text{-}f, i\text{-}g$	$e\text{-}f, e\text{-}g, f\text{-}f$	$f\text{-}h, f\text{-}i, g\text{-}h,$ $g\text{-}i$

Figure 3.9: Examples for the four cases of mappings

showing input and output types, the result of unification, their species lists, and the species-pairs licensed by the algorithm described below. Calling these separate “cases” is misleading, however, since the algorithm for deciding which mappings are licensed is the same in every case.

Chapter 4

Output

4.1 Saving of outputs

It can be useful to be able to save the output of a command like `mgsat`, `rec`, `lex` etc, e.g. in order to

- output it again without reperforming the actual task
- view it pretty printed using different pretty printers (e.g. `grisu` or `text`)
- run a diff of the two structures (see below)
- `save_results_on`. saves copies of the output for later use (during the same session)
- `save_results_off`. switches saving results off. What was saved is preserved.
- `show_saved(<nr>)`. shows saved result number `nr`
- `show_all_saved`. shows all saved results
- `saved_id(<nr>)`. returns number of saved results
- `save_results(<filename>)`. save results in a file
- `load_results(<filename>)`. loads results from a file

At system startup, saving of results is off.

4.2 Grisu interface

The Grisu interface developed by Holger Wunsch and Detmar Meurers is a standalone program written in C++, based on the freely available Qt-www.trolltech.com and KDE-libraries www.kde.org. By starting `trale` with the `-g` option, the Grisu

interface is automatically started and used to display trees and attribute-value matrices (AVMs). Grisu can also produce Latex output of trees and AVMs.

The Grisu interface is described in a separate manual that is included in its distribution. In this section we describe Trale options and features that are available when using the Grisu interface.

- General switches:
 - `grisu_off`. switches grisu output off and textual pretty printer on
 - `grisu_on`. switches grisu output on, if the system had been started with grisu
 - `grisu_debug`. sends the output normally sent to grisu to standard out instead
 - `grisu_nodebug`. reverts to sending grisu output to the socket at which grisu listens

At system startup, grisu is on if trale has been started with `-g`

- Tree- vs. AVM output:
 - `pref_struc_on`. switches grisu to show new data in the form of an AVM.
 - `pref_struc_off`. switches grisu to show new data in the form of a tree, if one exists in the data package.

At system startup, the setting is `pref_struc_off`. Note that both options only determine what is shown first—in Grisu one can select to show either representation.

4.2.1 Unfilling

When running a grammar with a large signature (e.g., MERGE), you'll immediately notice how essential proper unfilling of uninformative features is. The code now assumes a node to be informative if

- a) it is of a type that is more specific than the appropriate value of the feature that led to it. For the top level, the appropriate value is taken to be bot.
or
 - b) it is structure shared with some other node
or
 - c) the value of one of its features is informative according to a), b) or c)
- `unfill_on`. switches on unfilling of uninformative nodes in the output
 - `unfill_off`. switches it off

At system startup, unfill is on.

4.2.2 Feature ordering

To specify the order in which features are displayed by the pretty printer, include any number of statements of the form

- `f <<< g`. meaning: `f` will be ordered before `g`.

and at most one each of the following statements:

- `<<< h`. meaning: `h` will be ordered last.
- `>>> i`. meaning: `i` will be ordered first.

Currently only the `grisu` interface takes feature ordering into account, but this should be added to the default textual pretty printer at some point.

4.2.3 Diff of feature structures

- `diff(NrA,NrB)`.
- `diff(NrA,PathA,NrB,PathB)`.
 - `NrA` and `NrB` are numbers of saved results
 - `PathA` and `PathB` are paths of the form `f:g:h:i` or `[f,g,h,i]`. The empty path for both cases is `[]`.

Output is provided via the `grisu` interface.

