MIA 91-14: The Metaprogramming System - Reference Manual

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Metaprogramming System

The Metaprogramming System

A number of tools in the Mjølner BETA System are metaprograms, i.e. programs that manipulate other programs. The metaprogramming system is grammar-based in the sense that a metaprogramming tool may be generated from the grammar of any language. For each syntactic category of the language, a corresponding pattern is generated. The syntactic hierarchy of the grammar is mapped into a corresponding pattern hierarchy. This object-oriented representation of programs is further exploited by including a set of more general patterns that view a program as an abstract syntax tree and by allowing the user to add semantic attributes in sub-patterns.

The Mjølner BETA System is a programming environment that supports design, implementation and maintenance of large production programs. In such an environment support for structure and security is essential. The Mjølner BETA System is primarily aimed at supporting the object-oriented programming style.

All metaprogramming tools in the Mjølner BETA System manipulate programs through a common representation that is abstract syntax trees (ASTs). It was decided that for a language supported by the system, the corresponding ASTs should be instances of a well-defined data type. There is no commonly agreed definition of abstract syntax tree, which implies that each language implementor selects his own definition. A context-free grammar for a language induces an abstract syntax that may be used to give an AST-definition. In the Mjølner BETA System, the representation of a program as an AST is defined by means of a context-free grammar for the language. In addition there is a set of rules that specify how the context-free grammar is mapped into a set of data types. The context-free grammar is then part of the specification of the environment.

The ASTs defined by the context-free grammar may be described as Lisp S-expressions. An example of a Pascal statement and a corresponding AST in the form of an S-expression is:

```
while p<>q do if p<q then q:=q-p else p:=p-q
(while (<> p q)
        (if (< p q)
                (:= q (- q p))
                (:= p (- p q))))
```

S-expressions could in fact be used for manipulation of an AST. In order to do this in Simula, BETA, or other languages, predefined patterns (types) modelling S-expressions could be included in the environment.

Not all S-expressions do, however, constitute correct programs. In order for an S-expression to be an AST, a certain context-free structure must be satisfied. E.g. the S-expression '(while (if p) (else q))ó does not correspond to an AST for a Pascal program, even though it is a well defined tree structure.

An object-oriented model of the ASTs has been developed as part of the Mjølner BETA System. An AST is modelled as an instance of a pattern. There is a pattern corresponding to each syntactic category (nonterminal) of the grammar. ASTs derived from a syntactic category are then modelled as instances of the corresponding pattern. The pattern IfImp corresponds to the syntactic category <IfImp>. Instances of pattern IfImp then model ASTs that may be derived from <IfImp>.

The grammar hierarchy is modelled by a corresponding pattern hierarchy. E.g. if the nonterminal <Imp> may derive <IfImp>, <WhileImp> etc., then the pattern Imp will be a super-pattern of IfImp. The pattern hierarchy is derived automatically from the context-free grammar. In order for this to work properly, the context-free grammar must obey a certain structure.

Using the metaprogramming system, there is a well defined representation of programs in the form of ASTs. This implies that the various Mjølner BETA System tools and other metaprograms all are able to use the same representation of programs.

The grammar-based interface described above results in a set of patterns for each language. A metaprogram using the grammar-based interface will thus be language specific since it uses the set of patterns generated from the grammar of the actual language. A number of tools are language specific in the sense that usually one exists for each language. Examples of tools that benefit from using the grammar-based interface are: semantic checkers, program analysers, interpreters, browsers, graphical presentation tools, transformation tools.

For certain types of metaprograms it may be inconvenient to use the grammar-based interface, since it implies grammar-based information to be hard-coded in the programs. If manipulation of the AST could only take place through this interface, it would be necessary to write such tools for every language. This is of course not acceptable. Examples of such tools are table-driven parsers and syntax-directed editors.

In order to support both types of tools, the AST in the metaprogramming system may be accessed at three levels.

- Tree level: Here the AST is viewed as a tree. This corresponds to S-expressions.
- Context-free level: This is the grammar-based interface generated automatically from the grammar. This level corresponds to S-expressions where a context-free structure is imposed, together with functions for accessing the components of the AST.
- Semantic level: At this level semantic attributes may be added to the AST. The attributes are tool dependent and usually reflect context sensitive aspects of the language.

The three levels are also modelled by a pattern hierarchy. A generated context-free level is a subpattern of tree level, and a semantic level is a subpattern of the context-free level for the language in question.

In the metaprogramming system, an attempt has been made to view traditional tools like editor, compiler and debugger as metaprograms in general. The advantage of this is that all tools including user programs access programs through a common representation. This leads to the integration of the grammar-based interfaces with the tree level and semantic level described above.

The implementation language of the metaprogramming system is BETA. This means that all metaprograms are written in BETA. However, metaprograms can manipulate ASTs of any context-free language.

The metaprogramming system is also known under the name Yggdrasil. This name is used in a few operations, and in some of the diagnostic messages from the system. The name originates in the Nordic mythodology, where Yggdrasil is the name of the "Tree of Life".

Introduction to Context-Free Grammers

The theory of formal grammars is very extensive, and we will only describe here the very basics of formal grammars. Several textbooks dealing with formal grammars exists and their application as a basis for describing programming languages.

Formal grammars may be divided into several classes, of which the most important classes are the right-linear grammars, the context-free grammars and the context-sensitive grammars. Right-linear grammars are identical to regular expressions.

The most important result is that context-free grammars can be generated and recognized effectively by automated tools such as parsers, whereas context-sensitive grammars are undecidable in general.

Context-free grammars play an important role in the definition of programming languages and is therefore also the foundation for the grammar-based tools of the metaprogramming system. Before going into details with the particular grammar formalism used in the metaprogramming system, we will give a quick introduction to context-free grammars.

Any context-free grammar is defined by means of a set of terminals, a set of nonterminals, a set of productions (also called rules), and one startsymbol. A terminal is a string of characters (e.g. BEGIN in a Pascal grammar). A nonterminal is a special symbol that may derive other symbols. Productions are the means for specifying the rules for deriving sentences and sentential forms from the grammar. We say that the grammar is able to derive a set (possible indefinite) of sentences. A sentence consists solely of terminals (e.g. a Pascal program is a sentence derived from a Pascal grammar). A sentential form is like a sentence, except that nonterminals may be present in a sentential form. I.e. a sentential form is not fully derived (the remaining nonterminals have not been expanded).

Terminals are denoted by wi, nonterminals by <Ai>, productions by <A> ::= w0 <B0> w1 <B1> ..... The startsymbol is a nonterminal, from which all derivations according to the grammar are defined to constitute the language, defined by the grammar. There is one special symbol, empty, which stands for the empty terminal (string).

To illustrate these concepts, a small part of the Pascal grammar is given*[1]*:

```
<program>      ::= program <name>
                     <declarations>
                   begin
                     <statements>
                   end.
<statements>   ::= <statement> ; <statements>
<statements>   ::= empty
<statement>    ::= if <condition>
                   then <statement>
                   else <statement>
<statement>    ::= <name> := <value>
<condition>    ::= <name>
<declarations> ::= <declaration> ; <declarations>
<declarations> ::= empty
<declaration>  ::= <name> : <name>
```

<name> may be any identifier, <value> may be true or false

In this grammar, program, begin, end, ".", ";", ":=", ":", if, then, and else are terminals, whereas <program>, <name>, <declarations>, <declaration>, <statements>, <statement>, and <condition>

are all nonterminals. The nonterminal <program> is the startsymbol.

This grammar may e.g. generate the sentence:

```
program P
V:T;
begin V := true; end.
```

and the sentential form:

```
program P
V:T;
begin if <condition> then <statement> else V := false; end.
```

From this sentential form, several derivations are possible. Derivations are defined by the productions of the grammar. A derivation consists of substituting a nonterminal in the sentential form with the right-side of one of the productions having this nonterminal on the left-side of the "::=" symbol of the production. This implies that <condition> may be substituted with any legal name and <statement> with either an assignment statement or an if statement.

It is important to note, that if one takes another nonterminal as the startsymbol, the language that can be derived from that nonterminal, will be a sublanguage of the original language. That is, if we choose <statements> as the startsymbol, we will get the sublanguage of legal statements in Pascal.

The above discussion is taken in terms of derivations (i.e. the grammar generating the possible sentences defined by the grammar). The observations are equally important when we are talking about parsing a string of characters, and evaluate whether or not the string is a legal sentence according to the grammar.

---

[1] Please note, that this grammar specification is not fully consistent with the actual grammar specification syntax of the metaprogramming system (see chapter 7). The primary difference is, that terminals in the actual grammars to be used by the metaprogramming system must be enclosed in single quotes (e.g. 'begin' instead of begin.

Structured Context-Free Grammars

The grammar formalism used in the metaprogramming system is a variant of context-free grammars. The main reason for introducing this formalism is to make it possible automatically to generate pattern definitions from a grammar.

A structured context-free grammar is a context-free grammar where the rules (productions) satisfy a certain structure.

Each nonterminal must be defined by exactly one of the following rules:

- An alternation rule has the following form:
  `<A0>::| <A1> | <A2> | ... | <An>`
  where <A0>, <A1>,..., <An> are nonterminal symbols. The rule specifies that <A0> derives one of <A1>, <A2>,..., or <An>.
- A constructor rule has the following form:
  `<A0>::= w0 <t1:A1> w1 ... <tn:An> wn`
  where <A0>, <t1:A1>, ..., <tn:An> are nonterminal symbols and w0, w1, ..., wn are possibly empty strings of terminal symbols. This rule describes that <A0> derives the string w0 <A1> w1... <An>. A nonterminal on the right side of the rule has the form <t:A> where t is a tag-name and A is the syntactic category. Tag-names are used to distinguish between nonterminals belonging to the same syntactic category. Consequently all tag-names in a rule must be different. If no tag-name is provided the name of the syntactic category is used as a tag-name.
- A list rule has one of the following forms:
  `<A>::+ <B> w`
  `<A>::* <B> w`
  where <B> is a nonterminal and w is a possibly empty string of terminal symbols. The nonterminal <A> generates a list of <B>'s separated by w's: <B> w <B> w... w <B>. The +-rule specifies that at least one element is generated; the *-rule specifies that the list may be empty.
- An optional rule has the following form:
  `<A>::? <B>`
  where <B> is a nonterminal. The nonterminal <A> may generate either the same strings as <B> may generate, or the empty string (i.e. nothing).

There exists four predefined nonterminal symbols named <NameDecl>, <NameAppl>, <String> and <Const>. These nonterminals are called lexem-symbols. They derive identifiers, character-strings and integer constants. A lexem-symbol may also have a tag-name, like <Title:NameAppl>.

A nonterminal may only appear once on the left-hand side of a rule, and the complete grammar must be LALR(1)*[2]*. The limitations on the rules which can be used in a structured context-free grammar do not restrict the class of languages that can be described. Any context-free language may be generated by a structured context-free grammar. It may perhaps be awkward to be forced to follow the rules. On the other hand being forced to structure a grammar using the rules often results in a more readable grammar.

There is one important representation for sentential forms and sentences of any context-free grammar, the abstract syntax tree. An abstract syntax tree (for short AST) represents how a sentential form (or sentence) has been derived from the grammar (or how it has been constructed by the parser). The AST does not represent the terminals of the grammar, only the involved nonterminals. The nodes in an AST are productions and the branches in the AST signifies derivations of the nonterminals involved in the production in that node. The leaves of the AST are lexems, if the AST represents sentences. If the AST represents a sentential form, leaves may also be nonterminals. ASTs are a very convenient representation of programs and many manipulations of programs may be specified as manipulations on the underlying AST.

A context-free grammar for a language induces an abstract syntax that may be used to give an AST-definition. In the Mjølner BETA System, the representation of a program as an AST is defined by means of a context-free grammar for the language. In addition there is a set of rules that specify how the context-free grammar is mapped into a set of data types. The context-free grammar is then part of the specification of the environment.

The metaprogramming system is an object-oriented model of the ASTs. An AST is modelled as an instance of a pattern. There is a pattern corresponding to each syntactic category (nonterminal) of the grammar. ASTs derived from a syntactic category are then modelled as instances of the corresponding pattern. The grammar hierarchy is modelled by a corresponding pattern hierarchy.

Special grammar symbols are shown enclosed by << and >>. These symbols are called placeholders. Placeholders are always associated with a nonterminal of the grammar. A placeholder may have a tag-name in order to be able to distinguish between several instances of the same nonterminal in a program. I.e. <<PopLib:attributes>> is a placeholder, where attributes specifies the syntactic category and PopLib is the tag-name. As illustrated below, some placeholders are also equipped with the symbols SLOT or "...". These will be explained below

```
(# Private: @<<SLOT PrivateBody:descriptor>>;
   Push: (# e: @integer
         enter e
         do <<SLOT PushBody:descriptor>>
         #);
   Pop: (# <<PopLib:attributes>> ... #);
   <<attributes>>
#)
```

The above is a BETA pattern for a Stack. The pattern is not fully specified in the sense that the pattern contains placeholders that have not been expanded.

Generally, programs may contain placeholders of three different types: nonterminals, slots or contractions. Nonterminals and slots denote unexpanded nonterminals of the underlying grammar, whereas contractions denote expanded nonterminals of the underlying grammar. I.e. a program containing nonterminals and slots are sentential forms of the BETA language, whereas programs only containing contractions are sentences of the BETA language.

Nonterminals are indications that these parts of the program have not been specified yet (e.g. <<PopLib:attributes>>). The ability to leave nonterminals in the program is the means for allowing syntax directed editing.

Slots are indications of parts of the program that deliberately have been kept open (e.g. <<SLOT PushBody:descriptor>>). Slots are a means for specifying a program in which parts are separately specified (these parts are indicated by the slots). A program with slots may be separately compiled, and other programs may contain the slot definition to be applied later.

Contractions are placeholders indicating that this part of the program, derived from the nonterminal, is not shown (e.g. ...). I.e. contractions are a means for suppressing details that are otherwise present in the program. Note that contractions may suppress other placeholders, i.e. nonterminals, slots and other contractions may appear within a contraction. Contractions are merely a means for presenting an overview of programs etc., and the handlig of contractions are therefore totally controlled by the different tools (i.e. not managed by the metaprogramming system)

In terms of the underlying AST of the program, nonterminals are leaves in the tree, slots are references from one AST to another AST (possibly not yet derived), and contractions indicates a sub-AST that is not shown (i.e. only represented by the syntactic category of the root of the sub-AST.

The super-category of a given syntactic category A is defined as follows:

- If <A> appears on the right side of an alternation rule of the form:
  ```
  <B>::| ... | <A> | ... | ...
  ```
  then the super-category of A is B.
- If <A> appears in a list rule in one of the forms:
  ```
  <A>::+ <B> ...
  <A>::* <B> ...
  ```
  then the super-category of A is List.
- If <A> appears in an optional rule:
  ```
  <A> ::? <B>
  ```
  then no category A is defined (to be discussed later).
- Otherwise the super-category of A is Cons.

The inheritance hierarchy of the generated patterns of the context-free level is the same as the classification hierarchy of the syntactic categories. In general a syntactic category may have more than one super-category. This corresponds to multiple inheritance in object-oriented languages. Since BETA currently does not support multiple inheritance, there is the additional restriction that the hierarchy must be tree structured. That is, the following grammar will not be a legal grammar:

```
<A> ::| <B> | <C>
<B> ::+ <D>
<C> ::= <E> terminal <F>
```

since <B> will have both List and A as super-category.

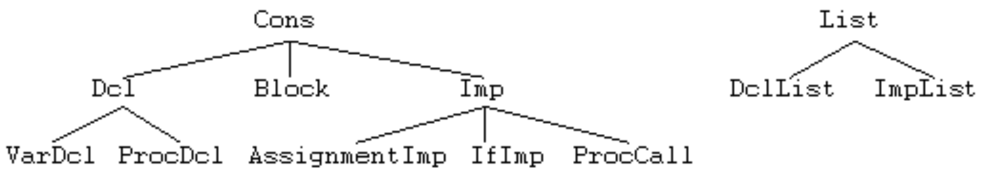
Example of Structured Context-Free Grammar

Below an example of a structured context-free grammar is given[3].

```
Grammar Small:
        <Block>::= begin <DclPart:DclLst>
                  do <ImpPart:ImpLst>
                  end
        <Dcl>::| <VarDcl> | <ProcDcl>
        <VarDcl>::= var <Name:NameDecl>: <VarType:Type>
        <ProcDcl>::= proc <Name:NameDecl> <Body:Block>
        <Imp>::| <IfImp> | <AssignmentImp> | <ProcCall>
        <IfImp>::= if <Condition:Exp>
                  then <ThenPart: ImpLst>
                  else <ElsePart: ImpLst> endif
        <AssignmentImp>::= <Var:NameAppl> := <Value:Exp>
        <ProcCall>::= <Proc:NameAppl>
        <DclLst>::* <Dcl>;
        <ImpLst>::* <Imp>;
```

The nonterminals <Type> and <Exp> will not be defined.

The syntactic categories of a structured context-free grammar may be organized into a classification hierarchy according to the set of strings being generated. The hierarchy mainly derives from the alternation rules of the grammar. The hierarchy for the example grammar is:



The categories Cons and List generalize all categories according to the rule type that defines the category. <Imp> is a super-category of <IfImp> since any string generated by <IfImp> may be generated by <Imp>.

[2] However, this restriction is only neceaasry if the grammar is to be used for parsing purposes (see chapter 7 for more details).

[3] Please note, that this grammar specification (as the previous grammar) is not fully consistent with the actual grammar specification syntax of the metaprogramming system (see chapter 7).

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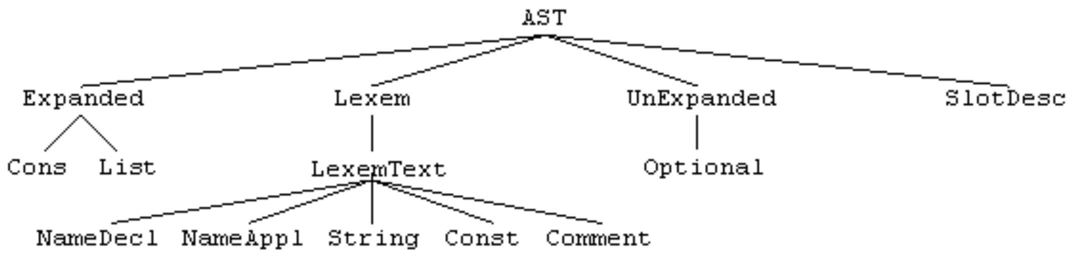
The Tree Level

As mentioned in the introduction, certain tools like syntax directed editors are usually table-driven in the sense that the code is independent of the actual grammar. The AST is manipulated as an ordinary tree. The context-free level must therefore be integrated with a level where the AST is viewed as an ordinary tree. This is straight forward using subclassing. The patterns generated from the grammar are all subpatterns of the general patterns Cons and List. These patterns are actually subpatterns of more general patterns describing ASTs as ordinary trees. In this section these general patterns are described. The general patterns are called the tree level.

At the tree level, an AST is modelled as an instance of the pattern AST. The pattern AST is further specialized into a number of sub-patterns. Some of these sub-patterns correspond to the rule types of a structured context-free grammar. The tree level corresponds to an ordinary data type for a tree. The specialization hierarchy for the patterns defined in the tree level is:



The following is a verbal description of these patterns:

- AST describes all ASTs. Operations of this pattern are: Symbol returns the nonterminal symbol of the AST. Kind returns the type of the AST (e.g. List). Father returns the father. SonNo returns the index of this AST in the list of sons of the father of this AST. NextBrother returns the next brother of this AST in the list of sons of the father of this AST. AddComment updates an associated comment, GetComment returns an associated comment, and HasComment tests whether a comment is associated with this AST. HasSemanticError and SemanticError is used by language-dependent tools to mark ASTs with information on semantic errors in the AST. Copy returns a copy. Match, Equal and Lt performs different kinds of comparisons of ASTs, and copy enables copying an entire AST. Finally, NearestCommonAncestor returns the nearest common ancestor of this AST and some other AST. GetAttribute, putAttribute, getNodeAttribute, putNodeAttribute, getSlotAttribute, putSlotAttribute, getSlotNodeAttribute and putSlotNodeAttribute, are operations for accessing and changing the different attributes, that are specified for this kind of ASTs. The number of attributes are defined as part of the grammar specification. Finally, the putCommentProp and getCommentProp is used for associating properties directly with individual ASTs. For a description of properties, see chapter 7.
- Expanded describes ASTs that are expanded into trees (i.e. something has been derived from the nonterminal of this AST). Get returns a son at a given position. Put updates a son at a given position. NoOfSons returns the number of sons of this AST. Scan iterates over the sons in this AST. SuffixWalk and SuffixWalkforProd perform preorder traversal of the tree with this node as root. Insert will insert an AST before a given son. Finally, expanded defines getson1, ..., getson9 and putson1, ..., putson9 for direct access to the given son number.
- Cons describes all nodes derived by a constructor rule. Delete deletes a son at a given position.
- List describes all nodes derived by a list rule. SonCat describes the category of the ASTs of

the list. Delete deletes an AST with a given position and Insert inserts an AST at a given position. Append inserts an AST as the last son in the list. NewScan iterates over the ASTs in this list.
- Lexem describes all nodes derived by one of the predefined nonterminals (e.g. Const). No special operations.
- LexemText describes leaves having textual contents. GetText returns the textual contents. PutText updates the textual contents. CurLength returns the length of the textual contents. GetChar and putChar allows for accessing and changing the individual chars in the textual contents. Clear empties the textual contents.
- NameDecl describes all name declarations. ScanUsage iterates over the name applications that use this declaration. This information is context-sensitive and if used it must be set up by a language specific tool. AddUsage and removeUsage is used by these language-specific tools to set-up and remove such informations.
- NameAppl describes all name applications. GetDecl returns a reference to the AST, containing the declaration of this name application. This information is context-sensitive and if used it must be set up by a language specific tool. NextUsage returns the next usage (reference to an AST) of this nameAppl, if any exists. DeclSet tells whether any language-specific tools have setup declaration information for this name application.
- String describes all strings. No special operations.
- Const describes all numeric constants. GetValue returns the value of the constant, PutValue updates the value of the constant.
- Comment describes comments associated with ASTs. CommentType returns the type of this comment.
- UnExpanded describes ASTs where nothing yet has been derived from the nonterminal of this AST. NonterminalSymbol returns the kind of nonterminal associated with this AST (Note that this(AST).symbol returns unExpanded). The kind of nonterminals are defined in the kinds object. The available kinds are: kinds.interior, kinds.unExpanded, kinds.optional, kinds.nameDecl, etc).
- Optional describes ASTs that are unexpanded, and where the nonterminal symbol of this AST is defined by an optional rule. No special operations.
- SlotDesc describes AST representing SLOTs. More on SLOTs later.

Assuming the patterns AssignmentImp, IfImp and ProcCall corresponding to ASTs generated from the respective nonterminals. These patterns are sub-patterns of the pattern Imp. Assume that a tool for counting the number of imperatives in an instance of ImpList is to be implemented. In addition the tool should count the number of different types of imperatives. The tool may be implemented by adding a virtual pattern attribute Count to the pattern Imp. The definition of Count may then be extended in the sub-patterns:

```
Imp: Cons(# Count:< (# do ImpCount.Add1; inner #) #)
AssignmentImp: Imp(# ...
                     Count::< (# do AssignmentCount.Add1 #)
                  #);
...
ImpList: List(# ... #)
IL: ImpList;
...
IL.Scan(# do thisElm.Count #)
```

The virtual pattern Count in AssignmentImp will be a sub-pattern of the Count pattern in Imp. ThisElm in IL.scan... will in turn refer to each element in IL. If ThisElm in IL.Scan denotes an instance of AssignmentImp then ThisElm.Count will result in execution of ImpCount.Add1 followed by AssignmentCount.Add1

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The Context-Free Level

The context-free level has explicit knowledge about the grammar for the language. For each nonterminal A of the grammar, a corresponding pattern is automatically generated, depending on the defining rule for A. For each rule type described in section 2, the list below describes the corresponding generated patterns.

1. Alternation: A pattern of the following form is generated:
   ```
   A: P(# #)
   ```
   where P is the pattern corresponding to the super-category of A. The pattern P is thus the super-pattern for A.
2. Constructor: A pattern of the following form is generated:
   ```
   A: P
      (#
           getT1: getson1(# #)
           putT1: putson1(# #)
           getT2: getson2(# #)
           putT2: putson2(# #)
           ...
           getTn: getsonn(# #)
           putTn: putsonn(# #)
      #)
   ```
   where P is the super-category of A. There is an attribute corresponding to each nonterminal on the right side of the rule. The suffix of the get- and put- attributes (Ti) is the same as the corresponding tag-name.
   If T is an instance of A, the i'th sub-AST can be accessed and changed through the get- and putTi operations. The put- and getsoni patterns have enter (respectively exit) parameters such that an AST can be inserted as the i'th sub-AST by ... Æ T.putTi and will be delivered by T.getTi Æ ...
3. List: A pattern of the following form is generated:
   ```
   A: List(# sonCat::< B #)
   ```
   where B is the name of the nonterminal on the right side of the rule. The super-pattern is List as the super-category of A is List.

Constructor rules are thus mapped into a composition hierarchy and alternation rules into a classification hierarchy.

By using the context-free level it is not possible for a programmer to construct an AST that violates the context-free syntax.

The Structure of the Context-free Level Interface

The above mentioned patterns that are generated by the metaprogramming system, are all declared local to a specialization of the treelevel pattern. That is, the structure of the context-free level interface is:

```
ORIGIN '~beta/ast/astlevel'
--- astInterfaceLib: attributes ---
grammarName: treelevel
  (# ...
     (* declaration of the patterns from the grammar *)
     ...
     init::< (# do ... (* some initializations *) ... #)
  #);
```

Treelevel contains a local AST, grammarAST, decribing the grammar and a number of patterns (e.g. newAST, newLexemText, newConst, etc.) for instantiating new ASTs from this grammar, for identifying the version and name of the grammar, and facilities for parsing a text representation into a fragment. Finally, treelevel contains a parser attribute which can be used for parsing a text stream into an AST from the grammar in grammarAST.

The applGram fragment contains a specialization of treeLevel, called applGram. ApplGram makes the necessary setup for using the treelevel interface to any grammar.

In addition patterns are generated which provide easy creation of new ASTs from existing ones. For each nonterminal A of the grammar a generator named NewA is generated. For nonterminals defined by a constructor rule, NewA will as enter parameter take as many ASTs as there are nonterminals on the right side of the rule. It will then exit an A-AST with the enter parameters as sons

---

Example of Structured Context-Free Grammar, cont.

The patterns generated for the example grammar are:

```
Small: TreeLevel
  (# Block: Cons(# getDclPart: getson1(# #);
                   putDclPart: putSon1(# #);
                   getImpPart: getson2(# #);
                   putImpPart: putson2(# #)
                #)
     Dcl: Cons(# #);
     VarDcl: Dcl(# getName:    getson1(# #);
                   putName:    putson1(# #);
                   getVarType: getson2(# #);
                   putVarType: putson2(# #)
                #)
     ProcDcl: Dcl(# getName: getson1(# #);
                    putName: putson1(# #);
                    getBody: getson2(# #);
                    putBody: putson2(# #)
                    #)
     Imp: Cons(# #);
     IfImp: Imp(# getCondition: getson1(# #);
                  putCondition: putson1(# #);
                  getThenPart:  getson2(# #);
                  putThenPart:  putson2(# #);
                  getElsePart:  getson3(# #);
                  putElsePart:  putson3(# #)
               #)
     ProcCall: Imp(# getProc: getson1(# #);
                     putProc: putson1(# #)
                  #)
     AssignmentImp: Imp(# getVar:   getson1(# #);
                          putVar:   putson1(# #);
                          getValue: getson2(# #);
                          putValue: putson2(# #)
                       #)
     DclLst: List(# #);
     ImpLst: List(# #);
     ...
  #)
```

Metaprogramming System	Mjølner Informatics

The Context-Free Level

Using the Context-Free Level

Consider the references:
```
P: ^ProcDcl; B: ^Block; N: ^nameDecl
```

P.getBody refers to the block of P, and after executing the assignment P.getBody -> B[], B will refer to this block. P.getName->N[]; N.GetText will return the name of the procedure as a text.

Consider a tool for investigating the contents of a block, where part of the investigation is to count the number of imperatives in the block. In addition the number of different types of imperatives will be counted.

This tool may be implemented by adding the operation Investigate to the pattern Block. Investigate makes use of the virtual operation Count which is added to the pattern Imp. Count is further specialized in the sub-patterns of Imp.
```
Small: Treelevel
  (# ImpCount, AssignmentCount,
     ProcCallCount, ICount: @Integer;
     Block: Cons
       (# Investigate:
            (# do
               0 Æ ImpCount Æ AssignmentCount
                 Æ ProcCallCount Æ IfCount;
               ImpPart.Scan(# do Current.Count #);
               ... (* Use ImpCount, ProcCallCount, ... *)
            #);
       #);
     ...
     Imp: Cons
       (# Count:< (# do ImpCount.Add1; inner #) #);
     IfImp: Imp
       (# Count::<
            (# do
               IfCount.Add1;
               ThenPart.Scan(#do Current.Count #);
               ElsePart.Scan(#do Current.Count #);
            #);
       #);
     AssignmentImp: Imp
       (# Count::< (# do AssignmentCount.Add1 #) #);
     ProcCall: Imp
       (# Count::< (# do ProcCallCount.Add1 #) #);
     ...
  #);
```

B can now be investigated by B.Investigate.

In spite of the limited usefulness of the above example it gives a flavour of how semantic attributes may be added to the generated patterns. Tools like a semantic analyzer, a code generator, a program interpreter, a browser, presentation tools, program analyzers, transformation tools benefit from the possibility to add semantic attributes.

The next example will demonstrate how the syntax directed editor of the Mjølner BETA System can be extended to provide the user of the editor with transformations.

The editor is an ordinary syntax directed editor which presents an AST in a window by means of a pretty-printer, it allows the user to navigate in the AST and to edit it. The pattern describing the editor has the outline:

```
Sde:
  (# Grammar:< TreeLevel;
     G: @Grammar;
     Root, CurrentSelection: ^G.AST;
     ... (* a lot of other stuff *)
  #)
```

Grammar describes which grammar is actually used. An editor for Pascal may be constructed by binding the context-free level generated for Pascal to Grammar. The reference Root denotes the program fragment being edited by the user. CurrentSelection denotes the sub-AST which is the current focus of the user.

To extend the editor with transformations the pattern SdeWithTransformations is declared as a sub-pattern to Sde. SdeWithTransformations declares the pattern Transformation, which has three virtual operations Init, EnablingCondition and Perform and a static reference Name.

SdeWithTransformations keeps a list containing an instance of each sub-pattern of Transformation. This list is created by means of initialization operations not shown here.

When the user selects a new node in the tree EnablingCondition will be tested for all transformations. The Names of those that are enabled will be presented to the user in a menu, and if the user selects one of the items in this menu, Perform for the corresponding transformation will be called.

```
SdeWithTransformations: Sde
  (# Transformation:
       (# Name: (* Presented in the menu *) @Text;
          Init:< (* Called when an instance is created *)
            (# do ... inner; ... #);
          ...
          EnablingCondition:<
            (* Virtual operation to test if transformation
             * is applicable for the current selection of
             * the editor.
             *)
            (# Enabled: @Boolean
            do inner
            exit Enabled
            #);
          Perform:<
            (* Operation to be performed if the user
             * selects this transformation
             *)
            (# do inner #);
       #);
     ...
  #);
```

Assume a grammar for Pascal has been written, structured as Small, and including the rule
`<WhileImp>::= while <Condition:Exp> do <DoPart:ImpLst>`

A syntax directed editor for Pascal with a transformation that will allow the user to transform an IfImp into a WhileImp could be created by the pattern:

```
PascalEditor: SdeWithTransformations
  (# Grammar::< PascalGrammar;
     IfToWhileTransformation: Transformation
       (# Init::< (# do 'IfImp to WhileImp' -> Name #)
          EnablingCondition::<
            (# do (CurrentSelection## = G.IfImp##)
                    -> Enabled
            #);
          Perform::<
```

```
            (# theIfImp: ^G.IfImp;
               theWhileImp: ^G.WhileImp;
               frag: ^fragmentForm;
            do CurrentSelection[] -> theIfImp[];
               (whileImp, frag[]) -> newAst
                 -> theWhileImp[];
               theIfImp.getCondition
                 -> theWhileImp.putCondition;
               theWhileImp -> ReplaceCurrentSelection;
            #);
       #);
     ... (* More Pascal-transformations *)
  #);
```

The pattern ReplaceCurrentSelection used by Perform is an attribute of pattern Sde.

The IfToWhileTransformation is a simple tree-match transformation. In the same way more advanced context-sensitive transformations could be added to the Pascal-editor. A transformation that extends a <Procedure-Identifier> with a template for the list of actual parameters is an example of this. This list could be generated with the correct number of parameters, and the parameters could be specialized such that a <Variable> nonterminal is inserted if the formal parameter is a <Var-Parameter>, an <Exp> nonterminal if it is a <Value-Parameter>, etc.

The context-free level provides the programmer with much more structure and security than the tree level alone. Consider the declaration P: ^ProcDcl. The body part of P may be denoted by P.getBody. If only the tree level is used, the corresponding declaration and denotation will be P: ^AST and P.getson2. This is less readable and it is solely the responsibility of the programmer that P actually denotes an AST for <ProcDcl> otherwise P.getson2 will not return an AST for <Block>.

The Semantic Level

As indicated by the investigation example in the previous section, it is often useful for tools to be able to add attributes (operations, data) to the patterns of the context-free level. A simple way to add semantic attributes is to let the tool programmer textually edit the patterns of the context-free level. In a programming environment with many grammars and tools this is not satisfactory from a maintenance point of view. If semantic attributes have to be manually inserted into the patterns this has to be done each time changes are made to the grammar. From a structuring point of view it would be an advantage if the definition of semantic attributes could be kept separate from the generated patterns.

The semantic level of the metaprogramming system is therefore defined as part of the grammar. The semantic level allows the specification of the number of semantic attributes of each syntactic category in the grammar. The metaprogramming system will then ensure that the proper memory space is allocated for these attributes, and their values will be maintained by the system and stored along with the AST.

It is important to know, that the persistent parts of the ASTs (i.e. the information stored in the files) is not in the form of BETA objects (instances of the AST patterns). The storage is instead in the form of an encoded bytestream, which also is the runtime representation of the ASTs, and the AST patterns are merely interfaces to this compact representation. This also implies that information in various types of objects as part of the instances of the AST patterns will not be stored when the AST is stored onto the disk. Such information is transient and cannot be shared with other tools. Since the semantic information is to be shared between tools, and stored onto the persistent representation of ASTs, it is specified in the grammar (in the attributes part, see chapter 6).

These persistent attributes of ASTs are accessed through the putAttribute and getAttribute of ASTs. The attributes are integer-valued and indexed, and may be used for any purpose.

To enable the specification of transient properties of AST to be used at the semantic level, the metaprogramming system offers facilities for specifying that SLOTs should be inserted at various places in the generated context-free level interface. First of all, if a nonterminal is mentioned in the attribute part of the grammar, an attribute slot is automatically inserted in the pattern generated for that nonterminal (see chapter 6 and appendix 3). Secondly, the options part of the grammar may specify an identifier in the substanceSlot option in the options part of the grammar, and the result is that a descriptor slot with that name is inserted in the treelevel subpattern for the grammar (see chapter 6 and appendix 3).

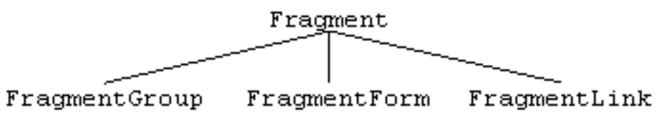
These slots are used for specifying the transient properties in separate fragments, such that changes in the grammar (and thereby regeneration of the context-free level interface, does not destroy any semantic specifications. See appendix 3 for an example of this usage of semantic level slots.

The Fragment System Interface

The metaprogramming system also contains an interface to the Fragment System of the Mjølner BETA System. The fragment system enables the management and manipulation of ASTs located on different files. The functionality of the fragment system allows the splitting of an AST into an number of sub-ASTs (sub-trees) by allowing some interior nodes in the original AST to be replaced by special nodes, called slotDesc. The AST, originally positioned at the position of that node, may by located on a totally different file (possibly along with other sub-ASTs). All these ASTs are called fragments. Fragments are named in an hierarchical name space, similar to the UNIX hierarchical file system. The full name of a fragment has the following structure: /name1/name2/.../namen/frag, where /name1/name2/.../namen is called the path of the fragments and frag is called the local name of the fragment. The path of a fragment is the same as the full name of the father of the fragment. Fragments are usually located in files on the file system. Fragments are stored in two different formats: textual representation and binary representation. The binary representation is considered the essential representation of fragments, and the purpose of the textual representation is human reading, printing or parsing into the binary representation. If the fragment is created using tools based on the metaprogramming system, there is no reason for storing the textual representation since the binary representation contains all necessary information.

The fragment system interface of the metaprogramming system is used as the basis for the fragment system for BETA [MIA 90-2].

The fragment system interface consists essentially of four major patterns:



- Fragment is an abstract pattern for the three other patterns, implementing the following operations: Name accesses the local name of the fragment and fullName accesses the full name of the fragment. DiskFilename refers to the name of the file containing the binary representation, and textFilename refers to the file containing the textual representation. Father returns a reference to the father of this fragment, and type refers to the fragment type (group, form, or link). Init initializes the fragment, reset resets the fragment as if it has just been parsed from the textual representation, and close closes the fragment. ModTime returns the time for the last change to this fragment, changed indicates whether this fragment has been changed, markAsChanged sets the changed mark, and checkDiskRepresentation will check if the disk representation has been changed. Fragments may have properties associated with them. These properties are kept in the prop attribute, which is a list of properties, where each property carries one value. In a subsequent section, properties are discussed in more detail.
- Fragment also contains a few operations, related to the BETA specific fragment system: Origin refers to the origin of the BETA fragmens, bind binds a fragment within this BETA fragment and bindToOrigin binds this fragment to its origin.
- FragmentForm represents one single (sub-)AST. It contains the following operations: Category refering to the syntactic category of the root node of the AST in this fragmentForm. Print makes an almost readable dump of the fragmentForm. Root refers to the AST of this fragmentForm, grammar refers to the grammar, describing the grammar of the language of this fragmentForm, and scanSlots iterates through all slots in this fragmentForm. Finally, the BETA specific attribute binding refers to the slot to which this fragmentForm have been bound.

- FragmentGroup represents a group of (sub-)ASTs. FragmentList is the list, containing all the fragments in this group. Open makes it possible to get access to a single fragment in the group, scan makes it possible to iterate through all the fragments of this group, and parse makes it possible to parse a file into a fragment group. DefaultGrammar refers to the grammar used for this fragmentGroup. SetupOrigin, getBinding and getBETAbindings can be used for accessing the slot bindings.
- FragmentLink represents a link to some other fragment (e.g. the INCLUDE link in the BETA fragment system). It contains a reference to the fragment, and the various names for that link.

The fragment system interface also influences the AST interface a few places. First of all, an AST has a frag attribute, which refers to the fragment containing this AST. Secondly, unExpanded has the attributes isSlot and theSlot, where isSlot is true if this node in the AST represents a slot, and theSlot contains information (name and syntactic category) on the slot. Slots is inserted in the AST in the following way:

```
(# aSlot: ^slotDesc; anUnexpanded: ^unExpanded;
do ... -> newUnExpanded -> anUnexpanded[];
   newSlot -> aSlot[];
   'foo' -> aSlot.name;
   aSlot[] -> theUnexpanded.theSlot
#)
```

Generating a Metaprogramming Interface

Many of the tools in the Mjølner BETA System are available as generators, such that given a specific grammar for some language, new program development tools may be generated. These tools will offer extensive support of the specific language, such as parsing, pretty-printing, hyper structure editing (including syntax directed editing), and modularization etc. as offered by the fragment system. Finally, the meta programming system is available for that language.

This section will describe how to construct a structured context-free grammar, and generate a new set of program development tools that supports this language. The grammar-based tools are Parser, Pretty-printer, Editor, Fragment system, and the meta programming system.

Constructing a Grammar

We are assuming that an ordinary context-free grammar is given for the selected language. Strategies for constructing such a grammar can be found in most textbooks, that deals with compiler construction. In order for the grammar to be useful, it has to fullfill the following requirements:

1. The grammar must be converted into a structured context-free grammar. Since any context-free grammar can be converted into a structured grammar, this step should not cause major difficulties (except possibly for the restriction that the resulting hierarchy must be tree-structured, as discussed in chapter 2).
2. The resulting structured context-free grammar has to be LALR(1). This requirement may be ignored, if there is no need for generating a parser for that language (i.e. all programs in that language will be manipulated, using the editor and the meta programming system). Unless otherwise explicitly noted, we will, in the following, always be refering to the structured context-free grammar when we are discussing the grammar.
3. Along with the grammar, several additional properties of the grammar need to be specified, namely unused predefined nonterminals, the comment symbols of the grammar, the string symbol of the grammar, etc. All these options are described in chapter 6. We will discuss here only the most commonly used options.

The grammar definition is divided into five parts: the fragment part, tthe naming part, the options part, the rules part, and the attributes part: The naming part specifies the name of the grammar, the options part specifies the valid options of that grammar, the rules part contains the productions of the grammar, and the attributes part specifies for each nonterminal, the number of semantic attributes defined at the semantic level for that nonterminal. The options part and the attributes part are optional parts and may thus be absent from the grammar definition. The meta grammar describing the language for grammar specification is given in appendix 1.

The Fragment Part

In order to make the grammar specification readable for the various grammar tools, it must start with a fragment form specification. The format of a fragment form specification for a grammar is:

```
-- name: aGrammar: metagrammar --
```

where name must be the name chosen for this grammar.

The Naming Part

The grammar definition must begin by naming the grammar. This is done in the naming part of the grammar. The naming part consists of one clause:

```
Grammar name:
```

where name must be the name chosen for this grammar.

The Options Part

The options part of the grammar contains various settings of variables, that control the way in which the grammar processor treats the productions in the rules part, and other issues.

Each option is specified by the name of the option followed by "=" followed by the value of the option. The valid options are:

- version: Defines the version number of the grammar. The version number is used by the meta programming system to ensure that different AST's handled in a meta program are using the same version of the grammar. Default is 'undefined'.
- astVersion: Defines the version of the metaprogramming system to be used for this grammar. Default is the same version as the version used for the generator.
- comBegin: Defines the string that signifies a beginning of comment in the language of the grammar. Default is '(*'.
- comEnd: Defines the string that signifies the end of comment in the language of the grammar. If the string is the empty string, end of line acts as the comment end string. Default is '*)'
- stringChar: Defines the string literal enclosing symbol (e.g. in a Pascal grammar, stringChar will be "). containing programs, written in the language of this grammar. Default is ' (single quote)
- Unused Lexem Terminals: If not all lexem terminals (e.g. <nameApp> are used in the grammar, these should be marked as unused. This is done by using the name of the lexem terminal as the option name and associate the value unused to it (e.g nameApp = unused). Default is none.
- substanceSlot: Specifies an identifiers: id. The result of specifying this identifier is, tha the metaprogramming system will generate the following attribute in the generared context-free interface fragment: id: <<SLOT id: descritor>>.
- subOf: Specifies the pattern name to be used as the superpattern for the context free level patterns. Default is 'treelevel'.
- BobsOptions: String containing a comma separated list of options to be passed to the BOBS compiler-compiler. Default is '32,34,59'.
- splitOnFiles: Specifies that the generated BETA patterns, interfacing to the context free level should be split on the given number of files. Default is 1.
- suffix: Defines the file name suffix, that is expected on files, containing programs in the syntax of this grammar. Default is '.text'.
- startsymbol: Defines the startsymbol of the grammar. If no startsymbol option is defined for the grammar, the nonterminal on the left-hand side of the first production of the rules part of the grammar is chosen as the startsymbol of the grammar.

The Rules Part

The rules part of the grammar contains the specifications of the productions of the grammar.

The productions must follow the structure of a structured context-free grammar, as described ealier. Terminals have the form 'w', i.e. a string enclosed in single quotes (e.g. 'enter'). Nonterminals has either the form <A> or <t:A>, where t is a tag-name, and A is the syntactical category. If no tag-name is provided, the name of the syntactic category is used as the default tag-name.

The complete grammar must be LALR(1), if a parser needs to be generated by the metaprogramming system.

The Attributes Part

The attributes part of the grammar is a specification of the additional memory, the metaprogramming system needs to allocate in order to be able to handle the semantic attributes defined at the semantic level of the grammar.

The attributes part is a list of
```
<nonterminalName>: number
```

where <nonterminalName> is the name of a nonterminal of the grammar, and number is the size of the semantic attributes defined for this nonterminal. These semantic attributes are saved as part of the AST, when it is stored on some file. Please note, that for efficiency reasons, the number of attributes must be even (or zero).

As a side effect of specifying the nonterminal in the attributes part, that the generated context-free level interface pattern for that pattern will contain an attributes slot:
```
<<SLOT nonterminalNameAttributes: attributes>>
```

An Example Grammar

The following grammar will be used in the following to illustrate the various tools:

```
-- mylang: aGrammar: metagrammar --
grammar mylang:
rule
<module>        ::= 'module' <module:id> ';' <importOpt>
                    'begin' <statement> 'end';
<id>            ::= <nameDecl>;
<importOpt>     ::? <import>;
<import>        ::= 'import' <nameList> ';';
<nameList>      ::+ <nameDecl> ',';
<statement>     ::| <if> | <while> | <procCall>;
<if>            ::= 'if' <condition:exp>
                    'then' <thenPart:statement>
                    'else' <elsePart:statement> 'endif';
<while>         ::= 'while' <condition:exp>
                    'do' <statementList> 'end';
<statementList> ::* <statement> ';';
<exp>           ::| <expProcCall> | <text> | <number>;
<text>          ::= <string>;
<number>        ::= <const>;
<expProcCall>   ::= <procCall>;
<procCall>      ::= <nameAppl> '(' ')'
```

Generating the Grammar-Based Information

After having constructed the grammar, several grammar analysis tools needs to be invoked in order to analyse the grammar and generate the necessary information for the various tools. In the following discussion, we will assume the grammar is named mylang and the grammar is residing on the file mylang-meta.gram.

The naming conventions used here are mandatory:
A grammar must reside on a file with a name that is the name of the grammar (as specified in the Grammar clause of the grammar) followed by -meta.gram.

Generating the Metaprogramming Interface

In order to generate the predefined patterns that constitute the tree- and context-free level interface to the AST's generated by the grammar, we have to invoke the generator tool:

```
generator mylang
```

The generator checks whether the grammar is a valid structured context-free grammar, and generates the following files:

- mylang-meta.ast: This file contains an AST of the grammar itself. This AST is in accordance with the metagrammar specification given in appendix 1.
- mylangcfl.bet: This file contains BETA patterns, constituting the BETA interface (as described above) to the context-free level of AST's that will be generated by the parser (or other tools, such as the editor). If the grammar options (discussed later) specify that these patterns should be split on several files, the files mylang2.bet, mylang3.bet, etc. will also exist.
- mylang-parser.bobs: This file contains the grammar in a special format to be used by the parser generator (see below).

Generating Parser and Parser Tables

The next step is to analyse the grammar (to check that the grammar is LALR(1) and otherwise well-formed). This is done by the bobsit tool:

```
bobsit mylang
```

Besides analysing the grammar, the bobsit tool generates the file:

- mylang-parser.btab: This file contains the parser tables, needed by mylang-parser.bet.

Bobsit may find errors in the grammar (such as the grammar not being LALR(1), nonterminals that cannot be reached from the startsymbol, etc). If a parser is not to be used at all for the mylang grammar (i.e. all AST's of the grammar is generated by grammar-based tools) these errors may be ignored.

Bobsit is a revised version of the BOBS compiler generator.

Generating Pretty-printer Specification

Having analysed and checked the grammar, generated the AST interface to the grammar, generated the BETA interface to the AST's of the language, and generated the parser and parser tables, the next step is to generate a pretty-printer specification for the language. This is done by the makepretty tool:

```
makepretty mylang
```

Makepretty generates the default pretty-printer specification for the grammar mylang on the file:

- mylang-pretty.pgram

This default pretty-printer specification is often not the best possible pretty-printer specification for the given grammar. The default pretty-printer specification is therefore often modified in order give a better reflection of the semantical structure of the language. These modifications are done manually and discussed later.

Generating Pretty-printer Specification Tables

As the final step in generating the grammar-based information to be used by the various grammar-based tools, the pretty-printer specification tables need to be generated. This in done by the morepretty tool:

```
morepretty mylang
```

Morepretty analyses and checks the pretty-printer specification on the file mylang-pretty.pgram and generates the pretty-printer specification tables on the file:

- mylang-pretty.ptbl

Generating the Grammar-based Information Easily

In order to make it easier to run these four tools in the right sequence, a utility tool is available:

```
dogram mylang
```

which runs generator, bobsit, makepretty and morepretty in that sequence. Please note, that the dogram tool will overwrite any existing manually edited pretty-printer specifications. If these should be retained, either run the three other tools (e.g. except makepretty) manually, or copy the manually edited pretty-printer specification file to a safe place before invoking dogram.

Registering the new grammar

The grammar is now ready for being used by the different grammar-based tools in the Mjølner BETA System. The grammar-based tools uses a particular searching strategy, when trying to locate the grammar to be used for interpreting a given file (textual source file, of a group file, containing the ASTs). This searching strategy is implemented in the findGrammar fragment, described later. This strategy is the following:

1. First try to locate the grammar in the current directory.
2. Then try to find the grammar among the grammars specified in one of the grammar specification files:

    a. First try among the grammars defined in the MBSgrammars.text file located in the current directory.
    b. Then try among the grammars defined in the MBSgrammars.text file located in the HOME directory of the user.
    c. Then try among the grammars defined in the MBSgrammars_DEMO.text file located in the ~beta directory.
    d. Finally try among the grammars defined in the MBSgrammars_STD.text file located in the ~beta directory.