Chapter 5

The Chart Display

Trale includes code to produce output for a Chart Display developed at the DFKI in Saarbrücken. The chart display has the following functionality:

- All passive edges that are produced during a parse are displayed.
- Several subsets of edges might be displayed:
 - All edges that contributed to solutions.
 - All edges that start/end at a certain position.
 - All edges that were licenced by a certain rule.
 - All dominated edges of a certain edge.
 - All edges that dominate a certain edge.
- A list of rules in the grammar is displayed and they can be inspected.
- The rules can be applied interactively to edges in the chart and unification failures are displayed (not fully implemented yet).
- You can generate from an edge (not fully tested).
- If your grammar has an MRS semantics you can display MRSses.

5.1 Installation and Customization

To get the Tcl/TK code please contact Stephan Busemann (Stephan.Busemann@dfki.de). The TCL/TK code has to be installed in the trale directory under `chart_display/TCL`. Tcl/TK has to be installed and `wish` has to be in your search path. Specify the following in your `theory.pl`

```
:- load_cd.                % loads the code for the chart display
```

```

root_symbol(@root).      % symbol for input that does not end with punctuation
imp_symbol(@imp).        % symbol for input that ends with '!'
decl_symbol(@decl).      % symbol for input that ends with '.'
que_symbol(@que).        % symbol for input that ends with '?'

cont_path([synsem,loc,cont]). % the path to the semantic content

:- chart_display.        % switches the chart display on (default)
:- nochart_display.      % switches the chart display off

:- english.              % the commands in the Chartdisplay are English (default)
:- german.               % the commands in the Chartdisplay are German

:- tcl_warnings.         % output of warnings in a TCL window (default)
:- notcl_warnings.       % output of warnings to console

:- mrs.                  % output of MRS for a parsed string
:- nomrs.                % no output (default)

:- fs.                   % switches feature structure output on (default)
:- nofs.                 % switches feature structure output off

```

The macros that are given as arguments to `root_symbol`, `imp_symbol`, `decl_symbol`, and `que_symbol` have to be specified in your grammar.

You may customize the chart display yourself or use one of the `dot.chartdisplay` files supplied in `trale.home(chart_display)`. They should be moved to `~/chartdisplay`.

If you put the following line in your `.emacs`, the prompt of the command `go` will be recognized by SICStus Prolog and you can type `Ctrl-C Ctrl-P` to get to the previous input and parse it (or call it) again.

```
(setq sicstus-prompt-regexp ">>> *\\|| [ ?][- ] *")
```

If your cursor is in the line of a previously parsed utterance, you may simply hit return and the sentence is parsed again.

5.2 Working with the Chart Display

Typing `go.` brings you to an interactive mode. You can type in a sentence and you will get parsing results displayed either with `grisu` or to `stdout` depending on whether you use `grisu` (strongly recommended). If not open the chart display will pop up (after a parse) and the chart will be displayed. The left mouse button gives you actions you can apply to the edge you point to and the right mouse button gives you actions you can perform on the whole chart. The rule names at the left hand side are also clickable. Empty elements are not clickable yet.

While in the interactive mode, you can execute simple commands directly, provided the command does not correspond to a lexical item in your grammar. For instance reloading of a grammar can be done in the interactive mode by typing `c..`. However, if your grammar contains the letter `c` as a lexical object, it will be parsed rather than executed.

`fs` and `nofs` only affect the feature structure output for sentences parsed in the interactive mode. Parses initiated with `rec` directly are not affected by this switch.

5.2.1 Debugging

You can use the chart display for debugging rule applications: First select a rule by clicking at the rule and choosing the menu item ‘Select rule’. Then select an edge from the chart. All goals that are at the first position of the rule (specified with `goal>` in the rule) will be executed. Then the selected edge will be unified with the first daughter of the rule. If the unification succeeds and the blocked constraints that are attached to the rule and to the edge are satisfied, the next goals specified in the rule will be executed. If this succeeds it is checked whether there are further daughters. If this is not the case we have a passive edge which is shown to the user. If there are further daughters an active edge is stored. This active edge can be displayed by clicking somewhere in the display and pressing the right mouse button. In the following other passive edges from the chart can be combined with the active edge. If the combination succeeds, the rule and the successfully combined daughters are marked green. Otherwise the edge that could not be combined is marked red. In case of a failure another passive edge can be tested against the active edge.