The first grammar found in this sequence will be used. The format of these grammar specification files are:

```
[[
-- INCLUDE 'filename of grammar'
-- INCLUDE 'filename of grammar'
... etc. ...
-- INCLUDE 'filename of grammar'
]]
```

The filename of the grammar should not include the -meta suffix. If we assume that your new grammar mylang is located in the ~you/mylang directory, you can specify the grammar by inserting the following line in one of the grammar specification files:

```
-- INCLUDE '~you/mylang/mylang'
```

In order to have your new grammar being usable by the grammar-based tools, you therefore either have to have the grammar files located in the current directory, or have the grammar specified in one of the above mentioned grammar specification files. Since the grammarsDEMO.text and grammarsSTD.text files are located in the ~beta directory, these files will not usually be modifyable by the normal users. You will therefore most often be specifying your grammar in one of the .MBSgrammars.text files mentioned above.

> Important note: In this release, it is necessary to specify the grammar also in the file
>
> MBSgrammarsExt.text
>
> to make the grammar usable for the grammar-based tools (Sif, Freja, Frigg, Valhalla).

Using the Pretty-printer and the Hyper-structure Editor

After having specified your grammar, you will be able to use the new grammar with the pretty-printer and the hyper-structure editor.

In order to make a pretty-print of the mylang program on the file tst.mylang, the pp tool must be used:

```
pp tst.mylang > tst.pp
```

This will pretty-print the file tst.mylang (or tst.ast) and deliver the pretty-print on the file tst.pp. pp accepts two options:

- -p ppSpecFile: name of a pretty-print specification to be used for this pretty-print
- -d ppDepth: the depth of the AST to be pretty-printed. Can be used for making abstract interface descriptions.

The grammar is now also ready for use by the hyper-structure editor Sif in the Mjolner tool. Usage of mylang in Sif is described in detail in the Mjolner manual [MIA 99-34]. However, in order to be able to utilize the automatic contraction facilities of Sif, the grammar specification needs to be augmented with one additional section, namely definition of the contractionCategories property. This property is specified at the very beginning of the grammar specification (in the form of a fragment property). As an example, we can define the contractionCategories property for the mylang grammar:

```
contractioncategories
        module
        import
        if
        while;
-- mylang: aGrammar: metagrammar --
grammar mylang:
rule
<module>        ::= 'module' <module:id> ';' <importOpt>
                    'begin' <statement> 'end';
<id>            ::= <nameDecl>;
<importOpt>     ::? <import>;

etc. as previously
```

In this example, we have specified the rules module, import, if and while as the contractions categories. This implies, that Sif automatically will contract these parts when displaying a program derived from mylang. Please refer to the Sif.

Please note, that we in this example shows the entire file, including the fragment syntax needed:

```
-- mylang: aGrammar: metagrammar --
```

Note, that aGrammar and metagrammar are mandatory names, whereas mylang can be freely chosen.

Modifying the Pretty-print Specification

If you want to modify the specification, then modify the file: mylang-pretty.pgram either by means of a text editor or the pretty-print specification language-editor. After modifying the pretty-print specification morepretty is used again to create new tables for the editor. Note that if the grammar is modified, then the file mylang-pretty.pgram must be updated accordingly, e.g. a new production in the grammar might require a new production in the pretty-print specification grammar. In order to be able to modify the pretty-print specification the user must know the pretty-print algorithm.

The Pretty-print Algorithm

The pretty-print algorithm is an adaptive pretty-printer, i.e. the pretty-printer always tries to print as much as possible on each line. If the pretty-printed text cannot fit on one line, the pretty-print specification tells where to break the line. For each production in the grammar, there is a specification of how to pretty-print that production. Furthermore it is indicated where to associate a possible comment.

The pretty-printer algorithm takes as input a stream of tokens. A token is a text string, a break or a block.

- a text string is a sequence of characters
- a break specifies, where a line may be broken
- a block is specified by means of two delimitor tokens: [and].

A stream is defined by

- a text string is a stream and
- if s1, s2, ... sn is a stream then [s1 <break> s2 <break> .. <break> sn] is also a stream.

The algorithm gives a text string as output. The text string has a fixed maximal width. The block concept is used in the following way: the algorithm tries to break onto different lines as few blocks as possible according to the maximal width. If a block cannot fit on one line the block has to be broken. The breaks are used to specify where to break the block. A break has a length and an indention. The length specifies the number of single space characters to be written if the block is not broken. The indention specifies the number single space characters to be written (relative to the surrounding block) at the beginning of a new line if the block is broken.

There exist two types of blocks: consistent and inconsistent blocks. If a consistent block cannot be written on one line the substreams of the block will be written on separate lines. I.e. all breaks in the block will imply a line break. If an inconsistent block cannot be written on one line the substreams are only written on a separate line if they cannot be written on the rest of the current line.

The reason for the distinction between consistent and inconsistent blocks is that one might prefer:

```
if <<condition:exp>> then
       <<thenPart:statement>>
else
       <<elsePart:statement>>
endif
```

to

```
if <<condition:exp>> then <<thenPart:statement>> else
<<elsePart:statement>> endif
```
and
```
import a,b,
       c
```
to[4]
```
import a,
       b,
       c
```

The Pretty-print Specification

The pretty-printer is based on the algorithm just described, but because the internal representation of a document is an abstract syntax tree, the input stream to the pretty-printer algorithm must be generated from the AST. This step is called unparsing. The structure of an AST is described by means of a grammar. The pretty-print specification defines for each production in the grammar how it shall be unparsed.

Only those productions, that result in nodes in the AST, has a corresponding specification. The productions are constructor and list productions as described previously.

The grammar for pretty-print specifications is described in appendix 2.

The pretty-print specification of a constructor production has the following form:
```
<Constructor> ::= <ProductionName:nameAppl> '=' <Stream:ItemList>;
<ItemList>    ::* <Item>;
<Item>        ::| <Terminal> | <NontTerm> | <Break>
                | <Block> | <CommentPlace>
```

The ProductionName is the name of the syntactic category on the left side of the corresponding production in the language grammar. The items in the stream can be terminals, nonterminals, breaks, blocks or comment places:

- A terminal can be a terminal symbol from the corresponding production. This is specified by T:n, where n is the terminal number in the production. A terminal can also be an explicit terminal symbol: abc.
- A nonterminal is referring to the nonterminal symbol in the corresponding production or, if the nonterminal has been expanded, to the underlying sub-AST. Like terminals the nonterminals are numbered (N:n).
- A break is specified by $<length>,<indention>. The meaning of length and indention is described above. The default break $$ has length 0 and indention 1.
- A consistent block is specified by [c ...] and an inconsistent block is specified by [i ...].
- The comment place character * is used to indicate where to pretty-print the comment that may be associated with the node (corresponding to the production) in the AST. A comment place character shall be positioned after a terminal symbol and cannot be used in a list production.

The pretty-print specification of a list production has the following form:
```
<ListProd> ::= <ProductionName:nameAppl> '=' '(' <ListSpec> ')';
<ListSpec> ::= <Beginning:ItemList>
               '{' <BlockType> <Separator:ItemList> '}'
               <Ending:ItemList>
```

The list production specifies what is going to be pretty-printed before the list, between the list elements and after the list. A list is always surrounded by a block. Note the the block delimitors for lists are { and }.

The pretty-print specification must always start with a fragment form soecification (similar to the grammar specification). For a pretty-print specification the syntax is:
```
-- name: prettyprint: prettyprint --
```

where name must be the name chosen for this grammar.

An Example of Modifying the Pretty-print Specification

As mentioned the makepretty script generates a default pretty-print specification. This section illustrates the default pretty-print specification of the sample grammar and how the specification can be improved to obtain a more "pretty" pretty-printing.

The default pretty-print specification for mylang (mylang-pretty.pgram) might looks like[5]:
```
-- mylang: prettyprint: prettyprint --
PrettyPrintScheme mylangSpec
for mylang:
module  =  T:1 $$ * $$ N:1 $$ T:2 $$ N:2 $$ T:3 $$ N:3 $$ T:4;
id      =  N:1;
importOpt       =  N:1 ;
import  =  T:1 $$ * $$ N:1 $$ T:2;
nameList        =  ( {c T:1 $$ } );
statement       =  N:1 ;
if      =  T:1 $$ * $$ N:1 $$ T:2 $$ N:2 $$ T:3 $$ N:3 $$ T:4;
while   =  T:1 $$ * $$ N:1 $$ T:2 $$ N:2 $$ T:3;
statementList   =  ( {c T:1 $$ } );
exp     =  N:1 ;
text    =  N:1;
number  =  N:1;
expProcCall     =  N:1;
procCall        =  N:1 $$ T:1 $$ * $$ T:2
```

As can be seen the default specification uses default breaks; there are no blocks except in lists; the block type of a list is consistent and only the list separator is specified; comments are only associated with constructor productions and always after the first terminal symbol.

Let us look at the following source file:
```
-- test: module: mylang --
module pip;
(* Copyright 1992*)
(* Mjølner Informatics *)
import dyt, baat, olsen; (* some imported operations *)
begin
  while olsen() do
     if (* the test condition will be filled out later *) <<condition:exp>>
     then
        dyt()
     else if <<condition:exp>> then baat() else <<elsePart:statement>> endif
     endif;
     <<statement>>
  end
end
```

Using the default pretty-printer specification as generated by the makepretty tool (see above) results in the following pretty-print[6]:
```
-- test: module: mylang --
```

```
module (* Copyright 1992 *)
(* Mjølner Informatics *) pip ; import
(* some imported operations *) dyt, baat, olsen ; begin while olsen ( ) do
if
(* the test condition will be filled out later *)
<<condition: exp>>
then
dyt
(
)
else
if
<<condition: exp>>
then
baat
(
)
else
<<elsePart: statement>>
endif
endif;
<<statement>> end end
```

Because there are no blocks in the specification, the pretty-printer tries to write as much as possible on each line as can be seen on the first three lines of the program. Note that no blocks in the specification has the same effect as one surrounding inconsistent block. After the third line each item is written on a separate line. This is caused by the statementList, that introduces a consistent block of statements.

This pretty-printing is certainly not very pretty, but only a few modifications of the specifiation improves the layout drastically. Consider the following modified specification:

```
-- mylang: prettyprint: prettyprint --
PrettyPrintScheme mylangSpec
for mylang:
module  =  [c [i T:1 $$ N:1 T:2 ] $$ * $$ N:2 $$ [c T:3 $1,2 N:3 $$ T:4] ];
id      =  N:1;
importOpt       =  N:1 ;
import  =  [i T:1 $$ N:1 T:2 $$ *];
nameList        =  ( {i T:1 $$ } );
statement       =  N:1 ;
if      =  [c [i T:1 $$ * $1,3 N:1 $$ T:2 ] $1,3 N:2 $$ [i T:3 $1,3 N:3] $$ T:4 ];
while   =  [c [i T:1 $$ * $$ N:1 $$ T:2 ] $1,3 N:2 $$ T:3];
statementList   =  ( {c T:1 $$ } );
exp     =  N:1 ;
text    =  N:1;
number  =  N:1;
expProcCall     =  N:1;
procCall        =  N:1 T:1 T:2 $$ *
```

The test program now looks much nicer:

```
-- test: module: mylang --
module pip;
(* Copyright 1992 *)
(* Mjølner Informatics *)
import dyt, baat, olsen; (* some imported operations *)
begin
  while olsen() do
     if (* the test condition will be filled out later *)
        <<condition: exp>> then
        dyt()
     else
        if <<condition: exp>> then
           baat()
        else <<elsePart: statement>>
        endif
     endif;
     <<statement>>
  end
end
```

The following changes have been made: In the module production some blocks have been introduced: one that surrounds the whole production, one that surrounds the header of the module and one that surrounds the body of the module. It is important that the block types of the first and the last block are consistent. The break between the module name and the ":" have been removed. The comment character have been moved. The break between the begin keyword and the <statement> has been changed to an indention of two characters.

In the nameList production, the block type has been changed to inconsistent. The import production is surrounded by an inconsistent block in order to "overload" the consistent block of the start production. In the if and while productions, blocks has been introduced and the indention has been changed. In the procCall production, the breaks has been removed.

The reader is recommended to try to understand the effect of these modifications in order to gain insight into the workings of the pretty-print specification.

---

[4] Naturally, we are assuming that the line width is not sufficient to have the entire import a, b, c on one single line

---

[5] This default pretty-print speficication is subject to changes. The default pretty-print specification on your system might differ from the one shown here. Especially will all construction nonterminals have consistent blocks surrounding their right-hand pretty-print specifications.

---

[6] Since the default pretty-print specification might differ on your system, the same applies for this pretty-print example.

Generating a Metaprogramming Interface

Format of Source Files

The source files to be read by the different grammar tools (e.g. pp and sif) must all start by giving a specification of the fragment form (similar to grammar specifications and pretty-printer specifications).

The fragment form syntax for source files is:

```
-- name: category: grammar --
```

where grammar be the name for the grammar for this source file. Category must be the name of a construction nonterminal in the grammar, and finally name is the name chosen for this fragment form (mostly not significant). If ': grammar' is omitted, the BETA grammar is assumed.

Please note, that it is important that category is the name of a construction nonterminal, i.e. a nonterminal specified by a construction rule:

```
category ::= ...;
```

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Metaprogramming System

Fragment and AST Properties

The metaprogramming system enables associating properties with each fragment and with the individual nodes in an AST. The fragment properties are defined as part of the fragment syntax (e.g. the ORIGIN and INCLUDE properties). The AST properties may be attached to the nodes by metaprogramming tools.

The properties are defined as instances of the propertyList pattern (defined in the property fragment). Properties are lists of (name, parameterList) pairs. Name may be any text string, and parameterList is a list of values, where each value may be an integer, a textstring or a name (also a textstring).

The attributes of propertyList are: addProp, findProp, deleteProp, scanProp and getProp.

The fragment properties are available through the prop attribute of the fragment pattern. The AST properties may be accessed through the following attributes of the AST pattern: setCommentProp, getCommentProp and hasCommentProp. SetCommentProp makes it possible to associate a propertyList with an AST, and getCommentProp makes it possible to gain access to the propertyList associated with an AST, and finally hasCommentProp is used for testing whether a propertyList is currently associated with an AST.

Please note, that the current implementation of properties of ASTs implies that the properties replaces any comments, which might have been associated with the AST.

The Metaprogramming System Libraries

The metaprogramming system consists of a number of fragments: astlevel, applgram, findgrammar, property, metagrammarcfl and metagramsemAtt:

- astlevel.bet contains the metaprogramming interface to the ASTs and fragments, as described above.
- applgram.bet contains one single pattern (subpattern of treelevel), which defines the proper initializations etc. for utilizing the treelevel interface for any given grammar.
- findgrammar.bet contains the grammarFinder used in the Mjølner BETA System (i.e. findgrammar seeks for grammars the places where the Mjølner BETA System locates its grammars).
- metagrammarcfl.bet contains the context-free level interface for the metagrammar, thus defining the interface to any grammar information, maintained by the Mjølner BETA System. metagrammarcfl is used by tools that needs to know about the structure of the grammar for the ASTs they are working on (e.g. the metaGrammarcfl interface is used by the Sif editor to find out about the valid derivations of a given nonterminal).
- metagramsematt.bet contains the semantic level interface for the metagrammar, and defines the interface to the available semantic information for grammars (e.g. options).

Appendix A: The Metagrammar

See doc/grammars/metagrammar.html

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Appendix B: The Pretty-print Specification Grammar

See doc/grammars/prettyprint.html

Appendix C: Expression Grammar Example

This appendix contains an example of use of the metaprogramming system for generating an expression calculator, enabling the user to enter expressions from the keyboard, which are then parser and the resulting AST is then evaluated by an interpreter (actually a recursive traversal of the AST, eveluating sunexpressions), and the calculated result is then printed on the screen. To give an impression of the application, the following is an example of an execution of the calculator (the underlined text is entered by the user Ñ expreval is the name of the calculator):

```
expreval
Eval? 3+4
7
Eval? (3+4)*(20+2)/4
38
Eval? (3+4
PARSE-ERRORS
#   1 (3+4
# ****** ^
#  Expected symbols:  / mod ) * +
Eval? 22 mod 5
2
Eval? .
```

This application consists of five files:

- expr-meta.gram: Contains the grammar specification for the valid expressions.
- expr-pretty.pgram: Contains the pretty-printer specification.
- exprcfl.bet: Contains the generated context-free level interface.
- exprsematt.bet: Contains the additional semantic level interface. Primerily the eval routine.
- expreval.bet: Contains the initialization, and keyboard and screen handling code.

We will in the following present the five files along with a few comments on the important aspects of the particular file.

The Expression Grammar

This file contains the grammar that are used to check the syntax of the expressions of the calculator. The grammar is a fairly ordinary expression grammar, except that assignment statements are part of the legal syntax of the calculator, making the use of variables valid in the calculator. Please note the declaration of the substanceSlot and the attribute part.

```
--- expr: AGrammar: metagrammar ---
Grammar expr:
option
    string = unused
    substanceSlot = dcAtt
Rule
  <stat> ::| <assignment> | <evalStatement> | <quit>;
  <assignment> ::= <name : nameDecl> '=' <expression>;
  <evalStatement> ::= <expression>;
  <quit> ::= '.';
  <expression> ::| <Term> | <addExpression>;
  <term> ::| <factor> | <multExpression>;
  <factor> ::| <number> | <bracketExpression> | <variable>;
  <bracketExpression> ::= '(' <expression> ')';
  <MultExpression> ::= <Operand1 : Term> <MultOperator> <Operand2 : Factor>;
  <AddExpression> ::= <Operand1 : Expression> <AddOperator> <Operand2 : Term>;
  <MultOperator> ::| <TimesOp> | <DivOp> | <ModOp>;
  <AddOperator> ::| <PlusOp> | <MinusOp>;
  <Number> ::= <Const>;
  <Variable> ::= <NameAppl>;
  <TimesOp> ::= '*';
  <DivOp> ::= '/';
  <ModOp> ::= 'mod';
  <plusOp> ::= '+';
  <minusOp> ::= '-'
attribute
  (* the following definitions will trigger the generator to make
   *  semantic attribute slots for the generated context free level
   *)
  <expression> : 0
```

The Expression Pretty-Print Grammar

This file contains the pretty-pring grammar, used by the calculator. Strictly speaking this pretty-print grammar is not used by the calculator.

```
--- expr : prettyprint : prettyprint ---
PrettyPrintScheme exprSpec
for expr:
stat    =  N:1 ;
assignment      = [c  N:1 $1,0 T:1 $1,0 * $1,2 N:2];
evalStatement   =  N:1;
quit    =  T:1 $1,0 *;
expression      =  N:1 ;
term    =  N:1 ;
factor  =  N:1 ;
bracketExpression       = [c  T:1 $1,0 * $1,2 N:1 $1,0 T:2];
MultExpression  = [c  N:1 $1,2 N:2 $1,2 N:3];
AddExpression   = [c  N:1 $1,2 N:2 $1,2 N:3];
MultOperator    =  N:1 ;
AddOperator     =  N:1 ;
Number  =  N:1;
Variable        =  N:1;
TimesOp =  T:1 $1,0 *;
DivOp   =  T:1 $1,0 *;
ModOp   =  T:1 $1,0 *;
plusOp  =  T:1 $1,0 *;
minusOp =  T:1 $1,0 *
```

The Expression Context-Free Level Interface

This file contains the generated context-free level interface. Please note the effects of the substanceSlot and attribute part specifications in the grammar. The init routine only contains initializations that can be ignored.

```
ORIGIN '~beta/mps/astlevel'
--- astInterfaceLib: attributes---
expr: TreeLevel
  (# stat: cons
       (# <<SLOT statAttributes: attributes>> #);
     expression: cons
       (# <<SLOT expressionAttributes: attributes>> #);
     term: expression
       (# #);
     factor: term
       (# #);
     MultOperator: cons
       (# #);
     AddOperator: cons
       (# #);
     assignment: stat
       (# getname: getson1(# #);
          putname: putson1(# #);
          getexpression: getson2(# #);
          putexpression: putson2(# #);
       exit 2
       #);
     evalStatement: stat
       (# getexpression: getson1(# #);
          putexpression: putson1(# #);
       exit 3
       #);
     quit: stat
       (# exit 4 #);
     bracketExpression: factor
       (# getexpression: getson1(# #);
          putexpression: putson1(# #);
       exit 8
       #);
     MultExpression: term
       (# getOperand1: getson1(# #);
          putOperand1: putson1(# #);
          getMultOperator: getson2(# #);
          putMultOperator: putson2(# #);
          getOperand2: getson3(# #);
          putOperand2: putson3(# #);
       exit 9
       #);
     AddExpression: expression
       (# getOperand1: getson1(# #);
          putOperand1: putson1(# #);
          getAddOperator: getson2(# #);
          putAddOperator: putson2(# #);
          getOperand2: getson3(# #);
          putOperand2: putson3(# #);
       exit 10
       #);
     Number: factor
       (# getConst: getson1(# #);
          putConst: putson1(# #);
       exit 13
```

```
        #);
      Variable: factor
        (# getNameAppl: getson1(# #);
           putNameAppl: putson1(# #);
        exit 14
        #);
      TimesOp: MultOperator
        (# exit 15 #);
      DivOp: MultOperator
        (# exit 16 #);
      ModOp: MultOperator
        (# exit 17 #);
      plusOp: AddOperator
        (# exit 18 #);
      minusOp: AddOperator
        (# exit 19 #);
      grammarIdentification::<
        (# do 'expr'->theGrammarName #);
      version::<
        (# do -1->value #);
      suffix::<
        (# do '.text'->theSuffix #);
      maxproductions::<
        (# do 19->value #);
      dcAtt: @
        <<SLOT dcAtt: descriptor>>;
      init::<
        (# ... #);
   #)
```

The Expression Semantic Level Interface

This file contains the semantic level interface, written for the calculator. Please note the utilization of the SLOTs, generated as the result of the substanceSlot and attribute part of the grammar.

```
ORIGIN 'exprcfl';
INCLUDE '~beta/containers/hashTable'
--- expressionAttributes: attributes ---
eval:
  (# value: @integer ;
     n: ^number;
     cnst: ^const;
     m: ^multExpression;
     a: ^addExpression;
     anAst: ^ast;
     be: ^bracketExpression;
     e1,e2: ^expression;
     var: ^variable;
     na: ^nameAppl;
  do (if symbol
      //bracketExpression then
         this(expression)[] -> be[]; be.getExpression -> e1[]; e1.eval -> value
      //multexpression then
         this(expression)[] -> m[];
         m.getOperand1 -> e1[]; m.getoperand2 -> e2[];
         m.getMultOperator -> anAst[];
         (if anAst.symbol
          //timesop then e1.eval * e2.eval -> value
          //divop then e1.eval div e2.eval -> value
          //modOp then e1.eval mod e2.eval -> value
         if);
      //addexpression then
         this(expression)[] -> a[];
         a.getOperand1 -> e1[]; a.getOperand2 -> e2[];
         a.getAddOperator -> anAst[];
         (if anAst.symbol
          //plusOp then e1.eval + e2.eval -> value
          //minusOp then e1.eval - e2.eval -> value
         if)
      //number then this(expression)[]->n[];
                    n.getConst->cnst[]; cnst.getValue -> value
      //variable then this(expression)[] -> var[];
         var.getnameAppl -> na[];
         (# e: ^dcAtt.symbolTable.element
         do na[] -> dcAtt.symbolTable.findKey -> e[];
            (if e[]//none then
                na.getText -> screen.putText;
                ' is not declared ' -> screen.putLine;
             else e.e.eval -> value
            if);
         #);
     if)
  exit value
  #)

--- dcAtt: descriptor ---
(# symbolTable: @hashTable
     (# element::< (# id: ^lexemText; e: ^expression #);
        hashFunction::<
          (# t: ^text
          do e.id.getText -> t[];
             t.scan(# do (ch->ascii.lowCase)+133*value -> value #);
          #);
        equal::<
          (# equalText:
               (# t1,t2: ^text enter (t1[],t2[]) exit t1[] -> t2.equalNCS #)
          do (left.id.getText,right.id.getText) -> equalText -> value
          #);
        findKey:
          (# e: @element; found: ^element
          enter e.id[]
          do scan(# where::< (# do (e[],current[]) -> equal -> value #)
                 do current[] -> found[] #)
          exit found[]
          #);
     #);
   init: (# do symbolTable.init #);
#)

------ statAttributes: attributes ------
run:
  (# expr: ^expression;
     eval: ^evalStatement;
     let: ^assignment;
     elm: ^dcAtt.symbolTable.element
  do (if symbol
      //assignment then
         this(stat)[] -> let[];
         &dcAtt.symbolTable.element[] -> elm[];
         let.getName -> elm.id[];
         let.getExpression -> elm.e[];
         elm[] -> dcAtt.symbolTable.insert;
      //evalStatement then
         this(stat)[] -> eval[];
         eval.getExpression -> expr[];
         expr.eval -> screen.putInt;
         screen.newLine
      //quit then (normal,'') -> stop
     if);
```

The Expression Evaluator Program

This file contains the initialization of the metaprogramming system and the handling of the keybroard and screen. Please note the use of the parser, the handling of parse errors, and the evaluation of the ASTs, resulting from successful parsing of the input.

```
ORIGIN 'exprcfl';
INCLUDE 'exprsematt'
--- program: descriptor ---
(# (* This is a small demo-program of how to use the MetaProgrammingSystem.
    * The program implements a small desc-calculator a la dc in unix.  The
    * grammar for expressions is on the file expr-meta.gram.  The generated
    * context free level is on exprCfl.  Exprsematt contains semantic
    * attributes for expr.
    *)
   ast: @astinterface;
   expr: @ast.expr; (* the cfl of the grammar *)
   exprFragment: ^ast.fragmentForm;
   evalString: ^text;
   stat: ^expr.stat;
   ok: @boolean;
   btabFile: ^text;
do ast.astLevelInit; (* initialize astlevel *)
   expr.init;        (* and the context free level of the generated grammar *)
   'expr-parser' -> btabFile[];
   ast.parserFileExtension->btabFile.puttext;
   btabFile[] -> expr.parser.initialize; (* and the parser *)
   expr[] -> ast.newFragmentForm -> exprFragment[]
   (* create a fragmentform which can contain the asts *);
   cycle
   (# do
      'Eval? ' -> screen.putText;
      keyBoard.getLine -> evalString[]; (* read a string from keyboard *)
      evalString.newLine; (* add a newline to the string *)
      0 -> evalString.setPos;  (* reset evalString to start *)
      (1,evalString[],screen[],exprFragment[]) -> expr.parser -> ok;
      (* 1: goalSymbol,
       * evalString: input,
       * exprFragment: the fragmentform to contains the asts
       *)
      (if ok
       //false then
          'PARSE-ERRORS' -> screen.putLine;
          0 -> evalString.setPos; (* reset evalString to start *)
          (evalString[],screen[]) -> expr.parser.ErrorReport;
       else  (* there was no parse-errors *)
          exprFragment.root[] -> stat[];
          (* the parser returns the root of the parsed ast in fragment.root *)
          stat.run;
      if);
   #)
```