If you select another rule, the active edge is deleted.

The debugging of constraints that fire due to instantiations during a unification is difficult. To enable the debugging of single constraints a flag is set if the char tdisplay is used for debugging. For instance if you want to check whether a certain constraint fires, you may include debug information in the constraint. In the following example the flag `chart_debug/1` is tested and if its value is `on`, a debug message is printed.

```
undelayed_accusative([E1|T1]) if
  prolog((chart_debug(on) ->
    write(user_error,'Trying to assign accusative.'),
    nl(user_error)
  );true
 )),
  assign_acc(E1),
  accusative(T1).
```

Instead of printing a message you can also call the debugger or do other things. Since this constrinat may be called during the lexicon compilation as well it would be very difficult to debug without the flag, since you would enter debug modus thousand times before you loaded the grammar completely.

5.2.2 Generation

Chart edges can be used as input for generation. You have to specify the path in your feature structures that yields the semantic information. (SYNSEM|LOC|CONT is the predefined path.) The semantic contribution of a selected chart edge will be taken as input for generation and all generation results will be displayed.

Chapter 6

[incr TSDB()]

There is code that generates output for the profiling and test suite management tool [incr TSDB()] developed by Stephan Oepen. If you want to implement larger grammar fragments it is recommended to use this tool. It provides the following functionality (and much more):

- storing time, number of passive edges, memory requirements, errors for every parsed item
- compare test runs (performance, coverage, overgeneration)
- detailed comparison on item basis of
 - number of readings/edges
 - the derivations (i.e. tree structure with rule names)
 - the MRSes
- test parts of test suites on a phenomenon basis or some other selection from your test items (restrictions may be formulated in SQL queries)

The [incr TSDB()] uses the Parallel Virtual Machine. If you have several CPUs idle you may distribute the processing of your test suite over several machines which enormously shortens the time needed for testing and speeds up grammar development.

6.1 Installing [incr TSDB()]

Get the itsdb package from <http://lingo.stanford.edu/ftp/> and install it. How to do this is described in the documentation which can be found also at this site.

6.1.1 Setting up Shell Variables

Set the SICStus path. For instance, if you use tcsh, put the following in your .tcshrc:

```
setenv SP_PATH /usr/local/lib/sicstus-3.9.1/
```

[incr TSDB()] is called via foreign functions. The file is linked to libtsdb.so which has to be in the LD_LIBRARY_PATH.

Put something like the following in your ~/.tcshrc (or the respective file for the shell you are using):

```
setenv LD_LIBRARY_PATH /home/stefan/Lisp/lkb/lib/linux/
```

6.1.2 Setting up .tsdbrc

Create a file ~/.tsdbrc to include something like the following:

```
(setf *pvm-cpus*
  (list
    (make-cpu
      :host "laptop1"
      :spawn "/home/stefan/bin/trale"
      :options '("-s" "-c" "/home/stefan/Prolog/Trale/Bale/theory"
                "-e" "load_tsdb,itsdb:connect_tsdb")
      :class :bale :threshold 2)
  )
)
```

In the options line you give a path to the grammar that should be loaded.

The item following :class is an identifier. You may have several calls to make-cpu, for instance if you want to use different machines or if you want to load different grammars.

If you want to use two cpus in parallel, you specify two cpus with the same class name:

```
(setf *pvm-cpus*
  (list
    (make-cpu
      :host "server1"
      :spawn "/home/stefan/bin/trale"
      :options '("-s" "-c" "/home/stefan/Prolog/Trale/Bale/theory"
                "-e" "load_tsdb,itsdb:connect_tsdb")
      :class :bale1 :threshold 2)
    (make-cpu
      :host "server2"
      :spawn "/home/stefan/bin/trale"
      :options '("-s" "-c" "/home/stefan/Prolog/Trale/Bale/theory"
```

```

        "-e" "load_tsdb,itsdb:connect_tsdb")
    :class :bale1 :threshold 2)
)
)