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Astlevel Interface

```
ORIGIN '~beta/basiclib/betaenv';
LIB_DEF 'mpsastlevel' '../lib';
INCLUDE '~beta/sysutils/pathhandler'
        '~beta/containers/hashTable'
        'property';
BODY 'private/astPrivate';
(*
 * COPYRIGHT
 *       Copyright (C) Mjolner Informatics, 1986-93
 *       All rights reserved.
 *)
-- LIB: Attributes --
(* This fragment contains the tree level interface to the abstract syntax trees
 * and interface to the fragment library.
 *) (* idx: 2 *)
astInterface:
  (# <<SLOT astInterfaceLib:Attributes>>;
     yggdrasilVersion:
       (* describes the version of THIS(astInterface) *) (#  exit 'v5.2' #);
     ast:
       (* Basic class, which is the super-pattern of all patterns describing
        * abstract syntax trees.  Ast's are stored in a special purpose format
        * which is internally allocated in a repetition.
        *)
       (# <<SLOT astLib:Attributes>>;
          frag: (* where THIS(ast) belongs *)
            ^fragmentForm;
          symbol: (* the nonterminal symbol of THIS(ast) *)
            (# lab: @integer
            enter
               (# enter lab ... #)
            exit
               (# ...
               exit lab
               #)
            #);
          father:
            (* return the father of THIS(ast) or NONE, if we are in the root *)
            (#
            exit (# as: ^ast ... exit as[] #)
            #);
          nextBrother:
            (# brother: ^ast
            ...
            exit brother[]
            #);
          sonNo:
            (* returns the sonNo of THIS(ast) in the father node *)
            (# inx,finx,son: @integer
            ...
            exit son
            #);
          kind:
            (* return the subCategory of ast this node is *)
            (#
            exit (# kind: @integer ... exit kind #)
            #);
          equal:
            (* determines if THIS(ast) and another ast-reference points to the
             * same ast. This operations is to be used instead of testing
             * reference-equivalence directly: instead of testing
             *      a1,a2: ^ast;
             *      (if a1[]=a2[] then ... if);
             * you must test
             *      (if (a1[]->a2.equal) then ... if)
             *)
            (# comparedAst: ^ast;
            enter comparedAst[]
            exit (# eq: @boolean ... exit eq #)
            #);
          nearestCommonAncestor:
            (* find the nearest common ancestor of THIS(ast) and the ast
             * entered
             *)
            (# testAst,nca: ^ast; testSonNo,mySonNo: @integer
            enter testAst[]
            do ...
            exit
               (nca[],testSonNo,mySonNo)
                 (* TestSonNo is the number of the son where
                  * father-chain of the entered ast differs.  MySonNo is
                  * the number of the son where father-chain THIS(ast)
                  * differs
                  *)
            #);
          lt:
            (* Determine whether the ast entered or THIS(ast) will be met first
             * in a preorder traversal of the tree. Return true if the ast
             * entered comes first
             *)
            (# testAst: ^ast; testSonNo,mySonNo: @integer
            enter testAst[]
            do ...
            exit (testSonNo < mySonNo)
            #);
          putAttribute:
            (* save an integer value as an attribute to THIS(ast) *)
            (# val,attributNo: @integer;
            enter (val,attributNo)
               ...
            #);
          getAttribute:
            (* get an integer-valued attribute *)
            (# attributNo,val: @integer;
            enter attributNo
               ...
            exit val
            #);
          putNodeAttribute:
            (* save an ast-reference as an attribute to THIS(ast) *)
            (# val: ^ast; attributNo: @integer
            enter (val[],attributno)
               ...
            #);
          getNodeAttribute:
            (* get an ast-reference - valued attribute *)
            (# attributNo: @integer; val: ^ast
            enter attributno
               ...
            exit val[]
            #);
          putSlotAttribute:
            (* save an integer value as an attribute to THIS(ast) *)
            (# val,attributNo: @integer;
            enter (val,attributNo)
               ...
            #);
          getSlotAttribute:
```

```
  (* get an integer-valued attribute *)
  (# attributNo,val: @integer;
  enter attributNo
     ...
  exit val
  #);
```
putSlotNodeAttribute:
```
  (* save an ast-reference as an attribute to THIS(ast) *)
  (# val: ^ast; attributNo: @integer
  enter (val[],attributno)
     ...
  #);
```
getSlotNodeAttribute: `(* get an ast-reference - valued attribute *)`
```
  (# attributNo: @integer; val: ^ast
  enter attributno
     ...
  exit val[]
  #);
```
addComment:
```
  (* add a commment to THIS(ast). Overwrites existing comments *)
  (# l: ^lexemText;
  enter l[]
     ...
  #);
```
getComment:
```
  (* return the comment associated with THIS(ast) *)
  (#
  exit (# as: ^ast ... exit as[] #)
  #);
```
getNextComment:
```
  (* This is a special operation that only should be used by the
   * prettyprinter. A comment c for at subAST is organized as
   * follows:
   * c = c1 c2 ... cn, where the positions of the ci's are:
   * c1 son1 c2 son2 c3 .... cn sonn cn+1
   * each ci can be further divided into a subsequence of comments
   * that must be prettyprinted separately.
   * NextComment scans all subcomments one of the time.
   * A call of nextComment returns the next subcomment in the
   * sequence of comments belonging to THIS(ast).
   *
   * if n is -2 the whole comment is empty and subcomment is none
   * if n is -1 the subcomment is empty and 'subcomment' is none
   * if n is 0 there is only one comment between the two sons or
   *           it is the last subcomment
   * if n is 1 there are more than one subcomment and 'subcomment'
   *           contains the current one
   * if n is 2 the whole comment has been scanned, 'subcomment'
   *           contains the last one
   *
   * The representation of the comment looks like this:
   * ' xxx 21 yyy 2 zzz 21 aaa 2'
   *
   * where 1 (ascii 1) is the separator between the subcomments and
   * 2 (ascii 2) is the subsequence separator
   *
   * and it should be prettyprinted like this:
   * [* xxx *] son1 [* yyy *] [* zzz *] son2 [* aaa *]
   *)
  (# subcomment: ^text; n: @integer;
  do (if getNextCommentComponent[]=NONE then
         &|getNextCommentOp[]->getNextCommentComponent[]
     if);
     getNextCommentComponent->(subcomment[],n);
  exit (subcomment[],n)
  #);
```

```
getNextCommentComponent: (*private*)^|getNextCommentOp;
getNextCommentOp: (*private*)
  (# subcomment: ^text; n: @integer
  do ...
  exit (subcomment[],n)
  #);
insertSubcomments:
  (* This is a special operation that only should be used by the
   * editor Inserts the subcomments with index inx (1..n)
   * Subcomments must include subsequence separators.  THIS(ast)
   * must already have a comment.  An empty comment with separators
   * can be created using the prettyprinter.
   *)
  (# subcomments: ^text; inx: @integer
  enter (subcomments[],inx)
  do ...
  #);
setSubcomments:
  (* This is a special operation that only should be used by the
   * editor. Sets the subcomments corresponding to index inx (1..n)
   * Subcomments must include subsequence separators.  If
   * subcomments is empty, the existing subcomments at index inx
   * are deleted.  THIS(ast) must already have a comment.  An empty
   * comment with separators can be created using the
   * prettyprinter.
   *)
  (# subcomments: ^text; inx: @integer
  enter (subcomments[],inx)
  do ...
  #);
getSubcomments:
  (* This is a special operation that only should be used by the
   * editor. Returns subcomments with index inx (1..n), including
   * subsequence separators.  If the node has no comment or the
   * subcomments are empty the empty string is returned.
   *)
  (# subcomments: ^text; inx: @integer
  enter (inx)
  do ...
  exit subcomments[]
  #);
scanComments:
  (*
   * A comment c for at subAST is organized as follows:
   * c = c1 c2 ... cn, where the positions of the ci's are:
   * c1 son1 c2 son2 c3 .... cn sonn cn+1
   * Each ci can be further divided into comments that must be
   * prettyprinted separately.
   * ScanComment scans all subcomments one of the time
   * calling INNER for each subcomment.
   * 'current' contains the current subcomment with indexes
   * inx (1..n, the ci number) and subinx (1..n, the number in
   * the subsequence)
   *)
  (# current: ^text; inx,subinx: @integer
  do ...
  #);
insertSubcomment:
  (* Inserts subcomment with indexes inx and subinx
   * THIS(ast) must already have a comment.
   * An empty comment with separators
   * can be created using the prettyprinter.
   *)
  (# subcomment: ^text; inx,subinx: @integer
  enter (subcomment[],inx,subinx)
  do ...
  #);
setSubcomment:
  (* Sets subcomment with indexes inx and subinx,
   * If subcomment is empty, the existing subcomment is deleted.
   * THIS(ast) must already have a comment.
   * An empty comment with separators
   * can be created using the prettyprinter.
   *)
  (# subcomment: ^text; inx,subinx: @integer
  enter (subcomment[],inx,subinx)
  do ...
  #);
getSubcomment:
  (* Returns subcomment with indexes inx and subinx,
   * if the node has no comment or the subcomment is empty
   * the empty string is returned
   *)
  (# subcomment: ^text; inx,subinx: @integer
  enter (inx,subinx)
  do ...
  exit subcomment[]
  #);
hasComment:
  (* tells if there is a comment associated with THIS(ast) *)
  (# has: @boolean ... exit has #);
hasCommentProp:
  (#
  exit (typeOfComment = 17)
  #);
getCommentProp:
  (# prop: ^propertyList;
  do ...
  exit prop[]
  #);
setCommentProp:
  (# prop: ^propertyList;
  enter (prop[])
  do ...
  #);
typeOfComment:
  (* sets or returns the type of THIS(comment) *)
  (# type: @integer
  enter
     (#  enter type ... #)
  exit
     (# ...
     exit type
     #)
  #);
dump:< (* do a nearly human readable dump of THIS(ast) to a stream *)
  (# level: @integer; dmp: ^stream;
  enter (level,dmp[])
     ...
  #);
copy: protect
  (* make a copy of THIS(ast) with all sons. The enter-parameter
   * tells which fragmentForm the copy shall belong to
   *)
  (# copyFrag: ^fragmentForm
  enter copyFrag[]
  exit
     (# as: ^ast
     ...
     exit as[]
     #)
  #);
```

```
   match:<
     (* pattern-matching. Returns true if the entered ast match
      * THIS(ast)
      *)
     (# doesMatch: @boolean; treeToMatch: ^ast
     enter treeTomatch[]
        ...
     exit doesMatch
     #);
   hasSemanticError:
     (* returns true if THIS(ast) has semantic errors *)
     (#
     enter
        (# b: @boolean
        enter b
        do (b,1,1)->frag.a[index].%PutBits
        #)
     exit (1,1)->frag.a[index].%GetBits
     #);
   semanticError: (* if hasSemanticError, this is the errorNumber *)
     (#
     enter
        (# errorNumber: @integer
        enter errorNumber
        ...
        #)
     exit
        (# errorNumber: @integer;
        ...
        exit errorNumber
        #)
     #);
   stopYggdrasil:< astException;
   astException: astInterfaceException
     (#
     do INNER astException;
        msg.newLine;
        ' index = '->msg.puttext;
        (index)->msg.putInt;
        ' symbol = '->msg.puttext;
        (symbol)->msg.putInt;
     #);
   <<SLOT astPrivateLib:Attributes>>;
   index:
     (* Private: architecture of an ast:
      *
      *           |      ....    |
      *           -----------------
      * index ->  |    prodno     |
      *           -----------------
      *           |  next brother | (if negative: -index to father)
      *           -----------------
      *           |   first son   | (for lexems: pointer to text)
      *           -----------------
      *           |first attribute|
      *           -----------------
      *           |     ....      |
      *
      *) @integer;
   copyPrivate:< (* Private *)
     (# theCopy: ^ast; theCopyInx: @integer; copyFrag: ^fragmentForm;
     enter copyFrag[]
        ...
     exit theCopyInx
     #);
do INNER
```

```
    #);
  expanded: ast
    (* this pattern describes all expanded ast *)
    (# <<SLOT expandedLib:Attributes>>;
       noOfsons:
         (* return the number of sons of THIS(expanded) *)
         (# sons: @integer;
         do ...
         exit sons
         #);
       get:
         (* get a son with a given son-number *)
         (# i: @integer;
         enter i
         exit (# as: ^ast ... exit as[] #)
         #);
       put:
         (* sets the entered ast to be a son of this son with a given
          * son-number
          *)
         (# i: @integer;
            s: ^ast;
            notSameFragment:< astException
              (* exception called if the entered ast is not in same fragment
               * as THIS(expanded)
               *)
              (#
              do INNER notSameFragment;
                 'Error in put. Inserted ast is not from same fragmentForm '
                   ->msg.putline;
              #);
         enter (i,s[])
         do ...
         #);
       scan:
         (* iterates over all sons *)
         (# current: ^ast; currentSonNo: @integer;
         do ...
         #);
       suffixWalk:
         (* make a preorder traversal of the tree with THIS(expanded) as
          * root. cutIf can be used to cut the traversal of some sub-ast's
          *)
         (# cutIf:<
              (# prod: @integer; toCut: @boolean
              enter prod
              do false->toCut; INNER
              exit toCut
              #);
            current: (* the ast-iterator *) ^ast;
         do ...
         #);
       suffixWalkforProd:
         (* make a preorder traversal of the tree with THIS(expanded) as
          * root.  Will only call INNER for ast's which have the symbol
          * 'prod'. cutIf can be used to cut the traversal of some sub-ast's
          *)
         (# scanCat:< ast;
            cutIf:<
              (# prod: @integer; toCut: @boolean
              enter prod
              do false->toCut; INNER
              exit toCut
              #);
            current: (* the ast-iterator *) ^scanCat;
            prod: @integer;
         enter prod
         do ...
         #);
       insert:
         (* insert an ast before a son with the given son-number. Must
          * externally only be called for lists
          *)
         (# i: @integer;
            s: ^ast;
            notSameFragment:< astException
              (* exception called if the entered ast is not in same fragment
               * as THIS(expanded)
               *)
              (#
              do INNER notSameFragment;
                 'Error in put. inserted ast is not from same fragmentForm '
                   ->msg.putline;
              #);
         enter (i,s[])
         do ...
         #);
       getson1:
         (* optimized version of getson1: (# exit 1 -> get #) *)
         (#
         exit (1->frag.a[index+1].%getShort)*2
                ->frag.indexToNode
         #);
       getson2: (#  exit 2->get #);
       getson3: (#  exit 3->get #);
       getson4: (#  exit 4->get #);
       getson5: (#  exit 5->get #);
       getson6: (#  exit 6->get #);
       getson7: (#  exit 7->get #);
       getson8: (#  exit 8->get #);
       getson9: (#  exit 9->get #);
       putson1: (# a: ^ast enter a[] do (1,a[])->put #);
       putson2: (# a: ^ast enter a[] do (2,a[])->put #);
       putson3: (# a: ^ast enter a[] do (3,a[])->put #);
       putson4: (# a: ^ast enter a[] do (4,a[])->put #);
       putson5: (# a: ^ast enter a[] do (5,a[])->put #);
       putson6: (# a: ^ast enter a[] do (6,a[])->put #);
       putson7: (# a: ^ast enter a[] do (7,a[])->put #);
       putson8: (# a: ^ast enter a[] do (8,a[])->put #);
       putson9: (# a: ^ast enter a[] do (9,a[])->put #);
       <<SLOT expandedPrivate:Attributes>>;
       dump::< (* Private *)
         (# do ... #);
       match::< (* Private *)
         (# do ... #);
       copyPrivate::< (* Private *)
         (#  do ... #);
    do INNER ;
    #);
  cons: expanded
    (* describes ast's derived from a constructor-production *)
    (# <<SLOT consLib:Attributes>>;
       delete:
         (* delete a son with the given son-number. Inserts an unExpanded
          * instead
          *)
         (# sonnr: @integer;
         enter sonnr
         do ...
         #);
       dump::< (* Private *)
         (#
         do 'CONS'->dmp.puttext; INNER
         #)
    #);
  list: expanded
    (* describes ast's derived from a list-production *)
    (# <<SLOT listLib:Attributes>>;
       sonCat:< ast;
       newScan: (* iterates over all sons *)
         (# predefined:< (# current: ^Ast enter current[] do INNER #);
            a: ^ast;
            current: ^sonCat;
            currentSonNo: @integer;
         do ...
         #);
       append:
         (* append a son to the list *)
         (# a: ^ast;  enter a[] do (noOfSons+1,a[])->insert;  #);
       delete: (* delete the son with the given son-number from the list *)
         (# sonnr: @integer;
         enter sonnr
         do ...
         #);
       dump::< (* Private *)
         (#
         do 'LIST'->dmp.puttext;
            INNER
         #);
    #);
  lexem: ast
    (* describes all ast's derived from one of the predefined
     * nonterminals
     *)
    (# <<SLOT lexemLib:Attributes>> #);
  lexemText: lexem
    (* describes all ast's having textual contents *)
    (# <<SLOT lexemTextLib:Attributes>>;
       getText: (* get the textual content *)
         (# t: ^text;
         do &text[]->t[]; ...
         exit t[]
         #);
       putText: (* set the textual content *)
         (# t: ^text;
         enter t[]
         do ...
         #);
       clear: (* clear the textual content *)
       ...;
       getChar: (* get a char *)
         (# index: @integer; ch: @char
         enter index
         do ...
         exit ch
         #);
       putChar: (* append a char to the textual content *)
         (# c: @char;
         enter c
         do ...
         #);
       curLength: (* sets or returns the length of the textual contents *)
         (# l: @integer
         enter
            (#
            enter l
            do ...
            #)
```

```
          exit
             (# ...
             exit l
             #)
          #);
        <<SLOT lexemTextPrivate:Attributes>>;
        dump::< (* Private *)
          (#
          do INNER ;
             '^'->dmp.put;
             getText->dmp.puttext
          #);
        copyPrivate::< (* Private *)
          (# theLexCopy: ^lexemText
          do theCopy[]->theLexCopy[];
             getText->theLexCopy.puttext;
             INNER
          #);
        match::< (* Private *)
          (# theMatchLexem: ^lexemText;
             theT,theMatchText: ^text;
          ...
          #)
    #);
  nameDecl: lexemText
    (* describes ast's derived from the predefined nonterminal <nameDecl> *)
    (# <<SLOT nameDeclLib:Attributes>>;
    exit prodNo.nameDecl
    #);
  nameAppl: lexemText
    (* describes ast derived from the predefined nonterminal <nameAppl> *)
    (# <<SLOT nameApplLib:Attributes>>;
    exit prodNo.nameAppl
    #);
  string: lexemText
    (* describes ast derived from the predefined nonterminal <string> *)
    (# <<SLOT stringLib:Attributes>> exit prodNo.string #);
  comment: lexemText
    (# <<SLOT commentLib:Attributes>>;
       commentType:
          (# type: @integer
          enter
             (#  enter type ... #)
          exit
             (# ...
             exit type
             #)
          #);
       copyPrivate::< (* Private *)
          (#  ... #);
    exit prodNo.comment
    #);
  const: lexemText
    (* describes ast derived from the predefined nonterminal <const> *)
    (# <<SLOT constLib:Attributes>>;
       putValue:
          (# val: @integer;
          enter val
          do ...
          #);
       getValue:
          (# val: @integer;
          do ...
          exit val
          #);
       dump::< (* Private *)
```

```
        (# do INNER ; '&'->dmp.put; getText->dmp.putText #);
      copyPrivate::< (* Private *)
        (# theCnCopy: ^const;
        do theCopy[]->theCnCopy[]; getText->theCnCopy.putText;
        #);
    exit prodNo.const
    #);
  unExpanded: ast (* describes ast's which have not been derived yet *)
    (# <<SLOT unExpandedLib:Attributes>>;
      nonterminalSymbol:
        (* describes which symbol, THIS(unExpanded) may derive.
         * THIS(unexpanded).symbol returns prodNo.unExpanded
         *)
        (#
        enter
           (# val: @integer
           enter val
           do (val,1)->frag.a[index+1].%putShort
           #)
        exit 1->frag.a[index+1].%GetSignedShort
        #);
      isSlot:
        (# b: @boolean
        enter (#  enter b do (b,0,1)->frag.a[index].%PutBits #)
        exit (0,1)->frag.a[index].%GetBits->b
        #);
      theSlot:
        (#
        enter
           (# o: ^slotDesc
           enter o[]
           ...
           #)
        exit
           (# sd: ^slotDesc
           ...
           exit sd[]
           #)
        #);
      sy: (* Private *) @integer;
      dump::< (* Private *)  (#  ... #);
      copyPrivate::< (* Private *)
        (#  do ... #);
    do prodNo.unExpanded->sy;
       INNER
    exit sy
    #);
  optional: unExpanded
    (* nodes in the tree which are empty (for optionals) are generated as
     * instances of 'optional'
     *)
    (# <<SLOT optionalLib:Attributes>>;
      dump::< (* Private *)
        (#  do '#'->dmp.put; INNER #);
    do prodNo.optional->sy
    #);
  slotDesc: ast
    (# <<SLOT slotDescLib:Attributes>>;
      name:
        (#
        enter
              (# t: ^text;
              enter t[]
              do ...
              #)
        exit
```

```
              (# c: ^comment
                ...
              exit c.getText
              #)
          #);
        category:
          (# f: ^unExpanded do father->f[];  exit f.nonterminalSymbol #);
        isBound: (* Private *) @boolean;
        node: (* Private *)
          (# father: @integer; ff: ^fragmentForm
          ...
          exit (father,ff[])
          #);
        copyPrivate::< (* Private *)
          (#
          do ...
          #);
        dump::< (* Private *)  (#  ... #);
     exit prodNo.slotDesc
     #);
   nonterminalSymbol:
     (* may be used to describe symbol numbers *)
     (# <<SLOT nonterminalSymbolLib:Attributes>>;
        symbol: @integer;
        predefined:
          (#
          exit (symbol <= 0)
          #);
        isLexem:
          (#
          exit ((symbol < - 2) and (symbol > - 7))
          #)
     enter symbol
     exit symbol
     #);
   (*-------------------- Fragment patterns ----------------------------*)
   formType: (#  exit 0 #);
   groupType: (#  exit 1 #);
   fragment:
     (* Abstract super-pattern for fragments.  A fragment has a unique
      * identification in form of a hierarchical name: '/foo1/foo2/.../foon';
      * '/foo1/foo2/...' is called the path of the fragment; 'foo' is called
      * the (local) name.  Only name needs to be stored since the path can be
      * fetched recursively from the father.
      *)
     (# <<SLOT fragmentLib:Attributes>>;
        name:
          (* exit the local name of THIS(fragment) *)
          (#  enter nameT[] exit nameT[] #);
        fullName: (* exit the full name (path/name) of THIS(fragment) *)
          (# n: ^Text ... exit n[] #);
        father:
          (#
          enter fatherR[]
          exit fatherR[]
          #);
        isOpen:
          (* returns true if THIS(fragment) has been opened *) @boolean;
        close:< (* Close THIS(fragment) *)
          (#
          do (if changed then markAsChanged if);
             INNER ;
             false->isOpen
          #);
        type: (* returns one of formType or groupType *)
          (#  exit fragType #);
```

```
init:<
  (#
  do &propertyList[]->prop[]; prop.init; false->changed; INNER
  #);
reset:<
  (* reset fragmentForm to be as if it has just been parsed up *)
  (# do INNER #);
modtime: (* time of last visit of file-representation *) @integer;
markAsChanged: protect
  (* call this when you want to save some changes *)
  (# ... #);
changed: @boolean;
checkDiskRepresentation:<
  (* called when it should be checked, if the disk-representation
   * of the fragment have been changed by another fragment.  If it
   * have, the internal state of the fragment is updated according to
   * the disk-representation
   *)
  (# haveBeenChanged: @boolean; error: ^stream
  enter error[]
  do ...
  exit haveBeenChanged
  #);
diskFileName:< (* returns the filename of the disk-representation *)
  (# t: ^text do &text[]->t[]; INNER exit t[] #);
textFileName:<
  (* returns the file-name of the text-representation of
   * THIS(fragment)
   *)
  (# t: ^text do &text[]->t[]; INNER exit t[] #);
origin: (#  enter originR[] exit originR[] #);
bind:< (* bind the fragment f inside THIS(fragment) *)
  (# f: ^fragmentForm; op: ^slotDesc
  enter f[]
     ...
  exit op[]
  #);
bindToOrigin:
  (# f: ^FragmentForm; op: ^slotDesc
  enter f[]
     ...
  exit op[]
  #);
setupOrigin:
  (# error: ^stream
  enter error[]
  do ...
  #);
prop: ^propertyList;
pack:<
  (* Private: pack representation into byte stream *)
  (# fileName: (* if none diskFileName is used *) ^text
  enter fileName[]
  do INNER
  #);
unpack:< (* Private: unpack rep. from bytestream *)
  (# fileName: (* if none diskFileName is used *) ^text;
     error: ^stream
  enter (fileName[],error[])
  do INNER
  #);
bindMark:
  (* Private: true => attempting to bind slots in THIS(fragment) *)
  @boolean;
nameT: (* Private *) ^text;
fullNameT: (* Private *) ^text;
```

```
      fatherR: (* Private: the enclosing group *) ^fragmentGroup;
      fragType: (* Private *) @integer;
      originR: (* Private: Attribute where THIS(fragment) 'belongs' *)
        ^fragment;
      ffNameSeparatorChar: (* Private *) (#  exit '-' #);
      catcher: handler (* Private *)
        (#  ... #);
   do INNER
   #);
 newFragmentGroup:
   (* returns a new instance of fragmentGroup *)
   (# g: ^fragmentGroup do &fragmentGroup[]->g[]; g.init;  exit g[] #);
 fragmentGroup: fragment (* This is a group of fragments *)
   (# <<SLOT fragmentGroupLib:Attributes>>;
      scan:
        (* scans through all fragment forms in this(fragmentGroup) *)
        (# current: ^fragment
        ...
        #);
      scanIncludes:
        (* scans through all included fragmentGroups in
         * this(fragmentGroup)
         *)
        (# current: ^linklisttype.link;
        ...
        #);
      scanSlots:
        (* scans through all SLOTs in this(fragmentGroup) *)
        (# current: ^slotDesc
        ...
        #);
      open: protect
        (* This operation opens a local fragment, localPath, of this group.
         * LocalPath may be a local name of the form 'foo' or a local path
         * 'foo1/foo2/.../foon' which will be interpreted local to this
         * group
         *)
        (# localPath: ^text;
           f: ^fragment;
           g: ^fragmentGroup;
           error: ^stream;
           groupInx,dirInx: @integer
        enter (localPath[],error[])
        ...
        exit f[]
        #);
      close::<
        (#
        ...
        #);
      fragmentListElement:
        (# f: ^fragment;
           type: @integer;
           name: ^text;
           localName,
            fullNameOfLink
             (* ought to be in a subpattern, Only o.k. for link-type *)
             ^text;
           open:
             (# error: ^stream
             enter error[]
                ...
             exit f[]
             #);
            <<SLOT fragmentListElementPrivate:Attributes>>
        #);
```

```
fragmentList:
  ^fragmentListDescription;
loadIncludes: ...;
linkListType:
  (* to cache include links *)
  (# link:
       (# linkname: ^text;
          fullname: @
            (# fn: ^text
            ...
            exit fn[]
            #);
          next: ^link
       #);
     head: ^link
  #);
linkList: ^linkListType;
fragmentListDescription: containerList
  (# element::< fragmentListElement;
     deleteLocalName: (* delete the fragment with the local name n *)
       (# n: ^text (* the local path *)
       enter n[]
          ...
       #);
     find:
       (* find a local fragment. If the fragment is not open return
        * NONE
        *)
       (# n: ^text (* the local path *) ; r: ^fragment
       enter n[]
          ...
       exit r[]
       #);
     open:
       (* Find a local fragment. If the fragment is not open then
        * open it
        *)
       (# f: ^fragment;
          n: ^text;
          e: ^element;
          error: ^stream;
          removeHeadingSlashes:
            (* this routine removes '/' 's at the head of a
             * text
             *)
            (# t: ^text; ch: @char
            enter t[]
            do 0->t.setPos;
               loop:
                 (if (t.get->ch)='/' then restart loop if);
               (if (t.pos > 1) then
                   (1,t.pos-1)->t.delete
               if)
            exit t
            #);
       enter (n[],error[])
          ...
       exit f[]
       #);
     insertFragment: protect
       (# f: ^fragment;
          newElement: ^element;
          alreadyThere:< (* exception, which may be called *)
            astInterfaceException
       enter f[]
       ...
```

```
          #);
        addFragment: insertFragment (#  do newElement[]->append #);
        insertFragmentBefore: insertFragment
          (# before: ^theCellType
          enter before[]
          do (newElement[],before[])->insertBefore
          #);
        insertFragmentAfter: insertFragment
          (# after: ^theCellType
          enter after[]
          do (newElement[],after[])->insertAfter
          #);
        <<SLOT fragmentListDescriptorPrivate:Attributes>>
     #);
   defaultGrammar:
     ^treeLevel;
   saveAs: protect
     (* save THIS(FragmentGroup) using the name fullname *)
     (# fullname: ^Text
     enter fullname[]
     do ...
     #);
   saveBackup: protect
     (* save THIS(FragmentGroup) using the name diskFileName+ext *)
     (# ext: ^Text
     enter ext[]
     do ...
     #);
   restoreBackup: protect
     (* restore THIS(FragmentGroup) using the name diskFileName+ext *)
     (# ext: ^Text
     enter ext[]
     do ...
     #);
   diskFileName::<
     (#
     ...
     #);
   textFileName::<(#  ... #);
   isRealOpen:
     (# opened: @Boolean;
     ...
     exit opened
     #);
   realOpen: protect
     (* only to be used by the compiler *)
     (# do ... #);
   parse: (* for parsing a fragmentGroup *)
     (# groupParser:
        ...;
        parseErrors:< (* exception called if parse-errors *)
          astInterfaceException;
        fatalParseError:< astInterfaceException
          (# errNo: @integer enter errNo do INNER #);
        doubleFormDeclaration:<
          (* exception called if two fragmentForms with the same name *)
          astInterfaceException;
        inputname: ^text;
        error: ^stream;
        ok: @boolean
     enter (inputname[],error[])
     do groupParser
     exit ok
     #);
   init::<  (#  ... #);
   bind::<
```

```
  (#
  do ...
  #);
getBinding:
  (* Get the bindings of the slot within THIS(fragmentGroup).  All
   * bindings are delivered.  For each binding, found is called.  The
   * elements of THIS(fragmentGroup) must be fragment forms or
   * fragment links to such.
   *)
  (# mark: @
       (# f: ^fragmentGroup;
          inserted: @boolean;
          scan:
            (# current: ^fragmentGroup;
            do ...
            #);
          elm:
            (* Private *) (# f: ^fragmentGroup; succ: ^elm #);
          head: (* Private *) ^elm;
       enter f[]
          ...
       exit inserted
       #);
     markRelatedFragments:<
       (# f: ^fragment;
       enter f[]
       do (if (f[] <> none) then INNER if)
       #);
     found:<
       (# theBinding: ^fragmentForm
       enter theBinding[]
       ...
       #);
     sl: ^slotDesc
  enter sl[]
     ...
  #);
(* lock/unlock/locked operations *)
lock:
  (* operation to signal to the rest of the users of this MPS,
   * that I will be working on this fg, and it may be in
   * inconsistent state
   *)
  (# ... #);
unlock:
  (* operation to signal to the rest of the users of this MPS,
   * that I am releasing the lock on this fg.
   *)
  (# ... #);
locked: @booleanValue;
(********** PRIVATE PART *********************)
pack::< (* Private *)
  (#  ... #);
unpack::< (* Private *)
  (#
  do ...
  #);
checkDiskRepresentation::< (* Private *)
  (#  ... #);
isDirectory:
  (* Private: true if the group is not a 'real' group but a
   * directory
   *) @boolean;
controller: @ (* used by the control module in the compiler *)
  (# status: @integer;
     ancestorTime: @integer;
```

```
          ancestorsChecked: @boolean;
          doneCheck: @boolean;
          groupT: @Integer;
          printName: ^text;
        #);
     private: @...;
  #) (* fragmentGroup *);
newFragmentForm: (* returns a new instance of fragmentForm *)
  (# g: ^treeLevel; f: ^fragmentForm
  enter g[]
  do &fragmentForm[]->f[]; g[]->f.grammar[]; f.init;
  exit f[]
  #);
fragmentForm: fragment
  (* This is the basic form of a fragment defined by means of a general
   * sentential form
   *)
  (# <<SLOT fragmentFormLib:Attributes>>;
     category:
       (# sy: @integer
       ...
       exit sy
       #);
     theGsForm: (#  exit (root.index,THIS(fragmentForm)[]) #);
     fragNode: (#  exit (0,THIS(fragmentForm)[]) #);
     print:
       (#
       do 'Print called of fragmentForm '->screen.puttext;
          fullName->screen.puttext;
          screen.newLine;
       #);
     binding: (* The SLOT bound by THIS(fragmentForm) *) ^slotDesc;
     modificationStatus: @integer;
     root:
       (* the root symbol of the ast kept in the array.  Set by the
        * parser
        *) ^ast;
     recomputeSlotChain:
       (#  do ...;  #);
     scanSlots:
       (* access operations: scan all SLOTs in THIS(fragmentForm) *)
       (# inx: @integer; current: ^slotDesc;
       ...
       #);
     grammar: ^treeLevel;
     indexToNode:
       (# inx: @integer;
          as: ^ast;
          indexOutOfRange:<
            astInterfaceException;
          noSuchSymbol:< astInterfaceException;
          grammarGenRefArrayError:< astInterfaceException;
       enter inx
       do ...
       exit as[]
       #);
     <<SLOT fragmentFormPrivate:Attributes>>;
     a: (* Private *) [initialLength] @integer;
     curtop: (* Private: current heapTop in the array a *) @integer;
     l: (* Private *) [initialLength] @integer;
     lcurtop: (* Private: current heapTop in the array 'l' *) @integer;
     initialLength:< (* Private *)
       (# max: @integer do 200->max; INNER exit max #);
     firstSlot:
       (* Private: The index of the first SLOT in the array a. The SLOTs
        * are linked together through the 'slotUsage-field' of SLOTs
```

```
           *) @integer;
        diskFileName::< (* Private *)
          (#  do fatherR.diskFileName->t[] #);
        textFileName::< (* Private *)
          (#  do fatherR.textFileName->t[] #);
        import: @ (* Private *)
          (* An indexed collection of fragments referred by
           * THIS(fragmentForm)
           *)
          (# impL: ^list;
             inxC: @integer;
             element: (# n: ^text; f: ^fragmentForm #);
             list:
               (# noOfElements:<(# nu: @integer;  do 10->nu; INNER exit nu #);
                  l: [noOfElements] ^element;
               #);
             <<SLOT fragmentFormImportPrivate:Attributes>>
          #);
        rootInx: @integer;
        init::< (* Private *)
          (#
          ...
          #);
        reset::< (* Private *)
          (#  ... #);
        private: @...;
     #);
   astFileExtension:
     (* exits the filename extension for AST files on the particular
      * architecture (the extension differs e.g. for big- and little endian
      * architectures).  See e.g. initialization in astBody.bet
      *) (#  exit astFileExt[] #);
   parserFileExtension:
     (* exits the filename extension for parser table files on the particular
      * architecture (the extension differs e.g. for big- and little endian
      * architectures).  See e.g. initialization in astBody.bet
      *) (#  exit parserFileExt[] #);
   ppFileExtension:
     (* exits the filename extension for pretty-printer table files on the
      * particular architecture (the extension differs e.g. for big- and
      * little endian architectures).  See e.g. initialization in astBody.bet
      *) (#  exit ppFileExt[] #);
   astFileExt: (* Private *) ^text;
   parserFileExt: (* Private *) ^text;
   ppFileExt: (* Private *) ^text;

   (************** END The Fragment Library END ***************)
   top: @
     (# init: (#  ... #);
        groupTable: @HashTable
          (# element::
               (# fullname: ^Text;
                  g: ^FragmentGroup;
                  open:
                    (# error: ^Stream;
                    enter error[]
                       ...
                    exit g[]
                    #);
               #);
             dummy: @Element;
             hashFunction::
               (# inx: @Integer;
               do L:
                    (for i: 26 repeat
                         e.fullname.lgth-i+1->inx;
```

```
                 (if inx < 1 then leave L if);
                 e.fullname.T[inx]+value->value;

            for)
       #);
     equal::
       (#  do left.fullname[]->right.fullname.equal->value #);
     rangeInitial::  (#  do 500->value #);
     find:
       (* find a fragment group. If the fragment is not open return
        * NONE
        *)
       (# fullName: ^text (* the path *) ; g: ^fragmentGroup
       enter fullName[]
          ...
       exit g[]
       #);
     open:
       (* Find a local fragment. If the fragment is not open then
        * open it
        *)
       (# g: ^fragmentgroup;
          fullName: ^text;
          e: ^element;
          error: ^stream;
          removeHeadingSlashes:
            (* this routine removes '/' 's at the head of a
             * text
             *)
            (# t: ^text; ch: @char
            enter t[]
            do 0->t.setPos;
               loop:
                 (if (t.get->ch)='/' then restart loop if);
               (if (t.pos > 1) then
                   (1,t.pos-1)->t.delete
               if)
            exit t
            #);
       enter (fullName[],error[])
          ...
       exit g[]
       #);
     <<SLOT topTablePrivate:Attributes>>
  #);
open: protect
  (* This operation opens a fragmentgroup file: fileName
   *)
  (# fileName: ^text;
     g: ^fragmentGroup;
     f: ^fragment;
     error: ^stream
  enter (fileName[],error[])
  do ...;
     g[]->f[];
  exit f[]
  #);
newGroup: (* make a new group with top as father *)
  (# fullname: ^Text;
     fg: ^FragmentGroup;
     alreadyOpen:< astInterfaceException;
  enter fullname[]
     ...
  exit fg[]
  #);
close: (* close FragmentGroup fg *)
```

```
        (# fg: ^fragmentGroup;
        enter fg[]
        ...
        #);
      namedClose: (* close FragmentGroup fullname *)
        (# fullname: ^text
        enter fullname[]
        ...
        #);
      delete:
        (* delete FragmentGroup fg *)
        (# fg: ^fragmentGroup;
        enter fg[]
        ...
        #);
      insert:
        (* insert a FragmentGroup into top table *)
        (# fg: ^fragmentGroup;
        enter fg[]
        do ...
        #);
      isOpen:
        (* return Group fullname if it is already open, otherwise NONE *)
        (# fullname: ^Text; fg: ^FragmentGroup;
        enter fullname[]
           ...
        exit fg[]
        #);
      topGroup: ^FragmentGroup;
      catcher: handler (* Private *)
        (#  ... #);
  #);
(* end of top *)
parseSymbolDescriptor:
  (# terminals: (* is dynamically expanded *) [1]
        ^text;
     nonterminals: (* is dynamically expanded *) [1] @integer;
  #);
errorReporter:
  (* error-reporter pattern. Create a specialization of this pattern if
   * you want to do your own error-reporting
   *)
  (# frag: ^fragment;
     errorStream: ^stream;
     beforeFirstError:< object;
     afterLastError:< object;
     forEachError:<
       (# streamPos,startLineNo: @integer;
          errorLines:
            (* 1, 2 or 3 lines of text before the
             * error.  Approx. 100 chars
             *) @text;
          errorPos: (* the pos in errorLines of the error *) @integer;
          legalSymbols: ^parseSymbolDescriptor
       enter (streamPos,startLineNo,errorLines,errorPos (*inx*) ,legalSymbols[])
       do INNER
       #);
  #);
theErrorReporter:
  (* the error reporter which will be called from the fragmentGroupparser
   * or from fragmentForm.parser.errorReport
   *) ^errorReporter;
treeLevel:
  (* prefix for descriptions of grammars *)
  (# <<SLOT treeLevelLib:Attributes>>;
     grammarAst:
```

```
  (* if not NONE this point to the form of the ast describing the
   * grammar
   *) ^fragmentForm;
symbolToName: (* gives a human-readable name for a symbol-number *)
  (# symbol: @integer; t: ^text;
  enter symbol
  do &text[]->t[]; ...
  exit t[]
  #);
symbolToAst:
  (# symbol: @integer;
     as: ^ast;
  enter symbol
     ...
  exit as[]
  #);
newAst: (* returns a new instance of ast *)
  (# prod: @integer; as: ^ast; frag: ^fragmentForm;
  enter (prod,frag[])
  do ...
  exit as[]
  #);
newAstWithoutSons:
  (# prod: @integer;
     as: ^ast;
     frag: ^fragmentForm;
  enter (prod,frag[])
     ...
  exit as[]
  #);
newLexemText: (* returns a new instance of lexemText *)
  (# length: @integer;
     prod: @integer;
     frag: ^fragmentForm;
     inx,base: @integer;
  enter
        (#
        enter (prod,length,frag[])
           ...
        #)
  exit
       (# as: ^ast
         ...
       exit as[]
       #)
  #);
newConst: (* returns a new instance of const *)
  (# c: ^const; frag: ^fragmentForm
  enter frag[]
     ...
  exit c[]
  #);
newUnexpanded:
  (* returns a new instance of unExpanded *)
  (# s: ^unExpanded; syncatNo: @integer; frag: ^fragmentForm
  enter (syncatNo,frag[])
     ...
  exit s[]
  #);
newOptional:
  (* returns a new instance of optional *)
  (# s: ^optional; syncatNo: @integer; frag: ^fragmentForm;
  enter (syncatNo,frag[])
     ...
  exit s[]
  #);
```

```
newSlot:
  (* returns a new instance of slotDesc *)
  (# s: ^slotDesc; frag: ^fragmentForm
  enter frag[]
     ...
  exit s[]
  #);
version:< (* returns the grammar version *)
  integerObject (# ... #);
grammarIdentification:< (* the grammar name *)
  (# theGrammarName: ^text
  ...
  exit theGrammarName[]
  #);
suffix:<
  (* the file-name extension used for files containing programs
   * derived from this grammar.  Default extension is '.text'.
   *)
  (# theSuffix: ^text
  ...
  exit theSuffix[]
  #);
init:<(# do ... #);
parser: @parse;
parse:
  (# errorReport:
       (* produce an errorReport on stream if the last parse did not
        * succeed
        *)
       (# input,error: ^stream;
       enter (input[],error[])
       do ...
       #);
     findSymbolNo:
       (* given a text-string, find the nonterminal-symbol, that has
        * that name
        *)
       (# symbol: ^text; no: @integer
       enter symbol[]
          ...
       exit no
       #);
     input,error: ^stream;
     goalSymbol:
       @nonterminalSymbol;
     frag: ^fragmentForm;
     ok,haveBeenInitialized: @boolean;
     parseEndPos: @integer;
     lastCh: @char;
     privatePart: @...;
     initialize:
       (# fileName: ^text;
          isEos:<
            (* '--' may be considered as end-of-stream *)
            booleanValue(# do true->value #);
          longLexems:<
            (* the lexems may be long (multi-word lexems) *)
            booleanValue;
          dashNames:< (* dash '-' may be allowed in indentifiers *)
            booleanValue;
          caseSensitive:< (* allows keywords to be case sensitive *)
            booleanValue;
          EOLasComEnd:< (* EOL is also accepted as end-of-comment *)
            booleanValue;
          SplitString:<(* a string may be split into several units
                        * 'xxx' 'yyy' is lexed as 'xxx<0>yyy'
```

```
                         *)
                   BooleanValue
              enter fileName[]
                 ...
              #);
           doParse: protect
              (# catcher: handler (* Private *)
                   (#  ... #)
              enter (goalSymbol,input[],error[],frag[])
              do ...
              exit ok
              #);
           commentId:
              (* declared to be able to get the value of comment inside the
               * comment-binding in the parser
               *) (#  exit comment #);
        enter (goalSymbol,input[],error[],frag[])
        do doParse;
        exit ok
        #);
      <<SLOT treeLevelPrivate:Attributes>>;
      private: @ ...;
      kindArray: (* Private *) [maxProductions] @integer;
      nodeClassArray: (* Private *) [maxProductions] @integer;
      sonArray: (* Private *) [maxProductions] @integer;
      roomArray: (* Private *) [maxProductions] @integer;
      genRefArray: (* Private *) [maxProductions] ##ast;
      prettyPrinter: (* Private *) ^object;
      maxProductions:< integerObject (* Private *)
        (#  do 400->value; INNER #);
   #);
 kinds: @
   (# interior: (#  exit 1 #);
      unExpanded: (#  exit 2 #);
      optional: (#  exit 3 #);
      nameAppl: (#  exit 4 #);
      nameDecl: (#  exit 5 #);
      string: (#  exit 6 #);
      const: (#  exit 7 #);
      comment: (#  exit 8 #);
      slotDesc: (#  exit 9 #);
      list: (* this will only be returned by 'nodeClass' *)
        (#  exit 117 #);
      cons: (* this will only be returned by 'nodeClass' *)
        (#  exit 118 #);
      dummy: (* temporary declaration. Is never returned *)
        (#  exit - 317 #)
   #);
 prodNo: @
   (# unExpanded: (#  exit - 1 #);
      optional: (#  exit - 2 #);
      nameAppl: (#  exit - 3 #);
      nameDecl: (#  exit - 4 #);
      const: (#  exit - 5 #);
      string: (#  exit - 6 #);
      comment: (#  exit - 7 #);
      slotDesc: (#  exit - 8 #)
   #);
 CommentSeparator1: (#  exit 1 #);
 (* Separation of comments *)
 CommentSeparator2: (#  exit 2 #);
 (* Separation of comments in same son *)
 CommentSeparator3: (#  exit 3 #);
 (* Separation of comments in properties *)
 CommentSieve: [256] @Char;
 printComment:
   (# comment: ^Text; output: ^Stream;
   enter (comment[],output[])
      ...
   #);
 undefinedGrammarName:
   (* describes unknown grammars *) (#  exit '????' #);
 undefinedVersion: (* describes unknown versions of grammars *)
   (#  exit - 1 #);
 grammarTable: @
   (# BETA,propertyGrammar,meta,pretty:
        (* some different grammars, which might by instantiated by the
         * application
         *) ^treeLevel;
      noOfKnownGrammars: @integer;
      scan:
        (# current: ^treeLevel;
           currentName, currentExtension, currentPath: ^text
          ...
        #);
      scanExtensions:
        (# currentExtension: ^text
          ...
        #);
      legalExtension: booleanValue
        (# ext: ^text
        enter ext[]
        ...
        #);
      find:
        (# grammarName: ^text;
           error: ^stream;
           ifNotFound:< astInterfaceException
             (* exception called if grammar not found *)
             (# ... #);
           noParserAvailable:< astInterfaceNotification
             (* notification invoked if no parser is available
              * for this grammar
              *)
             (# ... #);
           accessError:< astInterfaceException
             (* invoked if any access error occurs during the
              * search of grammars
              *);
           MPSerror:< astInterfaceException
             (* invoked if any MPS error occurs during the
              * opening of grammars
              *);
           startParsing:<
             (* invoked if parsing is done during the opening of
              * grammars
              *)
             (# do INNER #);
           inx: @integer;
           thename: @text;
           treelevelGrammarTableFindCatcher: (* Private *) @handler
             (# ... #)
        enter (grammarName[],error[])
        do ...
        exit table[inx].gram[]
        #);
      element: (# name, extension, path: ^text; gram: ^treelevel #);
      table: [0] (* Private *) ^element;
      tableCheck: (* private *)
        ...;
      insert: (* Private *)
        (# theGrammar: ^treeLevel
        enter theGrammar[]
           ...
        #);
      insertMetagrammar:
        (* Private: an instance of metaGrammar must be inserted into
         * grammarTable before any usages of grammarTable
         *)
        (# location: ^text
        enter (meta[],location[])
           ...
        #)
  #);
registerGrammar:
(# name, ext, path: ^text; inx: @integer;
enter (name[], ext[], path[])
...
#);
grammarFinder:
  (* create subpatterns of this pattern to implement your strategy for
   * looking-up grammars.  The fragment: findGrammar.bet contains such a
   * subpattern, implementing the standard look-up method used in the
   * Mjolner BETA System
   *)
  (# grammar: ^text;
     error: ^stream;
     installed: @boolean;
     noRegisteredGrammars:< astInterfaceException
        (* invoked if no grammars have been registered.  If
         * grammars are registered during this exception, and
         * control is returned to grammarFinder, the registered
         * grammars will be used.
         *)
        (# ... #);
     registerGrammars:< (* invoked to register the grammars *)
        (# error: ^stream;
        enter error[]
           ...
        #);
     registeredGrammars:<
        (* may return a fragmentGroup containing the registered grammars *)
        (# grammarsGroup: ^fragmentGroup
        do INNER
        exit grammarsGroup[]
        #);
  enter (grammar[],error[])
        (* here the look-up for a grammar should takes place.  Either by
         * looking somehow amoung the previously registered grammars, or by
         * using some dynamic grammar look-up method
         *)
     ...
  exit installed
        (* true if new grammar installed in grammarTable *)
  #);
defaultGrammarFinder:<
  (* default grammarFinder installed by astLevelInit *) grammarFinder;
grammarMissing:
  (* called when a grammar is missing.
   * grammarMissing.registerGrammars is invoked in astLevelInit
   *) ^grammarFinder;
thePathHandler: @fileNameConverter;
stripPathName:
  (* Strips last filename from a path specification in order to
   * conform with the new pathHandler.
   *)
  (# PN,newPN: ^text; ix: @integer;
  enter PN[]
  do directoryChar->PN.findAll(#  do inx->ix #);
     (if ix=0 then
         none ->newPN[]
      else
         (* terminating directoryChar is not removed due to 'strange'
          * behavior in localPath
          *)
         (1,ix)->PN.sub->newPN[]
     if)
  exit newPN[]
  #);
expandToFullPath:
  (# name: ^text;
  enter name[]
  exit
       (name[],currentDirectory)->thePathHandler.convertFilePath
  #);
offendingFormName:
  (* set in case of a doubleDeclaration in fragmentForm names *) ^text;
trace: @
  (* different tracing possibilities. I.e. to trace open of
   * fragments use
   *      (trace.fragmentOpen,true) -> trace.set;
   * To activate tracing through the BETA compiler,
   * set compileroption=number given here+400
   * (e.g. "beta -s 490 ..." to activate trace of slot bindings).
   * The trace will be delivered on the stream trace.str.  This may be
   * set by e.g.:
   *      traceFile[] -> trace.output;
   * By default, trace is delivered on screen.
   *)
  (# fragmentOpen: (#  exit 1 #);
     onParse: (#  exit 2 #);
     topOpen: (#  exit 3 #);
     fragmentClose: (#  exit 4 #);
     topClose: (#  exit 4 #);
     compactOpen: (#  exit 10 #);
     grammars: (#  exit 20 #);
     parsingComments: (#  exit 30 #);
     getnextComment: (#  exit 31 #);
     editingComments: (#  exit 32 #);
     parser: (#  exit 50 #);
     getBinding: (#  exit 90 #);
     getBindingMark: (#  exit 91 #);
     set: (* call this to trace something in the astInterface *)
       (# no: @integer; on: @boolean;
       enter (no,on)
       ...
       #);
     output:
       (# str: ^stream
       enter str[]
       ...
       #);
     active: (* true iff any trace options are set *) @boolean;
     d: (* Private *) [100] @boolean;
     private: @...
  #);
options: @
  (* different options available.  I.e. to set these options use
   *       true -> options.forceParse
   * and to test whether these options are set, use
   *      (if options.forceParse ... if)
   *)
  (# forceParse: (#  enter option[1] exit option[1] #);
     option: (* Private *) [10] @boolean
  #);
astInterfaceNotification:
  notification
  (# m: ^text
  enter m[]
     ...
  #);
astInterfaceException: exception
  (# m: ^text
  enter m[]
     ...
  #);
astInterfaceError:< astInterfaceException;
protect:
  (* This operation is used to protect a MPS operation (or
   * sequence of MPS operations agains the dynamically generated
   * MPS exceptions.
   *)
  (# astOverflow:< astInterfaceException;
     startingParsing:< (# do INNER #);
     fragmentNotExisting:< astInterfaceException
       (# do true->continue; INNER #);
     grammarNotFound:< astInterfaceException;
     badFormat:< astInterfaceException;
     parseErrors:< astInterfaceException;
     fatalParseError:< astInterfaceException
       (# errNo: @integer enter errNo do INNER #);
     doubleFormDeclaration:< astInterfaceException;
     readAccessError:< astInterfaceException;
     writeAccessError:< astInterfaceException;
     writeAccessOnLstFileError:< astInterfaceException;
     EOSError:< astInterfaceException;
     noSuchFileError:< astInterfaceException;
     fileExistsError:< astInterfaceException;
     noSpaceLeftError:< astInterfaceException;
     otherFileError:< astInterfaceException;
     protectCatcher: @handler (* Private *)
       (# ... #)
  ...
  #);
astLevelInit:
  (#
  do ...
  #);
(********* PRIVATE PART ********************)
private: @...;
parseErrorsLst: ^text; (* if during, the last parsing, there was
                        * parse errors, and no '.lst' file could
                        * be written, then this will contain the
                        * information otherwise found in the
                        * '.lst' file
                        *)
(*      referenceGenerator: {* Private *}
 *        (# as: ^ast do INNER exit as[] #);
 *      genUnExpanded: {* Private *} @referenceGenerator
 *        (#  do &unExpanded[]->as[] #);
 *      genOptional: {* Private *} @referenceGenerator
 *        (#  do &optional[]->as[] #);
 *
 *)
  offset: @
  (* Private: the following constants are private constants to ast, which
   * tells where in array A relative from 'index' different information
   * can be found
   *)
  (# attribute: (#  exit 2 #);
     slotUsage: (#  exit 2 #);
     slotAttribute: (#  exit 3 #);
     commentType: (#  exit 2 #);
     sizePerNode:
       (* tells how many entries in A is needed per node (not including
        * extra attributes)
        *) (#  exit 2 #);
     sizePerUnExpanded: (#  exit 2 #);
     sizePerNameAppl: (#  exit 2 #);
     sizePerNameDecl: (* must be equal to sizePerNameAppl *)
       (#  exit 2 #);
     sizePerString: (#  exit 2 #);
     sizePerConst: (#  exit 4 #);
     sizePerComment: (#  exit 4 #);
     sizePerSlotDesc: (#  exit 12 #);
  #);
groupBlackNumber: (* Private *)
  (* magic number. To be used to recognize group-files *)
  (#  exit 131453937 #);
errorNumbers: @ (* Private *)
  (#  noReadAccess: (#  exit 1 #);
     noWriteAccess: (#  exit 2 #);
     notExisting: (#  exit 3 #);
     badFormat: (#  exit 4 #);
     parseErrors: (#  exit 5 #);
     grammarNotFound: (#  exit 6 #);
     arrayTooBig: (#  exit 7 #);
     noSpaceLeft: (#  exit 8 #);
     writeAccessOnLstFileError: (#  exit 9 #);
     doubleFormDeclaration: (#  exit 10 #);
     EOSError: (#  exit 14 #);
     noSuchFile: (#  exit 15 #);
     fileExists: (#  exit 16 #);
     otherFileError: (#  exit 18 #);
     fatalParseError:
       (* The error numbers between 101 and 199 are exclusively allocated
        * for BOBS fatal parse error numbers.  The original BOBS error
        * number is this (no-100):
        *) (# no: @integer enter no exit (100 < no) and (no < 200) #);
  #);
notificationNumbers: @ (* Private *)
  (# startingParsing: (#  exit 201 #);
     noParserAvailable: (#  exit 202 #)
  #);
handler: (* Private *)
  (# no: @integer; msg: ^text; oldCatcher: ^handler enter (no,msg[]) do INNER #);
theCatcher: ^handler (* Private *) ;
maxdepth: (* Private: maximal elements in a stack *) (#  exit 50 #);
stak: (* Private *)
  (# stakOverflowException: astInterfaceException
       (#  do INNER ; 'error: stack overrun'->msg.putline #);
     a: [maxdepth] @integer;
     topindex: @integer;
     init: (#  do 0->topindex #);
     push:
       (# e: @integer
       enter e
       do (if topIndex=maxDepth then stakOverflowException if);
          e->a[topindex+1->topindex]
       #);
     pop:
       (# e: @integer;
       do a[topindex]->e; topindex-1->topIndex;
       exit e
       #);
     empty: (#  exit (topindex = 0) #);
```

```
         #);
       (* The following category defines some constants used as values for super
        * attributes in metagrammar-ast's
        *)
       super: @ (* Private *)
         (# undefined: (#  exit - 10 #);
            cons: (#  exit - 11 #);
            list: (#  exit 99999 #)
         #);
       tracer: (* Private *)
         (# traceNo: @integer; dmp: ^stream
         enter traceNo
         ...
         #);
       repS: (* Private *) ^repetitionStream;
       doRealOpen:
         (* Private: if this boolean is false, unpack of fragments will only
          * read in part of the fragment description.  Should only be used by the
          * BETA compiler
          *) @boolean;
       useModificationStatus: (* Private *) @boolean;
    do astLevelInit; INNER ;
    #);
containerList: list
    (* Private: Empty specialization of the list pattern defined in the
     * containers library.  It is only defined to circumvent name-clash between
     * the list pattern defined in containers, and the list pattern defined here
     * in astInterface.
     *) (#  #)
```

Astlevel Interface Mjølner Informatics

Findgrammar Interface

```
ORIGIN 'astlevel';
LIB_DEF 'mpsfindgram' '../lib';
BODY 'private/findGrammarBody'
(*
 * COPYRIGHT
 *       Copyright (C) Mjolner Informatics, 1986-93
 *       All rights reserved.
 *)
--- astInterfaceLib: attributes ---
findGrammar: grammarFinder
  (# registerGrammars::<(# do ...; INNER #);
     registeredGrammars::<(# ... #);
     grammarsPATH:<
       (* the name of the file in which the valid grammars are specified.
        * Used by registerGrammars
        *)
       (# grammars: ^text
       ...
       exit grammars[]
       #);
     metaGrammarFile:<
       (* the name of the file in which the  meta-grammar is specified *)
       (# metaGrammar: ^text
       ...
       exit metaGrammar[]
       #);
     loadingError:< exception
       (#
          nameError:< error
            (#
            do 'Grammar extension or path found in wrong position'
                 ->msg.puttext;
               INNER
            #);
          extensionPathError:< exception
            (#
            do 'Grammar extension or path found in wrong position'->msg.puttext;
               INNER
            #);
          constError:< exception
            (#
            do 'Const values does not make sense in grammar specifications'
                 ->msg.puttext; INNER
            #);
          formatError:< exception
            (#
            do 'Something wrong with the number of values in grammar specification'
                 ->msg.puttext; INNER
            #);
          MPSerror:< exception
            (# t: ^text enter t[] do t[]->msg.puttext; INNER #);
       #);
     private: @ ...;
  do ...;
  #)
```

Fragmentscanner Interface

```
ORIGIN 'astlevel';
(*
 * COPYRIGHT
 *   Copyright Mjolner Informatics, 1995-97
 *   All rights reserved.
 *)
-- fragmentGroupLib: Attributes --

scanPropsAndFrags:
  (# doProperty:<
       (# prop,s,selector: @text
       enter (prop,s,selector)
       do INNER
       #);
     doFragmentLink:<
       (# include: ^astinterface.fragmentgroup.linklisttype.link
       enter include[]
       do INNER
       #);
     doFragmentForm:<
       (# fle: ^fragmentListElement
       enter fle[]
       do INNER
       #);
     doFragmentGroup:<
       (# fle: ^fragmentListElement
       enter fle[]
       do INNER
       #);
     doConstProperty:<
       (# toggle: @boolean; const: @integer
       enter (toggle, const)
       do INNER
       #);
     inx: @integer; continue: @boolean;
     prophelp, selector: @text;
  do (if prop[] = none then
         'scanPropsAndFrags: prop is none'->putLine;
         leave scanPropsAndFrags
     if);
     (if fragmentlist[] = none then
         'scanPropsAndFrags: fragmentlist is none'->putLine;
         leave scanPropsAndFrags
     if);
     true->continue;
     propScan:
       prop.scanProp
       (# doProp::<
            (# propUC: ^text; strs: [10]@text; pos: @integer;
            do prop.copy->propUC[]; propUC.makeUC;
               (* Ignore some properties. *)
               (if true
                // propUC.t[1]='_'
                // ('DONECHECK'->propUC.equal)
                // ('FREJAMARK'->propUC.equal)
                // ('ABSTRACTED'->propUC.equal) then
                   (* These properties are internal - to be ignored *)
                // ('ON'->propUC.equal) then
                   scanParameters
                     (# doConst::<
                          (#
                          do inx+1->inx;
```

```
             (true,c)->doConstProperty;
             (if not continue then leave propScan if);
          #)
     #)
// ('OFF'->propUC.equal) then
   scanParameters
     (# doConst::<
          (#
          do inx+1->inx;
             (false,c)->doConstProperty;
             (if not continue then leave propScan if);
          #)
     #)
// ('ORIGIN'->propUC.equal) then
   scanParameters
     (# doString::<
          (#
          do inx+1->inx; (prop,s,'')->doProperty;
             (if not continue then leave propScan if);
             (* handle INCLUDEs immediately after ORIGIN *)
             scanIncludes
               (#
               do inx+1->inx;
                  current[]->doFragmentLink;
                  (if not continue then leave propScan if);
               #)
          #)
     #)
// ('BODY'->propUC.equal) then
   scanParameters
     (# doString::<
          (#
          do inx+1->inx; (prop,s,'')->doProperty;
             (if not continue then leave propScan if);
          #)
     #)
// ('MDBODY'->propUC.equal)
// ('OBJFILE'->propUC.equal)
// ('BETARUN'->propUC.equal)
// ('MAKE'->propUC.equal)
// ('LIBFILE'->propUC.equal) then
   scanParameters
     (# doName::<
          (#
          do n[]->prophelp.putText;
             ' '->prophelp.put;
             n->selector;
          #);
        doString::<
          (#
          do inx+1->inx; (prop,s,selector)->doProperty;
             (if not continue then leave propScan if);
          #)
     #)
// ('BUILD'->propUC.equal) then
     scanParameters
     (# doName::<
          (#
          do n[]->prophelp.putText;
             ' '->prophelp.put;
             n->selector;
          #);
        doString::<
          (#
          do (if (pos+1->pos)>strs.range then
                 10->strs.extend
```

```
                          if);
                          s->strs[pos];
                       #)
                  #);
                inx+1->inx; (prop,strs[pos],selector)->doProperty;
                (for i: pos-1 repeat
                     inx+1->inx; (prop,strs[i],'')->doProperty;
                     (if not continue then leave propScan if);
                for);
            if)
         #)
    #);
  fragScan:
    (if continue then
        fragmentList.scan
          (#
          do (if current.type
              // formType then
                 (#
                 do inx+1->inx; current[]->doFragmentForm;
                    (if not continue then leave fragScan if);
                 #)
              // groupType then
                 (#
                 do inx+1->inx; current[]->doFragmentGroup;
                    (if not continue then leave fragScan if);
                 #);

             if)
          #)
    if);
#);

scanPropsAndFragsForText: scanPropsAndFrags
  (# displayText:< (# t: ^text;  enter t[] do INNER #);

     doProperty::<
       (# propUC: ^text;
       do prop.copy->propUC[]; propUC.makeUC;
          propUC->prophelp;
          ' '->prophelp.put;
          (if true
           // ('MDBODY'->propUC.equal)
           // ('OBJFILE'->propUC.equal)
           // ('BETARUN'->propUC.equal)
           // ('MAKE'->propUC.equal)
           // ('LIBFILE'->propUC.equal) then
              selector[]->prophelp.putText;
              ' '->prophelp.put
           // ('BUILD'->propUC.equal) then
              (if selector.lgth=0 then
                  '      $'->prophelp;
                  fileno->prophelp.putint; fileno+1->fileno;
                  '='->prophelp.put
               else
                  0->fileno;
                  selector[]->prophelp.putText;
                  ' '->prophelp.put;
              if)
          if);
          '\''->prophelp.put;
          s[]->prophelp.putText;
          '\' '->prophelp.putText;
          prophelp[]->displayText;
          prophelp.clear
       #);
```

```
      doFragmentLink::<
        (# t: ^text;
        do 'INCLUDE \''->t[];
           include.linkname[]->t.putText;
           '\''->t.put;
           t[]->displayText
        #);
      doFragmentForm::<
        (# catName,t: ^text
        do (if fle.type=formType then
               (# ff: ^astInterface.fragmentForm
               do fle.open->ff[];
                  (ff.name).copy->t[];
                  ': '->t.append;
                  (if ff.grammar[] = none then
                      'ff.grammar[] is none!!'->putLine; (*leave scanFrags*)
                  if);
                  ff.category->ff.Grammar.symbolToName->catName[];
                  (if catName[]=none then
                      'ff.category: '->putText;
                      ff.category->putInt;
                      newLine;
                      'ff.root.symbol: '->putText;
                      ff.root.symbol->putInt;
                      newLine
                   else
                      (if true
                       // ('DescriptorForm'->catName.equal)
                       // ('ObjectDescriptor'->catName.equal) then
                          'Descriptor'->t.putText;
                       // ('AttributesForm'->catName.equal)
                       // ('AttributeDecl'->catName.equal) then
                          'Attributes'->t.putText;
                       else
                          (if catName.empty then
                              'Unexpanded'->t.putText;
                           else
                              catName[]->t.putText;
                          if)
                      if)
                  if);
                  t[]->displayText
               #)
           if)
        #);
      doFragmentGroup::< (# do INNER #);
      doConstProperty::<
        (#
        do (if toggle then
               'ON '->prophelp.append
            else
               'OFF '->prophelp.append
           if);
           const->prophelp.putInt;
           prophelp[]->displayText;
           prophelp.clear
        #);
      fileno: (*private*) @integer;
   #);

findPropsAndFrags: scanPropsAndFrags
   (# doProperty::<
        (#
        do (if inx=currentItemNo then
               INNER doProperty; false->continue
           if)
        #);
      doFragmentLink: :<
        (#
        do (if inx=currentItemNo then
               INNER doFragmentLink; false->continue
           if)
        #);
      doFragmentForm: :<
        (#
        do (if inx=currentItemNo then
               INNER doFragmentForm; false->continue
           if)
        #);
      doFragmentGroup: :<
        (#
        do (if inx=currentItemNo then
               INNER doFragmentGroup; false->continue
           if)
        #);
      doConstProperty: :<
        (#
        do (if inx=currentItemNo then
               INNER doConstProperty; false->continue
           if)
        #);
      currentItemNo: @integer;
   enter currentItemNo
   #)
```

Grammarinit Interface

```
ORIGIN 'astlevel';
BODY 'private/grammarinitbody';
-- treelevelLib: Attributes --
grammarInit:
  (# grammarLocation, grammarName: ^text; error: ^stream;
     MPSerror:< astInterfaceException
       (* invoked if any MPS error occurs during the initialization of
        * this grammar
        *);
     startParsing:<
       (* invoked if parsing is done during the initialization of
        * this grammar
        *)
       (# do INNER #);
     noParserAvailable:< astInterfaceNotification;
     grammarinitCatcher: (* Private *) @handler
     (# ... #);
     <<SLOT grammarinitlib: attributes>>
  enter (grammarLocation[], grammarName[], error[])
  do ...;
     INNER
  #);

betaGrammarInit: grammarInit
  (# ... #)
```

Grammarinit Interface Mjølner Informatics

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Metagrammarcfl Interface

```
ORIGIN '~beta/mps/astlevel'
--astInterfaceLib: attributes--

metagrammar: TreeLevel
  (# <<SLOT metagrammarAttributes:attributes>>;
     AGrammar: cons
       (# getGrammarName: getson1(# #);
          putGrammarName: putson1(# #);
          getOptionOp: getson2(# #);
          putOptionOp: putson2(# #);
          getProductionList: getson3(# #);
          putProductionList: putson3(# #);
          getAttributeOp: getson4(# #);
          putAttributeOp: putson4(# #);
          <<SLOT AGrammarAttributes:attributes>>
       exit 1
       #);
     GrammarName: cons
       (# getNameDecl: getson1(# #);
          putNameDecl: putson1(# #);
       exit 2
       #);
     ProductionList: list
       (# soncat::< Prod;
       exit 3
       #);
     Prod: cons
       (# <<SLOT ProdAttributes:attributes>> #);
     LeftSide: cons
       (# getSynDeclName: getson1(# #);
          putSynDeclName: putson1(# #);
          <<SLOT LeftSideAttributes:attributes>>
       exit 5
       #);
     Alternation: Prod
       (# getLeftSide: getson1(# #);
          putLeftSide: putson1(# #);
          getSynCatList: getson2(# #);
          putSynCatList: putson2(# #);
       exit 6
       #);
     SynCatList: list
       (# soncat::< SynCat;
       exit 7
       #);
     Constructor: Prod
       (# getLeftSide: getson1(# #);
          putLeftSide: putson1(# #);
          getConsElemList: getson2(# #);
          putConsElemList: putson2(# #);
       exit 8
       #);
     ConsElemList: list
       (# soncat::< ConsElem;
       exit 9
       #);
     ConsElem: cons
       (# <<SLOT ConsElemAttributes:attributes>> #);
     TaggedSyn: ConsElem
       (# getTagName: getson1(# #);
          putTagName: putson1(# #);
          getSynName: getson2(# #);
          putSynName: putson2(# #);
          <<SLOT TaggedSynAttributes:attributes>>
       exit 11
       #);
     SynCat: ConsElem
       (# getSynName: getson1(# #);
          putSynName: putson1(# #);
          <<SLOT SynCatAttributes:attributes>>
       exit 12
       #);
     ErrorSpec: ConsElem
       (# exit 13 #);
     Lst: Prod
       (# #);
     ListOne: Lst
       (# getLeftSide: getson1(# #);
          putLeftSide: putson1(# #);
          getSynCat: getson2(# #);
          putSynCat: putson2(# #);
          getTermOp: getson3(# #);
          putTermOp: putson3(# #);
       exit 15
       #);
     ListZero: Lst
       (# getLeftSide: getson1(# #);
          putLeftSide: putson1(# #);
          getSynCat: getson2(# #);
          putSynCat: putson2(# #);
          getTermOp: getson3(# #);
          putTermOp: putson3(# #);
       exit 16
       #);
     Opt: Prod
       (# getLeftSide: getson1(# #);
          putLeftSide: putson1(# #);
          getSynCat: getson2(# #);
          putSynCat: putson2(# #);
       exit 18
       #);
     Dummy: Prod
       (# getLeftSide: getson1(# #);
          putLeftSide: putson1(# #);
          getSynCat: getson2(# #);
          putSynCat: putson2(# #);
       exit 19
       #);
     SynName: cons
       (# getNameAppl: getson1(# #);
          putNameAppl: putson1(# #);
          <<SLOT SynNameAttributes:attributes>>
       exit 20
       #);
     TagName: cons
       (# getNameDecl: getson1(# #);
          putNameDecl: putson1(# #);
       exit 21
       #);
     SynDeclName: cons
       (# getNameDecl: getson1(# #);
          putNameDecl: putson1(# #);
       exit 22
       #);
     Term: ConsElem
       (# getString: getson1(# #);
          putString: putson1(# #);
          <<SLOT TermAttributes:attributes>>
       exit 23
       #);
     OptionPart: cons
       (# getoptionList: getson1(# #);
          putoptionList: putson1(# #);
       exit 25
       #);
     optionList: list
       (# soncat::< optionElement;
       exit 26
       #);
     optionElement: cons
       (# getoptionName: getson1(# #);
          putoptionName: putson1(# #);
          getoptionSpecification: getson2(# #);
          putoptionSpecification: putson2(# #);
       exit 27
       #);
     optionSpecification: cons
       (# #);
     optionSpecLst: optionSpecification
       (# getoptionSpecList: getson1(# #);
          putoptionSpecList: putson1(# #);
       exit 29
       #);
     optionSpecList: list
       (# soncat::< singleOption;
       exit 30
       #);
     singleOption: optionSpecification
       (# #);
     optionName: singleOption
       (# getNameAppl: getson1(# #);
          putNameAppl: putson1(# #);
       exit 32
       #);
     optionConst: singleOption
       (# getConst: getson1(# #);
          putConst: putson1(# #);
       exit 33
       #);
     optionString: singleOption
       (# getString: getson1(# #);
          putString: putson1(# #);
       exit 34
       #);
     AttributePart: cons
       (# getattriblist: getson1(# #);
          putattriblist: putson1(# #);
       exit 36
       #);
     AttribList: list
       (# soncat::< Attrib;
       exit 37
       #);
     Attrib: cons
       (# getSynCat: getson1(# #);
          putSynCat: putson1(# #);
          getNoOfAttributes: getson2(# #);
          putNoOfAttributes: putson2(# #);
       exit 38
       #);
     NoOfAttributes: cons
       (# getconst: getson1(# #);
          putconst: putson1(# #);
       exit 39
```

```
      #);
    errorProd: Prod
      (# exit 40 #);
    optionError: singleOption
      (# exit 41 #);

    grammarIdentification::<(# do 'metagrammar' -> theGrammarName #);
    version::<(# do 5 -> value #);
    suffix::<(# do '.gram' -> theSuffix #);
    maxproductions::<(# do 41 -> value #);

    init::<(# ... #);
 #)
```