```

6.1.3 Setting up PVM

Furthermore you have to set up the parallel virtual machine (pvm): Create the file `~/pvm_hosts` containing something like the following:

```

#
# list machines accessible to PVM; option fields are (see pvmd(8))
#
# - dx: path to 'pvmd3' executable (on remote host);
# - ep: colon-separated PATH used by pvmd(8) to locate executables;
# - wd: working directory for remote pvmd(8);
# - ip: alternate (or normalized) name to use in host lookup;
#
# sp=VALUE Specifies the relative computational speed of this host
# compared to other hosts in the configuration.  VALUE is an inte
# ger in the range [1 - 1000000]

laptop1 dx=/home/stefan/Lisp/lkb/bin/linux/ \
        ep=/home/stefan/Lisp/lkb/lib/linux/ wd=/tmp sp=1004
server1 dx=/home/stefan/Lisp/lkb/bin/linux/ \
        ep=/home/stefan/Lisp/lkb/lib/linux/ wd=/tmp sp=1004
server2 dx=/home/stefan/Lisp/lkb/bin/linux/ \
        ep=/home/stefan/Lisp/lkb/lib/linux/ wd=/tmp sp=1004

```

The binaries and the man pages of pvm are part of the [incr TSDB()] distribution.

If you work on one host only, you will probably not have problems with PVM. If you want to work with several machines in parallel, chances are high that PVM does not work without debugging.

You can start the `pvmd3` that comes with [incr TSDB()] by hand and then call `pvm` to check if the pvm demon initialized the other machines properly. `pvm` provides a console. If you have one host and type `conf`, you get:

```

pvmd already running.
pvm> conf
1 host, 1 data format

```

	HOST	DTID	ARCH	SPEED	DSIG
	laptop1	40000	LINUX	1000	0x00408841

```

pvm>

```

If you configured several hosts in `.pvm_hosts`, you should see them here. If you do not, something went wrong in the initialization. If your PVM uses `rsh` (default) then you have to make sure that `rexec` is enabled on all hosts. You can test this by typing:

```
rsh server2 who
```

If this does not work, you have to consult your system administrator.

6.1.4 Initializing a CPU

Having loaded [incr TSDB()] you can initialize a CPU by typing:

```
(tsdb::tsdb :cpus :bale)
```

Where `:bale` is the identifier you have chosen for your CPU.

This should load the grammar and come back saying something like:

```
wait-for-clients(): 'laptop1' registered as tid <262179>.
```

After successful registration of a client (i.e. after loading your grammar) and after the creation of a test suite with the [incr TSDB()] podium you can process items for instance by using `Process|All Items` in the [incr TSDB()] podium. Processing can be interrupted by typing **CTRL-G** at the podium.

Initializing CPUs with `(tsdb::tsdb :cpus :bale)` redirects the output to the `/tmp/` directory. This is reasonable if you work with several cpus. If you want to see the output you may use:

```
(tsdb::tsdb :cpus :bale :file t)
```

Looking at the load messages is also useful if you see something like:

```
wait-for-clients(): client exit for 'laptop1' <262150>
```

Please refer to the [incr TSDB()] manual for a description of example sessions and further documentation.

6.1.5 Creating a Test Suite

You can put together your own test suite by using the [incr TSDB()] `import` function (`File|Import|Test Items`). This function imports data from an ASCII text file. For example:

```
;;; intransitive
Karl schläft.      ;; this is a very simple example
Der Mann schläft.
;;; transitive
Liebt Karl Maria?
Karl liebt Maria.
;;; np
der Mann
der klug Mann
der Mann, der ihn kennt
;;; pronoun
Er schläft
```

```

Er kennt ihn.
;; subjless
Mich dürstet.
;; particle_verbs
Karl denkt nach.
Karl denkt über Maria nach.
*Karl nachdenkt über Maria.
;; unaccusatives
Er fällt mir auf.
;;; perfect
Er hat geschlafen.
Du wirst schlafen.
Du wirst geschlafen haben.
;;; free_rc
Wer schläft, stirbt.
Wen ich kenne, begrüße ich.
Was er kennt, ißt er.
Wo ich arbeite, schlafe ich.
Über was ich nachdenke, hast du nachgedacht.
Ich liebe, über was du nachdenkst.
Über was du nachdenkst, gefällt mir.
;;; case
*Liebt ihn ihn?