Metagrammarcfl Interface Mjølner Informatics

Metagramsematt Interface

```
ORIGIN 'metagrammarcfl'
(*
 * COPYRIGHT
 *       Copyright (C) Mjolner Informatics, 1986-93
 *       All rights reserved.
 *)
--- prodAttributes: attributes ---
leftSide:
  (#
  enter putson1
  exit getson1
  #);
getSynDeclText:
  (# ls: ^this(metagrammar).leftSide;
     sd: ^SynDeclName;
     n: ^NameDecl;
  do getson1 -> ls[];
     ls.GetSynDeclName -> sd[];
     sd.getNameDecl -> n[];
  exit n.getText
  #);
superValue:
  (# ls: ^this(metagrammar).leftSide;
  do getson1 -> ls[];
  exit ls.superValue
  #);
superProd:
  (# prodNo: @integer;
     theProd: ^prod;
     predefined:< object;
     f: ^productionList
  do superValue -> prodNo;
     (if (prodNo>0) then
         father -> f[];
         prodNo -> f.get -> theProd[]
      else predefined
     if)
  exit theProd[]
  #)

--- leftsideAttributes: attributes ---
getSynDeclText:
  (# sd: ^SynDeclName;
     n: ^nameDecl;
  do GetSynDeclName -> sd[];
     sd.getNameDecl -> n[];
  exit n.getText
  #);
superValue:
  (# value: @integer
  enter (# enter value do (value,1) -> putAttribute #)
  exit 1 -> getAttribute
  #);
attributeSize:
  (# value: @integer
  enter (# enter value do (value,2) -> putAttribute #)
  exit 2 -> getAttribute
  #);

--- taggedSynAttributes: attributes ---
getSynText:
  (# sn: ^synName;
     n: ^nameappl;
  do getSynName -> sn[];
     sn.getNameAppl -> n[];
  exit n.getText
  #);
getTagText:
  (# tn: ^tagName;
     n: ^nameDecl;
  do getTagName -> tn[];
     tn.getNameDecl -> n[];
  exit n.getText
  #);

--- termAttributes: attributes ---
getText:
  (# s: ^string
  do getString -> s[];
  exit s.getText
  #)

--- syncatAttributes: attributes ---
getSynText:
  (# sn: ^synName;
     s: ^nameappl;
  do getSynName -> sn[];
     sn.getNameAppl -> s[];
  exit s.getText
  #);

--- synNameAttributes: attributes ---
dclRef:
  (# value: @integer
  enter (# enter value do (value,1) -> putAttribute #)
  exit 1 -> getAttribute
  #);
dclRefProd:
  (# prodNo: @integer;
     theProd: ^prod;
     predefined:< object;
     theGrammar: ^agrammar;
  do dclRef -> prodNo;
     (if (prodNo>0) then
         frag.root[] -> theGrammar[];
         prodNo -> theGrammar.getProd -> theProd[]
      else predefined
     if)
  exit theProd[]
  #);
getSynText:
  (# s: ^nameappl;
  do getNameAppl -> s[];
  exit s.getText
  #);

--- AGrammarAttributes: attributes ---
getProd:
  (# prodNo: @integer;
     theProd: ^prod;
     pl: ^productionList;
  enter prodNo
  do getProductionList -> pl[];
     prodNo -> pl.get -> theProd[]
  exit theProd[]
  #);
OptionSet:
  (# t: @text;
     optSpec: ^optionSpecification;
     opPart: ^optionPart;
     op: ^ast;
     optList: ^optionList;
  enter t
  do getOptionOp -> op[];
     (if (op.symbol=optionPart) then
         op[] -> opPart[];
         opPart.getOptionList -> optList[];
     if);
     (if (optList[]<>none) then
         scan: optList.scan
           (#
              optionEl: ^optionElement;
              optName: ^optionName;
              ap: ^nameAppl;
           do current[] -> optionEl[];
              optionEl.getOptionName -> optName[];
              optName.getNameAppl -> ap[];
              (if (ap.getText -> t.equalNCS) then
                  optionEl.getOptionSpecification -> optSpec[];
                  leave scan;
              if);
           #)
     if)
  exit OptSpec[]
  #);
```
checkOption:
```
   (# errortext: @text;
      spec: ^optionSpecification;
      checkedSymbol: @integer;
      as: ^ast;
   enter (spec[],errortext,checkedSymbol)
   do (if (spec.symbol=checkedSymbol) then
          spec.getson1 -> as[];
       else
          'ERROR in option-Specification for ' -> putText;
          errorText[] -> putText;
          screen.newLine;
          'Expected symbol: ' -> screen.putText;
          checkedSymbol -> screen.putInt;
          screen.newLine;
          'Found symbol: ' -> screen.putText;
          spec.symbol -> screen.putInt;
          screen.newLine;
      if)
   exit as[]
   #);
```
GetOptionValue:
```
   (# value: @integer;
      optionName: @text;
      c: ^const;
      optSpec: ^optionSpecification;
   enter (optionName,value)
   do (if ((optionName -> optionSet -> optSpec[])<>none) then
          (optSpec[],OptionName,optionConst) -> checkOption -> c[];
          c.getValue -> value;
      if);
   exit value
   #);
```
GetOptionName:
```
   (# value: @text;
      theOptionName: @text;
      c: ^lexemText;
      optSpec: ^optionSpecification;
   enter (theOptionName,value)
```

```
  do (if ((theOptionName -> optionSet -> optSpec[])<>none) then
         (optSpec[],theOptionName,optionName) -> checkOption -> c[];
         c.getText -> (# t: ^text enter t[] exit t #) -> value;
     if);
  exit value
  #);
```
GetOptionString:
```
  (# value: @text;
     optionName: @text;
     c: ^lexemText;
     optSpec: ^optionSpecification;
  enter (optionName,value)
  do (if ((optionName -> optionSet -> optSpec[])<>none) then
         (optSpec[],OptionName,optionString) -> checkOption -> c[];
         c.getText -> (# t: ^text enter t[] exit t #) -> value;
     if);
  exit value
  #)
```

Notifications Interface

```
ORIGIN 'astlevel';
INCLUDE 'observer';
LIB_ITEM 'mpsastlevel';
BODY 'private/notificationsbody';
(* This fragment implements a signalling system to be used by different
 * software components, each manipulating fragments through the same
 * mps instance.
 *
 * The system consists of the concept of a 'handle', which the software
 * component can use to both signal, that it has made some changes to
 * a fragment, and to subscribe to information on what other software
 * components are doing to the fragments.
 *
 * A handle therefore has a dual set of operations:
 *    'signal's and 'event's
 * A 'signal' operation is named 'signalXXX', and the corresponding
 * event is called 'onXXX', where 'XXX' is the name of the change
 * being reported.
 *
 * It is the responsability of the software component making the change
 * to signal this change.  This is done by invoking the corresponding
 * 'signalXXX' operation.  If a software component want to monitor
 * particular changes, it must obtain a handle with proper further
 * binding of the corresonding 'eventXXX' (more on this later).
 *
 * A few of these signals are automatically invoked by 'mps'.
 * In these cases, this is explicitly specified in the operation below.
 *
 * A software component obtains a handle by:
 *
 *    mps.getHandle
 *      (# handleType::
 *           (# onGroupOpen::
 *                (# do fg.fullname->puttext; ' opened'->putline #);
 *              onGroupClose
 *                (# do fg.fullname->puttext; ' closed'->putline #);
 *              ...etc...
 *           #)
 *      #);
 *
 * This handle monitors opening and closing of all fragment groups.
 *
 * If you want a handle, that only monitors a particular fragment
 * group, you can do this by:
 *
 *    mps.getHandle
 *      (# handleType::
 *           (# ignore:: (# (fg[]<>myFG[])->value #);
 *              ... som ovenfor ...
 *          #)
 *      #);
 *
 * You can get hold of this newly created handle by:
 *
 *    mps.getHandle(# ...som ovenfor... #)->h[];
 *
 * in which case it becomes possible later to decide to cancel this
 * handle by:
 *
 *    h[]->mps.ignoreHandle;
 *
 * If you later want to reactivate this handle, you can always do :
```

```
 *
 *    h[]->mps.activateHandle;
 *
 * If you have made changes to a fragment group, e.g. replaced an ast,
 * you can signal this to the other components by:
 *
 *    (fg[], ff[], oldAst[], newAst[])->mps.signalAstReplaced
 *
 * If you wish to control which handlers, signals are send to, you can
 * use the 'where' clause of 'signal'.  E.g. if you with to send a
 * signal to all handlers, except 'h[]', you can do this by:
 *
 *    (fg[], ff[], oldAst[], newAst[])->mps.signalAstReplaced
 *      (# where:: (# do (current[]<>h[])->value #) #)
 *)
(* This fragment implements a signalling system to be used by different
 * software components, each manipulating fragments through the same
 * mps instance.
 *
 * The system consists of the concept of a 'handle', which the software
 * component can use to both signal, that it has made some changes to
 * a fragment, and to subscribe to information on what other software
 * components are doing to the fragments.
 *
 * A handle therefore has a dual set of operations:
 *    'signal's and 'event's
 * A 'signal' operation is named 'signalXXX', and the corresponding
 * event is called 'onXXX', where 'XXX' is the name of the change
 * being reported.
 *
 * It is the responsability of the software component making the change
 * to signal this change.  This is done by invoking the corresponding
 * 'signalXXX' operation.  If a software component want to monitor
 * particular changes, it must obtain a handle with proper further
 * binding of the corresonding 'eventXXX' (more on this later).
 *
 * A few of these signals are automatically invoked by 'mps'.
 * In these cases, this is explicitly specified in the operation below.
 *
 * A software component obtains a handle by:
 *
 *    mps.getHandle
 *      (# handleType::
 *           (# onGroupOpen::
 *                (# do fg.fullname->puttext; ' opened'->putline #);
 *              onGroupClose
 *                (# do fg.fullname->puttext; ' closed'->putline #);
 *              ...etc...
 *           #)
 *      #);
 *
 * This handle monitors opening and closing of all fragment groups.
 *
 * If you want a handle, that only monitors a particular fragment
 * group, you can do this by:
 *
 *    mps.getHandle
 *      (# handleType::
 *           (# ignore:: (# (fg[]<>myFG[])->value #);
 *              ... som ovenfor ...
 *          #)
 *      #);
 *
 * You can get hold of this newly created handle by:
 *
 *    mps.getHandle(# ...som ovenfor... #)->h[];
 *
 * in which case it becomes possible later to decide to cancel this
 * handle by:
 *
 *    h[]->mps.ignoreHandle;
 *
 * If you later want to reactivate this handle, you can always do :
 *
 *    h[]->mps.activateHandle;
 *
 * If you have made changes to a fragment group, e.g. replaced an ast,
 * you can signal this to the other components by:
 *
 *    (fg[], ff[], oldAst[], newAst[])->mps.signalAstReplaced
 *
 * If you wish to control which handlers, signals are send to, you can
 * use the 'where' clause of 'signal'.  E.g. if you with to send a
 * signal to all handlers, except 'h[]', you can do this by:
 *
 *    (fg[], ff[], oldAst[], newAst[])->mps.signalAstReplaced
 *      (# where:: (# do (current[]<>h[])->value #) #)
 *)
-- astinterfacelib: Attributes --
getHandle: (* called to get a new handle on this MPS *)
  (# handleType:< handle; h: ^handleType
  ...
  exit h[]
  #);
ignoreHandle:
(* called to return a handle (i.e. now wanting to be monitoring
 * this MPS through this handle 'h' any longer
 *) (# h: ^handle enter h[] ... #);
activateHandle:
(* called to activate a handle (i.e. now wanting to be monitoring
 * this MPS through this handle 'h' again
 *) (# h: ^handle enter h[] ... #);
handle:
(* this defines the events of a handle *)
  (#
     ignore:< booleanValue
     (* if this returns TRUE, this(handle) will be ignored *)
       (#
          fg: ^astInterface.fragmentGroup;
          ff: ^astInterface.fragmentForm;
          node: ^astInterface.ast
       enter (fg[],ff[],node[])
       do INNER
       #);
     event: (* abstract superpattern *) (# do INNER #);
     fragmentGroupEvent: event (* abstract superpattern *)
       (# fg: ^astInterface.fragmentGroup;  enter fg[] do INNER ;  #);
     fragmentFormEvent: fragmentGroupEvent (* abstract superpattern *)
       (# ff: ^astInterface.fragmentForm;  enter ff[] do INNER ;  #);
     astEvent: fragmentFormEvent (* abstract superpattern *)
       (# node: ^astInterface.ast enter node[] do INNER #);
     onGroupOpen:< fragmentGroupEvent
     (* invoked by MPS when fg[] have been opened by someone *)
       (# do INNER #);
     onGroupLock:< fragmentGroupEvent (* invoked by MPS when fg[] is locked *)
       (# do INNER #);
     onGroupUnlock:< fragmentGroupEvent
     (* invoked by MPS when fg[] is unlocked *) (# do INNER #);
     onGroupPack:< fragmentGroupEvent
     (* invoked by MPS when fg[] is saved to disk *) (# do INNER #);
     onGroupUnpack:< fragmentGroupEvent
     (* invoked by MPS when fg[] is unpacked from disk *)
```

```
        (# do INNER #);
      onBeforeGroupClose:< fragmentGroupEvent
      (* invoked by MPS before fg[] is closed
       *    okToClose=false   => fg will not be closed.
       *)
        (# okToClose: @boolean
        do true->okToClose; INNER
        exit okToClose
        #);
      onGroupClose:< fragmentGroupEvent
      (* invoked by MPS when fg[] have been closed *) (# do INNER #);
      onTrace:< event (* invoked by MPS if tracing is activated *)
        (# msg: ^text enter msg[] do INNER #)
   #);
signal:
   (#
      where:< booleanValue (#  do true->value; INNER #);
      start:< object (* executed before the signal is posted to all handlers *) ;
      current: ^handle;
      fg: ^astInterface.fragmentGroup;
      ff: ^astInterface.fragmentForm;
      node: ^astInterface.ast;

   ...
   #);
fragmentGroupSignal: signal
(* abstract superpattern *) (#  enter fg[] do INNER #);
fragmentFormSignal: signal (* abstract superpattern *)
   (#  enter ff[] do INNER #);
astSignal: signal (* abstract superpattern *)
   (#  enter node[] do INNER #);
signalGroupOpen: fragmentGroupSignal (#  do fg[]->current.onGroupOpen #);
signalGroupLock: fragmentGroupSignal (#  do fg[]->current.onGroupLock #);
signalGroupUnlock: fragmentGroupSignal
   (#  do fg[]->current.onGroupUnlock #);
signalGroupPack: fragmentGroupSignal (#  do fg[]->current.onGroupPack #);
signalGroupUnpack: fragmentGroupSignal
   (#  do fg[]->current.onGroupUnpack #);
signalBeforeGroupClose: fragmentGroupSignal
   (# okToClose: @boolean; start::<  (#  do true->okToClose; INNER #);
   do (okToClose and (fg[]->current.onBeforeGroupClose))->okToClose
   exit okToClose
   #);
signalGroupClose: fragmentGroupSignal (#  do fg[]->current.onGroupClose #);
signalTrace: signal
   (#
      traceNo: @integer;
      msg: ^text;
      start::<
        (#
        do 'Trace: '->msg[]; traceNo->msg.putInt; ' '->msg.put; INNER
        #)
   enter traceNo
   do msg[]->current.onTrace
   #);
astFocus:
   (# node: ^astInterface.ast; length,subCommentInx1,subCommentInx2: @integer
   enter (node[],length,subCommentInx1,subCommentInx2)
   exit (node[],length,subCommentInx1,subCommentInx2)
   #);
astList: (# elm: [50] ^astInterface.ast #);
astReplacedElement: (# oldAst,newAst: ^astInterface.ast #);
astReplacedList: containerList
   (#
      element:: astReplacedElement;
      appendElement:
        (# oldAst,newAst: ^astInterface.ast; e: ^astReplacedElement;
        enter (oldAst[],newAst[])
        do &astReplacedElement[]->e[];
           oldAst[]->e.oldAst[];
           newAst[]->e.newAst[];
           e[]->append
        #)
   #);

-- fragmentGroupLib: Attributes --
attachObserver: (* called to attach a new observer on this fragmentgroup *)
   (# theObserver: ^fragmentGroupObserver;
   enter theObserver[]
   ...
   #);
detachObserver:
(* called to detach an observer (i.e. now wanting to be monitoring
 * this fragmentGroup through this observer 'o' any longer
 *)
   (# theObserver: ^fragmentGroupObserver;
   enter theObserver[]
   ...
   #);
notify:
   (#
      where:<
       booleanValue (#  do true->value; INNER #);
      before:< object
      (* executed before the notification is posted to all observers *) ;
      after:< object
      (* executed after the notification is posted to all observers *) ;
      current: ^fragmentGroupObserver;
      ff: ^astInterface.fragmentForm;

   ...
   #);
notifyAs:
   (#
      where:< booleanValue
        (#
        do true->value; INNER
        #);
      before:< object
      (* executed before the notification is posted to all observers *) ;
      after:< object
      (* executed after the notification is posted to all observers *) ;
      current: ^type;
      type:< fragmentGroupObserver;
      ff: ^astInterface.fragmentForm;

   ...
   #);
fragmentFormNotify: notify
   (#  enter ff[] do INNER #);
notifyNameChanged:
 fragmentFormNotify
   (# oldName,newName: ^text;
   enter (oldName[],newName[])
   do (ff[],oldName[],newName[])->current.onNameChanged
   #);
notifyFragmentInserted: fragmentFormNotify
   (#  do ff[]->current.onFragmentInserted #);
notifyFragmentDeleted: fragmentFormNotify
   (#  do ff[]->current.onFragmentDeleted #);
notifyPropertiesChanged: notify
   (# oldProp,newProp: ^propertyList;
   enter (oldProp[],newProp[])
   do (oldProp[],newProp[])->current.onPropertiesChanged
   #);
notifyGroupSaved: notify (#  do current.onGroupSaved #);
notifyGroupNotSaved: notify (#  do current.onGroupNotSaved #);
notifyGroupAutosaved: notify (#  do current.onGroupAutosaved #);
notifyGroupChecked: notify
   (# semanticErrors: @boolean
   enter semanticErrors
   do semanticErrors->current.onGroupChecked
   #);
notifyGroupLocked: notify (#  do current.onGroupLocked #);
notifyGroupUnlocked: notify (#  do current.onGroupUnlocked #);
notifyBeforeGroupClose: notify
   (# okToClose: @boolean; before::<  (#  do true->okToClose; INNER #);
   do (okToClose and current.onBeforeGroupClose)->okToClose
   exit okToClose
   #);
notifyGroupClosed: notify (#  do current.onGroupClosed #);

-- fragmentFormLib: Attributes --
attachObserver: (* called to attach a new observer on this fragmentform *)
   (# theObserver: ^fragmentFormObserver;
   enter theObserver[]
   ...
   #);
detachObserver:
(* called to detach an observer (i.e. now wanting to be monitoring
 * this fragmentForm through this observer 'o' any longer
 *)
   (# theObserver: ^fragmentFormObserver
   enter theObserver[]
   ...
   #);
notify:
   (#
      where:<
       booleanValue (#  do true->value; INNER #);
      before:< object
      (* executed before the notification is posted to all observers *) ;
      after:< object
      (* executed after the notification is posted to all observers *) ;
      current: ^fragmentFormObserver;
      node: ^astInterface.ast;

   ...
   #);
notifyAs:
   (#
      where:< booleanValue
        (#
        do true->value; INNER
        #);
      before:< object
      (* executed before the notification is posted to all observers *) ;
      after:< object
      (* executed after the notification is posted to all observers *) ;
      current: ^type;
      type:< fragmentFormObserver;
      node: ^astInterface.ast;

   ...
   #);
listNotify: notify
(* abstract superpattern *) (#  enter node[] do INNER #);
notifyAstReplaced: notify
```

```
  (# oldAst,newAst: ^astInterface.ast;
  enter (oldAst[],newAst[])
  do (oldAst[],newAst[])->current.onAstReplaced
  #);
notifyAstReplacedSequence: notify
  (# theSequence: ^astReplacedList
  enter (node[],theSequence[])
  do (node[],theSequence[])->current.onAstReplacedSequence
  #);
notifyListElementInserted: listNotify
  (# position: @integer
  enter position
  do (node[],position)->current.onListElementInserted
  #);
notifyListElementsDeleted: listNotify
  (# oldElements: ^astList; position,length: @integer
  enter (position,length,oldElements[])
  do (node[],position,length,oldElements[])->current.onListElementsDeleted
  #);
notifyListElementsReplaced: listNotify
  (# oldElements: ^astList; position,length,newLength: @integer
  enter (position,length,oldElements[],newLength)
  do (node[],position,length,oldElements[],newLength)
      ->current.onListElementsReplaced
  #);
locked: booleanValue (# ... #);
lock: (# ... #);
unLock: (# ... #);

-- lib: Attributes --
fragmentGroupObserver: observer
  (#
     group: ^astInterface.fragmentGroup;
     no: @integer;
     ignore:< booleanValue
     (* if this returns TRUE, this(fragmentGroupObserver) will be ignored *)
       (# do INNER #);
     fragmentFormEvent:
       (# ff: ^astInterface.fragmentForm enter ff[] do INNER #);
     fragmentGroupEvent: (# do INNER #);
     onNameChanged:< fragmentFormEvent
     (* invoked if ff[] have been given a new name *)
       (# oldName,newName: ^text;
       enter (oldName[],newName[])
       do INNER ;
       #);
     onFragmentInserted:< fragmentFormEvent
     (* invoked when ff[] is inserted in fg[] *) (# do INNER #);
     onFragmentDeleted:< fragmentFormEvent
     (* invoked when ff[] is deleted from fg[] *) (# do INNER #);
     onPropertiesChanged:< fragmentGroupEvent
     (* invoked when the properties of fg[] have changed *)
       (# oldProp,newProp: ^propertyList;
       enter (oldProp[],newProp[])
       do INNER
       #);
     onGroupSaved:< fragmentGroupEvent (* invoked when fg[] have been saved *)
       (# do INNER #);
     onGroupNotSaved:< fragmentGroupEvent
     (* invoked when quitting without saving the fg[],
      * either because no changes have been made to the fg
      * or becauset he user has decided not to save the changes
      *)
       (# do INNER #);
     onGroupAutoSaved:< fragmentGroupEvent
     (* invoked when fg[] have been auto-saved *) (# do INNER #);
```

```
    onGroupChecked:< fragmentGroupEvent
    (* invoked when fg[] have been checked by the checker *)
      (# semanticErrors: @boolean enter semanticErrors do INNER #);
    onGroupLocked:< fragmentGroupEvent (* invoked by MPS when fg[] is locked *)
    (# do INNER #);
    onGroupUnlocked:< fragmentGroupEvent
    (* invoked by MPS when fg[] is unlocked *) (# do INNER #);
    onBeforeGroupClose:< fragmentGroupEvent
    (* invoked by MPS before fg[] is closed
     *    okToClose=false   => fg will not be closed.
     *)
      (# okToClose: @boolean
      do true->okToClose; INNER
      exit okToClose
      #);
    onGroupClosed:< fragmentGroupEvent
    (* invoked by MPS when fg[] have been closed *) (# do INNER #)
  #);
fragmentFormObserver: observer
  (#
    frag: ^astinterface.fragmentForm;
    no: @integer;
    astEvent: (* abstract superpattern *)
      (#  do before; INNER ; after #);
    listEvent: astEvent
      (# node: ^astInterface.list enter node[] do INNER #);
    before:< object (* executed before INNER in all astEvents   *) ;
    after:< object (* executed after INNER in all astEvents *) ;
    onAstReplaced:< astEvent (* invoked when an ast has been replaced *)
      (# oldAst,newAst: ^astInterface.ast;
      enter (oldAst[],newAst[])
      do INNER
      #);
    onAstReplacedSequence:< astEvent
    (* invoked when a sequence of astReplaced events have occured in node[]  *)
      (# node: ^astInterface.ast; theSequence: ^astInterface.astReplacedList
      enter (node[],theSequence[])
      do INNER
      #);
    onListElementInserted:< listEvent
    (* invoked when a new list element have been inserted in node[] *)
      (# position: @integer;  enter position do INNER #);
    onListElementsDeleted:< listEvent
    (* invoked when a list of elements have been deleted from node[] *)
      (# oldElements: ^astInterface.astList; position,length: @integer
      enter (position,length,oldElements[])
      do INNER
      #);
    onListElementsReplaced:< listEvent
    (* invoked when a list of elements have been replaced in node[] *)
      (#
         oldElements: ^astInterface.astList;
         position,length,newLength: @integer
      enter (position,length,oldElements[],newLength)
      do INNER
      #)
  #)
```