```

Ungrammatical sentences are marked with a star. Everything that follows two ‘;’ is treated as a comment. The phenomenon is given on a separate line starting with three ‘;’. If you want [incr TSDB()] to display statistics on a phenomenon-based basis, you have to make [incr TSDB()] know these phenomena. This can be done by specifying them in the .tsdbrc file:

```

(setf *phenomena*
  (append
    (list "intransitive"
          "transitive"
          "np"
          "pronoun"
          "perfect"
          "free_rc"
          "case")
    *phenomena*))

```

The data base you created is in your data base root directory. If you want to use it as a general skeleton, you have to move it to the skeleton directory and update the Index.lisp file appropriately. You can find out about the location of these directories under Options in the [incr TSDB()] podium.

The following should be specified in your grammar file (theory.pl):

```

grammar_version('Trale GerGram 0.3').
root_symbol(@root).      % symbol for input that does not end with punctuation
imp_symbol(@imp).        % symbol for input that ends with '!'
decl_symbol(@decl).      % symbol for input that ends with '.'
que_symbol(@que).        % symbol for input that ends with '?'

```

The grammar version will be shown in the run relation. The root symbol is used for parsing. The macros that are given as arguments to root_symbol, imp_symbol, decl_symbol, and que_symbol have to be specified in your grammar.

If you use CVS for version control you may consider the following entry for your grammar version.

```

grammar_version('Trale GerGram $Revision: 1.20 $').

```

When you check in a new version the revision number is automatically updated by CVS.

The following specification can optionally be given in your theory.pl:

```

% before doing a parse all lexical descriptions
% given in retract_before_parsing/1 are removed
% this is used here to decrease the chart size
% zero inflected elements do not interfere.
retract_before_parsing(stem).

```

Chapter 7

Programming hooks in Trale

7.1 Pretty-printing hooks

This section is intended for more advanced audiences who are proficient in Prolog and ALE.

ALE uses a data structure that is not so easily readable without pretty-printing or access predicates. In order to make pretty-printing more customizable, hooks are provided to portray feature structures and inequations. If these hooks succeed, the pretty-printer assumes that the structure/inequation has been printed and quietly succeeds. If the hooks fail, the pretty-printer will print the structure/inequation by the default method used in previous versions of ALE. The hooks are called with every pretty-printing call to a substructure of a given feature structure. It is, therefore, important that the user's hooks use the arguments provided to mark visited substructures if the feature structure being printed is potentially cyclic, or else pretty-printing may not terminate.

7.1.1 Portraying feature structures

The hook for portraying feature structures is:

```
portray_fs(Type,FS,KeyedFeats,VisIn,VisOut,TagsIn,TagsOut,Col,
           HDIn,HDOut)
```

FS is the feature structure to be printed. This is ALE's internal representation of this structure¹. It is recommended that access to information in this structure be obtained by **Type** and **KeyedFeats** although the brave of heart may wish to work with it directly. **FS** is also used to check token identity with structures in the **Vis** and **Tags** trees, as described below. **Type** is the type of **FS**. **KeyedFeats** is a list of **fval/3** triples:

¹The reader is referred to the ALE User's Guide for the structure of this representation.

```
[fval(Feat_1,Val_1,Restr_1),..., fval(Feat_n,Val_n,Restr_n)]
```

where `n` is the number of appropriate features to `Type`. `FS`'s value at `Feat_i` is `Val_i`, and the appropriate value restriction of `Type` at `Feat_i` is `Restr_i`.