Observer Interface

```
ORIGIN '~beta/basiclib/betaenv';
INCLUDE '~beta/containers/sets';
-- lib: Attributes --
Subject:
  (#
     observerType:< Observer;
     init:< (#  do observers.init; INNER ;  #);
     attach:
       (# theObserver: ^observerType;
       enter theObserver[]
       do theObserver[]->observers.insert;
       #);
     detach:
       (# theObserver: ^observerType;
       enter theObserver[]
       do theObserver[]->observers.delete
       #);
     notify:
       (# current: ^observerType;
       do observers.scan
            (#
            do (if not current.ignore then
                   current[]->THIS(notify).current[]; INNER notify;
               if);

            #);

       #);
     notifyUpdate: notify (#  do current.Update;  #);
     notifyOfType:
       (# type:< Observer; current: ^type;
       do observers.scan
            (#
            do (if not current.ignore then
                   (if current## <= type## then
                       current[]->THIS(notifyOfType).current[];
                       INNER notifyOfType;

                   if);

               if);

            #);

       #);
     observers: @set (# element:: observerType #);

  #);
Observer: (# ignore:< booleanValue; update:< (# do INNER #);  #)
```

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Property Interface

```
ORIGIN '~beta/basiclib/betaenv';
LIB_DEF 'mpsproperty' '../lib';
INCLUDE '~beta/containers/list';
INCLUDE '~beta/basiclib/repstream';
BODY 'private/propertyBody'
(*
 * COPYRIGHT
 *       Copyright (C) Mjolner Informatics, 1986-93
 *       All rights reserved.
 *)

--- LIB: attributes ---
constType: (# exit 1 #);
StringType: (# exit 2 #);
nameType: (# exit 3 #);
parValue:
  (# repSave:< (* Private *)
       (# f: ^repetitionStream enter f[] do INNER #)
  #);
constElement: parValue
  (# c: @integer;
     repsave::< (* Private *) (# do c -> f.putInt #)
  #);
StringElement: parValue
  (# s: @text;
     repsave::< (* Private *) (# do s[] -> f.putText #)
  #);
nameElement: parValue
  (# n: @text;
     repsave::< (* Private *) (# do n[] -> f.putText #)
  #);
propertyList:
  (# propElement:
       (# prop: @text;
          par: @parameterList;
          <<SLOT propertyPropertyListPropElementRepresentationPrivate: attributes>>;
       #);
     propList: @list
       (# element::< propElement;
          <<SLOT propertyPropertyListPropListRepresentationPrivate: attributes>>;
       #);
     init: (# do propList.init #);
     <<SLOT propertyPropertyListRepresentationPrivate: attributes>>;
     addProp:
       (# propName: ^text;
          newPropElement: ^propElement;
          ifPropExist:< (# delete: @boolean do true -> delete; INNER exit delete #);
          newPar:
            (# parType:< parValue;
               val: ^parType;
               par: ^parElement;
            do &parElement[] -> par[];
               &parType[] -> par.val[] -> val[];
               INNER;
               par[] -> newPropElement.par.append
            #);
          addString: newPar
            (# parType::< stringElement;
               s: ^text;
            enter s[]
            do stringType -> par.type; s -> val.s;
            #);
          addName: newPar
            (# parType::< nameElement;
               n: ^text
            enter n[] do nameType -> par.type; n -> val.n;
            #);
          addConst: newPar
            (# parType::< constElement;
               c: @integer
            enter c do constType -> par.type; c -> val.c;
            #);
        enter propName[]
        ...
        #);
     findProp:
        (# name: ^text;
           l: ^proplist.element
        enter name[]
        ...
        exit l[]
        #);
     deleteProp:
        (# prop: ^text;
        enter prop[]
        do ...
        #);
     scanProp:
        (# currentParList: ^parameterList;
           doProp:<
             (# prop: ^text;
                getName:
                  (# notAName:< (# do INNER #);
                     name: ^text;
                  do ...
                  exit name[]
                  #);
                getConst:
                  (# notAConst:< (# do INNER #);
                     const: @integer
                  do ...
                  exit const
                  #);
                getString:
                  (# notAString:< (# do INNER #);
                     string: ^text
                  do ...
                  exit string[]
                  #);
                scanParameters:
                  (# doConst:< (# c: @integer enter c do INNER #);
                     doString:< (# s: ^text enter s[] do INNER #);
                     doName:< (# n: ^text enter n[] do INNER #);
                  ...
                  #)

             enter prop[]
             do INNER
             #);
        ...
        #);
     GetProp: ScanProp
        (# doProp::< (# do (if (prop[]->P.equalNCS) then INNER if)#);
           P: ^text
        enter P[]
        #);
  #);
parameterList: list(# element::< parElement #);
```

```
parElement:
  (# val: ^parvalue;
     type: @integer;
     <<SLOT propertyParElementLocalsPrivate: attributes>>;
  #)
```

Property Interface Mjølner Informatics

Propertycfl Interface

```
ORIGIN '~beta/mps/astlevel'
--astInterfaceLib: attributes--

property: TreeLevel
  (# <<SLOT propertyAttributes:attributes>>;
     Properties: cons
       (# getPropertyList: getson1(# #);
          putPropertyList: putson1(# #);
       exit 1
       #);
     PropertyList: list
       (# soncat::< Property;
       exit 2
       #);
     Property: cons
       (# #);
     ORIGIN: Property
       (# getTextConst: getson1(# #);
          putTextConst: putson1(# #);
       exit 5
       #);
     INCLUDE: Property
       (# getStringList: getson1(# #);
          putStringList: putson1(# #);
       exit 6
       #);
     BODY: Property
       (# getStringList: getson1(# #);
          putStringList: putson1(# #);
       exit 7
       #);
     MDBODY: Property
       (# getMachineSpecificationList: getson1(# #);
          putMachineSpecificationList: putson1(# #);
       exit 8
       #);
     OBJFILE: Property
       (# getMachineSpecificationList: getson1(# #);
          putMachineSpecificationList: putson1(# #);
       exit 9
       #);
     LIBFILE: Property
       (# getMachineSpecificationList: getson1(# #);
          putMachineSpecificationList: putson1(# #);
       exit 10
       #);
     LINKOPT: Property
       (# getMachineSpecificationList: getson1(# #);
          putMachineSpecificationList: putson1(# #);
       exit 11
       #);
     BETARUN: Property
       (# getMachineSpecificationList: getson1(# #);
          putMachineSpecificationList: putson1(# #);
       exit 12
       #);
     MAKE: Property
       (# getMachineSpecificationList: getson1(# #);
          putMachineSpecificationList: putson1(# #);
       exit 13
       #);
     BUILD: Property
```

```
    (# getMachineSpecificationList: getson1(# #);
       putMachineSpecificationList: putson1(# #);
    exit 14
    #);
  RESOURCE: Property
    (# getMachineSpecificationList: getson1(# #);
       putMachineSpecificationList: putson1(# #);
    exit 15
    #);
  LIBDEF: Property
    (# getStringList: getson1(# #);
       putStringList: putson1(# #);
    exit 16
    #);
  LIBITEM: Property
    (# getName: getson1(# #);
       putName: putson1(# #);
    exit 17
    #);
  ON: Property
    (# getIntegerList: getson1(# #);
       putIntegerList: putson1(# #);
    exit 18
    #);
  OFF: Property
    (# getIntegerList: getson1(# #);
       putIntegerList: putson1(# #);
    exit 19
    #);
  StringList: list
    (# soncat::< TextConst;
    exit 20
    #);
  IntegerList: list
    (# soncat::< IntegerConst;
    exit 21
    #);
  MachineSpecificationList: list
    (# soncat::< MachineSpecification;
    exit 22
    #);
  MachineSpecification: cons
    (# getMachine: getson1(# #);
       putMachine: putson1(# #);
       getStringList: getson2(# #);
       putStringList: putson2(# #);
    exit 23
    #);
  Machine: cons
    (# #);
  Default: Machine
    (# exit 25 #);
  Other: Property
    (# getNameDcl: getson1(# #);
       putNameDcl: putson1(# #);
       getPropertyValueList: getson2(# #);
       putPropertyValueList: putson2(# #);
    exit 26
    #);
  PropertyValueList: list
    (# soncat::< PropertyValue;
    exit 27
    #);
  PropertyValue: cons
    (# getValue: getson1(# #);
       putValue: putson1(# #);
```

```
      exit 28
      #);
    Value: cons
      (# #);
    NameDcl: Value
      (# getNameDecl: getson1(# #);
         putNameDecl: putson1(# #);
      exit 30
      #);
    NameApl: Machine
      (# getNameAppl: getson1(# #);
         putNameAppl: putson1(# #);
      exit 31
      #);
    TextConst: Value
      (# getString: getson1(# #);
         putString: putson1(# #);
      exit 32
      #);
    IntegerConst: Value
      (# getConst: getson1(# #);
         putConst: putson1(# #);
      exit 33
      #);

    grammarIdentification::<(# do 'property' -> theGrammarName #);
    version::<(# do 4 -> value #);
    suffix::<(# do '.prop' -> theSuffix #);
    maxproductions::<(# do 33 -> value #);

    init::<(# ... #);
  #)
```

Propertyparser Interface

```
ORIGIN 'astlevel';
INCLUDE '~beta/basiclib/file';
LIB_ITEM 'mpsastlevel';
(*
 * COPYRIGHT
 *       Copyright (C) Mjolner Informatics, 1986-93
 *       All rights reserved.
 *)
-- fragmentgrouplib: Attributes --
propertyParser: (* for parsing a property specification *)
(* Recursive-descend parser for the grammar:
 *
 *   <group> ::= <propertyList>;
 *   <propertyList> ::= <property> {';' property}* ;
 *   <property> ::| <predefined property>
 *                | <auxilary property> ;
 *   <predefined property> ::| <origin property> | <include property>
 *                           | <body property> | <mdbody property> ;
 *   <origin property>  ::= 'ORIGIN'  STRING                    ;
 *   <include property> ::= 'INCLUDE' STRING      {STRING}*      ;
 *   <body property>    ::= 'BODY'    STRING      {STRING}*      ;
 *   <mdbody property>  ::= 'MDBODY'  NAME STRING {NAME STRING}* ;
 *   <auxilary property>::= <propertyName> {NAME | STRING | CONST}* | EMPTY ;
 *
 * Lexical tokens: --(-)* [[ ]] ; : NAME STRING CONST EOF
 *
 *)
  (#
     parseErrors:< (* exception called if parse-errors *)
      astInterfaceException;
     doubleFormDeclaration:<
     (* exception called if two fragmentForms with the same name *)
      astInterfaceException;
     input: ^stream;
     error: ^stream;
     ok: @boolean;
     dash: (#  exit - 1 #);
     beginGroup: (#  exit - 2 #);
     endGroup: (#  exit - 3 #);
     name: (#  exit - 4 #);
     string: (#  exit - 5 #);
     const: (#  exit - 6 #);
     EOF: (#  exit - 7 #);
     origin: (#  exit - 8 #);
     include: (#  exit - 9 #);
     body: (#  exit - 10 #);
     mdbody: (#  exit - 11 #);
     semiColon: (#  exit ';' #);
     colon: (#  exit ':' #);
     EOSchar: @char;
     inputPos, lastOKPos: @integer;
     firstComment: @boolean;
     fgComment: @Text;
     get: @
       (# printError: @
            (#
            do 'Read ascii.nul character during property parsing.\n' -> screen.putText;
               'fullname is ' -> screen.putText;
               fullname->screen.putline;
               'inputpos is ' -> screen.putText;
               inputpos->screen.putint; screen.newLine;
            #);
     do (if input.eos then
               EOF->nextCh
            else
               inputPos+1->inputPos;input.get->nextCh;
               (if nextCh=0 then
                   printError;
               else
                  CommentSieve[nextCh]->nextCh;
               if)
          if)
     exit nextCh
     #);
   dirWriteable: @
     (# f: @file
     enter f.name
     exit f.entry.writeable
       (#
          error::
            (#
            do true->continue; (errorNumbers.otherFileError,msg[])->catcher
            #)
       #)
     #);
   markError:
     (#
        whatToBeExpected: @text;
        errorPos,inx,noOfTerminals: @integer;
        ch: @char;
        errorReport:
          (#
             N: @integer;
             beforeText: @text;
             get: @input.get;
             eos: @input.eos;
             ch: @char;
             print,oldPrint: @boolean;
             startLineNo,lineNo: @integer;
             pos,first,beforePos: @integer;
             lst: ^stream;
             constructLegals:
               (# symb: ^parseSymbolDescriptor; j: @integer; t: ^text
               do &parseSymbolDescriptor[]->symb[];
                  noOfTerminals->symb.terminals.new;
                  0->whatToBeExpected.pos;
                  (for i: NoOfTerminals repeat
                    whatToBeExpected.getAtom->t[]; t[]->symb.terminals[i][];
                  for)
               exit symb[]
               #);

          enter lst[]
          do 1->lineNo;
             THIS(fragmentGroup)[]->theErrorReporter.frag[];
             lst[]->theErrorReporter.errorStream[];
             theErrorReporter.beforeFirstError;
             1->N;
             Loop:
             (if (N <= 1) then
                 print->oldPrint;
                 ((errorPos-100) <= pos)->print;
                 (if print then
                     (if oldPrint then
                         (if (beforeText.length > 100) then
                             startLineNo+1->startLineNo;
                             test:
                             ascii.newLine
```

```
                          ->beforeText.findAll
                            (#
                            do inx+beforePos->beforePos;
                               (1,inx)->beforeText.delete;
                               leave test
                            #);

                    if)
                 else
                    beforeText.clear;
                    pos->beforePos;
                    lineNo->startLineNo;

                if)
            if);
            lineNo+1->lineNo;
            pos->first;
            readLine:
              (#
              do pos+1->pos;
                 (if eos then leave readline if);
                 get->ch;
                 (if print then ch->beforeText.put if);
                 (if ch = ascii.newline then leave readLine if);
                 restart readLine;

              #);
            (if print then
                mark:
                (if (errorPos <= pos) then
                    (errorPos,startLineNo,beforeText,errorPos-beforePos,
                     constructLegals)->theErrorReporter.forEachError;
                    N+1->N;

                if);

            if);
            restart Loop
        if);
        theErrorReporter.afterLastError;

     #);
   lstFile: @file
     (#
        accessError::
          (#
          do (errorNumbers.WriteAccessOnLstFileError,msg[])->catcher
          #)
     #);

enter (whatToBeExpected,NoOfTerminals)
do lastOKPos+1->errorPos;
   (if error[] = none then
       screen[]->error[];
       '***WARNING: error stream in markError not specified.  Using screen[] as error[]'
         ->error.putline;

   if);
   error.newLine;
   input.reset;
   error[]->errorReport;
     (# t: ^text
     do fullName->t[]; '.lst'->(t.copy).Append->lstFile.name;
     #);
   (if (lstFile.entry.path.head->dirWriteable) then
       (if lstFile.entry.writeable
         (#
            error::
              (#
              do true->continue;
                 (errorNumbers.otherFileError,msg[])->catcher
              #)
         #) then
           lstFile.openWrite;
           input.reset;
           lstFile[]->errorReport;
           lstFile.close;
           false->ok;
           ''->parseErrors;
        else
             (# t: @text
             do 'No write access to the file: "'->t;
                lstFile.name->t.append;
                '"'->t.putline;
                (errorNumbers.WriteAccessOnLstFileError,t[])->catcher
             #)
       if)
    else
         (# t: @text
         do 'No write access to the directory: "'->t;
            lstFile.entry.path.head->t.append;
            '"'->t.putline;
            (errorNumbers.WriteAccessOnLstFileError,t[])->catcher
         #)
   if);

#)
(* markError *)
;
```

currentToken: @ (# val: @integer; enter val exit val #);
advance: @|

```
     (#
     do get;
        cycle
          (#
          do inputPos->lastOKPos;
             (if nextCh
              // EOSchar then
                 (if get = EOSchar then
                     loop1: (if get = EOSchar then restart loop1 if);
                     dash->currentToken;
                     SUSPEND;

                  else
                     EOSchar->currentToken; SUSPEND;
                 if);

              // '[' then
                 (if get = '[' then
                     beginGroup->currentToken; SUSPEND; get
                  else
                     '['->currentToken; SUSPEND
                 if);

              // ']' then
                 (if get = ']' then
                     endGroup->currentToken; SUSPEND; get
                  else
                     ']'->currentToken; SUSPEND
                 if);

              // '\'' then
```

```
theText.clear;
get;
loop:
(if nextCh
 // '\'' then
    leave loop;
 // '\\' then
    (if get
     // ascii.newLine then
        ascii.newline->theText.put;
     // 'n' then
        ascii.newline->theText.put
     // 't' then
        ascii.ht->theText.put
     // 'v' then
        ascii.vt->theText.put
     // 'b' then
        ascii.bs->theText.put
     // 'r' then
        ascii.cr->theText.put
     // 'f' then
        ascii.np->theText.put
     // 'a' then
        ascii.bel->theText.put
     // '\\' then
        '\\'->theText.put
     // '?' then
        '?'->theText.put
     // '\'' then
        '\''->theText.put
     // '"' then
        '"'->theText.put
     // EOF then
        ('EOF reached while reading this string',6)
          ->markerror
     else
          (#
             V: @integer;
             oneMore: @boolean;
             isDigit:
               (# bool: @boolean
               do (if ('0' <= nextCh) and (nextCh <= '7')
                   then
                      nextCh-'0'+V*8->V; true->bool
                  if)
               exit bool
               #);

          do (if isDigit then
                 get;
                 (if isDigit then
                     get; (if isDigit then get;  if)
                 if);
                 V->theText.put
             if);
             restart loop
          #)
    if);
    get;
    restart loop
 // ascii.newLine then
    inputPos-1->inputPos;
    ('end-of-line is not allowed in strings',6)->markerror
 // EOF then
    ('EOF reached while reading this string',6)->markerror
 // ascii.nul then
```

```
       ('Ascii nul character reached while reading this string',6)->markerror
    else
       nextCh->theText.put; get; restart loop
   if);
   string->currentToken;
   SUSPEND;
   get
// '(' then
   (if get = '*' then
       (if firstComment then false->firstComment if);
       loop:
       (if get
        // '*' then
           loop1:
           (if get
            // '*' then
               nextCh->fgComment.put; restart loop1
            // ')' then
               CommentSeparator2->fgComment.put; get; leave loop
            // EOF then
               ('EOF reached while skipping this comment',6)
                 ->markerror
    // ascii.nul then
       ('Ascii nul character reached while skipping this comment',6)->markerror
            else
               '*'->fgComment.put;
               nextCh->fgComment.put;
               restart loop
           if)
        // EOF then
           ('EOF reached while skipping this comment',6)
             ->markerror
    // ascii.nul then
       ('Ascii nul character reached while skipping this comment',6)->markerror
        else
           nextCh->fgComment.put; restart loop
       if)
    else
       '('->currentToken; SUSPEND
   if)
// EOF // ascii.fs then
   EOF->currentToken; SUSPEND;
    // ascii.nul then
       ('Ascii nul character reached in non classified situation',6)->markerror
else
   (if true
    // ('0' <= nextCh) and ('9' >= nextCh) then
       nextCh-'0'->theConst;
       get;
       loop:
       (if ('0' <= nextCh) and ('9' >= nextCh) then
           10*theConst+nextCh-'0'->theConst; get; restart loop
       if);
       const->currentToken;
       SUSPEND;

    //
    ('A' <= (nextCh->ascii.upcase))
    and
    ('Z' >= (nextCh->ascii.upcase)) // ('_' = nextCh) then
       theText.clear;
       nextCh->theText.put;
       get;
       loop:
       (if true
        //
```

```
                   ('A' <= (nextCh->ascii.upcase))
                   and
                   ('Z' >= (nextCh->ascii.upcase))
                   // ('0' <= nextCh) and ('9' >= nextCh)
                   // ('_' = nextCh) then
                      nextCh->theText.put; get; restart loop
                  if);
                  (if true
                   // 'ORIGIN'->nameEqual then
                      origin->currentToken; SUSPEND
                   // 'INCLUDE'->nameEqual then
                      include->currentToken; SUSPEND
                   // 'BODY'->nameEqual then
                      body->currentToken; SUSPEND
                   // 'MDBODY'->nameEqual then
                      mdbody->currentToken; SUSPEND
                   else
                      name->currentToken; SUSPEND
                  if)
               // (0 <= nextCh) and (nextCh <= 32) then
                  get
               else
                  nextCh->currentToken; SUSPEND; get
              if)
          if)
       #)
  #);
nextCh: @integer;
theText: @text;
theConst: @integer;
accept: @
  (# token: @integer; errorText: @text
  enter token
  do (if currentToken <> token then
         (if token
          // name then
             ('NAME',1)->markError;
          // string then
             ('STRING',1)->markError;
          // const then
             ('CONST',1)->markError;
          // origin then
             ('origin',1)->markError;
          // include then
             ('include',1)->markError;
          // body then
             ('body',1)->markError;
          // mdbody then
             ('mdbody',1)->markError;
          // beginGroup then
             ('[[',1)->markError;
          // endGroup then
             (']]',1)->markError;
          // dash then
             errorText.clear;
             EOSchar->errorText.put;
             EOSchar->errorText.put;
             (errorText,1)->markError;

          // EOF then
             ('EOF',1)->markError;
               // ascii.nul then
                  ('Ascii nul character',6)->markerror
          else
             errorText.clear;
             token->errorText.put;
             (errorText,1)->markError
         if)
     if)
  #);
nameEqual: @
  (# name: ^text enter name[] exit (theText[]->name.equalNCS) #);
parsePropertyList:
  (#
  do parseProperty;
     loop:
     (if currentToken
      // semiColon then
         advance;
         CommentSeparator1->fgComment.put;
         parseProperty;
         restart loop
      // name // origin // include // body // mdbody then
         semiColon->accept
     if)
  #);
parseProperty: @
  (# propName: @text; pe: ^prop.propElement
  do (if currentToken
      // name then
         CommentSeparator3->fgComment.put;
         name->accept;
         theText->propName;
         advance;
         propName.copy
           ->prop.addProp
             (# ifPropExist::  (#  do false->delete #);
             do loop:
                (if currentToken
                 // name then
                    CommentSeparator3->fgComment.put;
                    theText.copy->addName;
                    advance;
                    restart loop
                 // string then
                    CommentSeparator3->fgComment.put;
                    theText.copy->addString;
                    advance;
                    restart loop
                 // const then
                    CommentSeparator3->fgComment.put;
                    theConst->addConst;
                    advance;
                    restart loop
                if)
             #)
      // origin then
         CommentSeparator3->fgComment.put;
         origin->accept;
         theText->propName;
         advance;
         string->accept;
         propName.copy
           ->prop.addProp
             (# ifPropExist::  (#  do false->delete #);
             do (if currentToken = string then
                    CommentSeparator3->fgComment.put;
                    theText.copy->addString;
                    advance;

                if)
             #);
```

```
// include then
   CommentSeparator3->fgComment.put;
   include->accept;
   theText->propName;
   advance;
   string->accept;
   propName.copy
     ->prop.addProp
       (# ifPropExist::  (#  do false->delete #);
       do loop:
          (if currentToken
           // string then
              CommentSeparator3->fgComment.put;
              theText.copy->addString;
              advance;
              restart loop
           // name // const then
              string->accept;
           // origin // include // body // mdbody then
              semiColon->accept
          if)
       #);

// body then
   CommentSeparator3->fgComment.put;
   body->accept;
   theText->propName;
   advance;
   string->accept;
   propName.copy
     ->prop.addProp
       (# ifPropExist::  (#  do false->delete #);
       do loop:
          (if currentToken = string then
              CommentSeparator3->fgComment.put;
              theText.copy->addString;
              advance;
              restart loop
          if)
       #)
// mdbody then
   CommentSeparator3->fgComment.put;
   mdbody->accept;
   theText->propName;
   advance;
   name->accept;
   propName.copy
     ->prop.addProp
       (# ifPropExist::  (#  do false->delete #);
       do loop:
          (if currentToken
           // name then
              CommentSeparator3->fgComment.put;
              theText.copy->addName;
              advance;
              string->accept;
              (if currentToken = string then
                  CommentSeparator3->fgComment.put;
                  theText.copy->addString;
                  advance;
                  restart loop
              if)
           // string // const then
              name->accept
           // origin // include // body // mdbody then
```

```
                         semiColon->accept
                     if)
                  #)
           if)
        #)
   enter (input[],error[])
   do 0->EOSchar;
      prop.proplist.clear;
      prop.init;
      none ->linklist[];
      (* to cancel cached INCLUDE's *)
      true->ok;
      0->inputPos;
      true->firstComment;
      fgComment.clear;
      advance;
      INNER propertyParser;
      'Comment'
        ->prop.addProp
          (#
             ifPropExist::
               (#
               do '**WARNING: Property Comment is predefined'->error.putline
               #);

          do fgComment.copy->addString;
          #);
      (*ESS: NO!!!!! (if ok then markAsChanged if);*)

   exit ok
   #);
parseProperty: propertyParser (#  do parsePropertyList #)
```

Propertyparser Interface Mjølner Informatics