`VisIn`, `VisOut`, `TagsIn` and `TagsOut` are AVL trees. They can be manipulated using the access predicates found in the `library(assoc)` module of SIC-Stus Prolog. `VisIn` is a tree of the nodes visited so far in the current printing call, and `TagsIn` is a tree of the nodes with re-entrancies in the structure(s) currently being printed (of which `FS` may just be a small piece). Each node in an AVL tree has a key, used for searching, and a value. In both `Vis` and `Tags` trees, the key is a feature structure such as `FS`. For example, the call:

```
get_assoc(FS,VisIn,FSVal)
```

determines whether `FS` has been visited before. In the `Vis` tree, the value (`FSVal` in the above example) at a given key is not used by the default pretty-printer. The user may change them to anything desired. When the default pretty-printer adds a node to the `Vis` tree, it adds the current `FS` with a fresh unbound variable as the value.

In the `Tags` tree, the value at key `FS` is the numeric tag that the default pretty-printer would print in square brackets to indicate structure-sharing at that location. The user may change this value (using `get_assoc/5` or `put_assoc/3`), and the default pretty-printer will use that (with a `write/1` call) instead.

A hook must return a `TagsOut` and `VisOut` tree to the pretty-printer if it succeeds. At a minimum, this means binding `TagsOut` to `TagsIn` and `VisOut` to `VisIn`. If the structure being traversed is potentially cyclic, `VisOut` should, in general, update `VisOut` to record that the current node has been visited to avoid an infinite traversal.

`Col` is the number of columns that have already been indented before the hook was called. This is useful for formatting. `HDIn` and `HDOut` are hook data. They are not used by the default pretty-printer, and are simply passed around for the convenience of hooks to record information to pass to their next invocation. The initial top-level call to a `portray_fs` hook contains 0 (zero) as the value of `HDIn`. Thus, `HDIn` can also be used to distinguish the first call from subsequent calls provided that the 0 is replaced with something else in recursive calls.

The file `pphooks.pl` (discussed in subsection 7.1.3 below) shows a simple printing hook to produce output very much as the default pretty-printer would.

When a `portray_fs` hook prints one of `FS`'s feature values, it typically will call the pretty-printer rather than attempt to manipulate the data structure directly. This callback is provided by:

```
print_fs(VarType,FS,VisIn,VisOut,TagsIn,TagsOut,Col,HDIn,HDOut)
```

Note that the type and feature values of `FS` do not need to be supplied—those will be filled in by the system before control is passed to `portray_fs` or the default pretty-printer.

`VarType` is currently not used. The other positions are the same as in `portray_fs`.

7.1.2 Portraying inequations

The hook for inequations is:

```
portray_ineq(FS1,FS2,IqsIn,IqsOut,TagsIn,TagsOut,VisIn,VisOut,Col,
             HDIn,HDOut).
```

This is called when there is an inequation between `FS1` and `FS2` with `IqsIn` being the remaining inequations. The hook should return the remainder to consider printing next in `IqsOut`, which is normally bound to `IqsIn`. `IqsIn` can also be used to test whether `FS1=FS2` is the last inequation.

`Col` is the number of columns that the default pretty-printer *would* print before printing `FS1`. This is different from the use of `Col` in `potray_fs` where it is the number of columns *already* printed. The other arguments are the same as in `portray_fs`.

Inequations are typically printed after all feature structures and their substructures in a top-level call to the pretty-printer have been printed. Likewise, `portray_ineq` is only called once `portray_fs` has been called on all feature structures and their substructures in a top-level call. Typically, the arguments to inequations will thus have been visited before—the only exceptions to this are inequated extensionally typed feature structures.

7.1.3 A sample pretty-printing hook

The following Prolog code shows how the default pretty-printer can be written as a hook. This code is available online on the ALE web site under the name `pphooks.pl`.

The file has two top-level predicates: `portray_fs/10` and `portray_ineq/11`. As mentioned above, the former is responsible for printing feature structures and the latter, for printing inequations.

The first thing that `portray_fs/10` does is check whether the feature structure it is printing is tagged, i.e., whether it is structure-shared with another feature structure. This check is made using `get_assoc(FS,TagsIn,Tag)`. If so, the tag is printed between square brackets. Then using `get_assoc(FS,VisIn,_)`, the system determines whether the feature structure has already been printed. Should this be the case, `VisOut`, `TagsOut` and `HDOut` are respectively bound with `VisIn`, `TagsIn` and `HDIn`, and the hook succeeds with nothing else printed.

If, on the other hand, the feature structure has not been printed already, and `FS` is a variable, then either `Type`, or in case `Type` has at least one appropriate feature, `mgsat(Type)`, is printed. Then, `put_assoc/4` is used to update `VisOut` to include `FS`, and `TagsOut` and `HDOut` are bound to `TagsIn` and `HDIn`, respectively.

In case the feature structure is not a variable, its type is written, and a call to a recursive predicate is made to print each feature-value pair of `FS` in turn.

Two important things to note are that (1) `VisOut` is updated to include `FS` *before* the call is made to avoid non-termination on cyclic structures, and (2) the feature values are actually printed with a callback to `print_fs/9` (which in turn calls `portray_fs/10` again).

The predicate `portray_ineq/11` works similarly. Note that `Col` spaces are added by the hook itself, unlike `portray_fs/10`.

The source code of `pphooks.pl` is given below:

```
% pphooks.pl

% default printer written as hook (w/o type or feat hiding or
% FS expansion)

portray_fs(Type,FS,KeyedFeats,VisIn,VisOut,TagsIn,TagsOut,Col,
           HDIn,HDOut):-

% print Tag if shared
( get_assoc(FS,TagsIn,Tag)
-> write('[',write(Tag),write('] '))
; true),

% print structure if not yet visited
( get_assoc(FS,VisIn,_)
-> VisOut = VisIn,
   TagsOut = TagsIn,
   HDOut = HDIn      % already printed

% variable - use Type to print
; var(FS) -> ( approp(_,Type,_)
               -> write('mgsat('),write(Type),write(')')
               ; write(Type)
               ),
               put_assoc(FS,VisIn,_,VisOut),
               TagsOut = TagsIn,
               HDOut = HDIn

% otherwise print Type and recurse
; write(Type),
  put_assoc(FS,VisIn,_,VisMid),
  print_feats(KeyedFeats,VisMid,VisOut,TagsIn,
              TagsOut,Col,HDIn,HDOut)
).

print_feats([],Vis,Vis,Tags,Tags,_,Col,HD,HD).
```

```

print_feats([fval(F,Val,Restr)|Feats],VisIn,VisOut,TagsIn,
            TagsOut,Col,HDIn,HDOut) :-
    nl,tab(Col),
    write_feature(F,LengthF), % capitalise, print and count
                              % characters
    NewCol is Col + LengthF + 1,
    print_fs(Restr,Val,VisIn,VisMid,TagsIn,TagsMid,NewCol,HDIn,
            HDMid),
    print_feats(Feats,VisMid,VisOut,TagsMid,TagsOut,Col,HDMid,
            HDOut).

portray_ineq(FS1,FS2,Rest,Rest,VisIn,VisOut,TagsIn,TagsOut,
            Col,HDIn,HDOut):-
    tab(Col),
    print_fs(bot,FS1,VisIn,VisMid,TagsIn,TagsMid,Col,HDIn,
            HDMid),
    nl,write(' =\\= '), NewCol is Col + 7,
    print_fs(bot,FS2,VisMid,VisOut,TagsMid,TagsOut,NewCol,
            HDMid,HDOut).

```

Bibliography

- Meurers, W. D. (2001). On expressing lexical generalizations in HPSG. *Nordic Journal of Linguistics* 24, 161–127.
- Meurers, W. D. and G. Minnen (1997). A computational treatment of lexical rules in HPSG as covariation in lexical entries. *Computational Linguistics* 23(4), 543–568.
- Pollard, C. and I. Sag (1994). *Head-Driven Phrase Structure Grammar*. Studies in Contemporary Linguistics. Chicago: CSLI.