PROLOG+CG version 2.0

User's Manual

By Dr. Adil KABBAJ[1]

Modified by Ulrik Sandborg-Petersen[2]

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Web: `http://prologpluscg.sourceforge.net/`

[1]I.N.S.E.A, Rabat, Morocco. **E-mail:** `akabbaj{a-t}insea{d-ot}ac{do-t}ma`

[2]Aalborg University, Denmark. **E-mail:** `ulrikp{at}users{d-ot}sourceforge{do-t}net`

Contents

Feedback

Please report any bugs, problems or suggestions to Ulrik Sandborg-Petersen at:

`ulrikp{a-t}user{do-t}sourceforge{do-t}net`

Please do not contact Prof. Kabbaj about Prolog+CG 2.0. Contact Ulrik Sandborg-Petersen instead.

Please note that Prolog+CG version 2.0 is **legacy code**, maintained by Ulrik Sandborg-Petersen. A new and better version has been released as part of the Amine-platform: `<http://amine-platform.sourceforge.net>`.

Chapter 1

Basics

1.1 Introduction

PROLOG (PROgramming in LOGic) is a programming language that has been designed first (around 1972) for natural language processing and theorem proving. It has been used, since that time in many fields of Artificial Intelligence (AI). Now, PROLOG is a standard programming language in AI.

This manual is not about PROLOG, even if a quick introduction of this language is given as the basic elements of PROLOG+CG are introduced. Several books and documentation concerning PROLOG language are available. This manual is about a descendant of PROLOG : **PROLOG+CG** which is *a conceptual and an object-oriented extension of PROLOG*. Indeed, to achieve more expressive power, the PROLOG language has been extended, in the past, in at least two directions :

- *Conceptual extension* **:** a goal can be represented by a term (a predicate) or by a complex structure, like typed feature structure [1, 2, 3, 10, 18].

- *Contextual extension* **:** it is illustrated first by object-based PROLOG [14, 16, 4, 5] where a Prolog program is partitioned into objects (or worlds, theories, modules, bases, spaces or other similar terms), each object contains a set of rules. A goal is then resolved in the context of a specific object. Contextual extension of PROLOG is illustrated also by object-oriented PROLOG [7, 15, 17] where inheritance between objects is considered.

PROLOG+CG is a conceptual extension of PROLOG in the sense that it integrates Conceptual Graphs (CG) at the basic level. Conceptual Graph (CG) formalism (for background knowledge about conceptual graphs, please see: `http://www.jfsowa.com/cg/index.htm`) is a synthesis of several works on semantic networks. CG has been used in many fields of AI, especially natural language processing and knowledge base systems. An integration of CG to Prolog is very interesting. In the Conceptual Graph community, some systems [6, 8, 9] incorporated a deductive component that interprets a set of rules, all the goals of a rule are represented by simple Conceptual Graphs (CG). However, these components do not subsume PROLOG and were not presented as extensions of PROLOG. For instance, no work has been done in the past to develop a Prolog version that provides CG as a basic data structure, beside term and list. PROLOG+CG fulfills this gap in the CG research (i.e., a need for a CG based extension of Prolog) : CG can be used to represent goals (beside terms) and can be used and manipulated as basic data structures, with operations like maximal join, projection (or more precisely subsumption), generalization and unification operations.

PROLOG+CG is a contextual extension of PROLOG in the sense that it integrates notions like objects and inheritance.

Also, PROLOG+CG integrates JAVA : PROLOG+CG can be called from a Java program and a Prolog+CG program can call Java classes.

The integration of **Prolog**, **object oriented programming**, the **manipulation of CG** and **Java** provides a powerful development environment for the creation of knowledge-based applications and their integration on the web. Java allows the development of multi-platform applications as well as the capabilities of object-oriented languages. Prolog provides the full power of a logic programming language well suited for natural language processing, inference and symbolic manipulations. CGs provide the expressive power of an advanced knowledge representation language (advanced semantic nets, type hierarchy, schemas, notion of context, etc.).

PROLOG+CG is implemented in JAVA 2. A beta version 2.0 is available through the site `http://prologpluscg.sourceforge.net/`

Please note that Prolog+CG version 2 is *legacy code*, maintained by Ulrik Sandborg-Petersen. A new and better version is available as part of the Amine platform.

1.2 Prolog+CG and its installation

The integrated environment of PROLOG+CG consists of a text editor, a "compiler", the debugger and the interpreter. The compiler performs a syntactic analysis of the program and if the analysis is successful, it generates an object file that contains an internal representation of the program, in terms of Java structures (vector, hashtable, etc.). Thereafter, the interpreter works on the object file.

At the interface level, the environment provides a split pane; the top pane is used to create/open/edit a program while the bottom pane is used as a console : the user asks a request and the system gives the answer (Figure 1.1). During the compilation, the console pane becomes a compiler pane where messages concerning this task are written. If the compilation has been successfull, the user has to click inside the pane to switch to the console pane.

The environment provides also a debug window (accessible from the Build menu) and a window that shows the primitive operations of the language (ac-

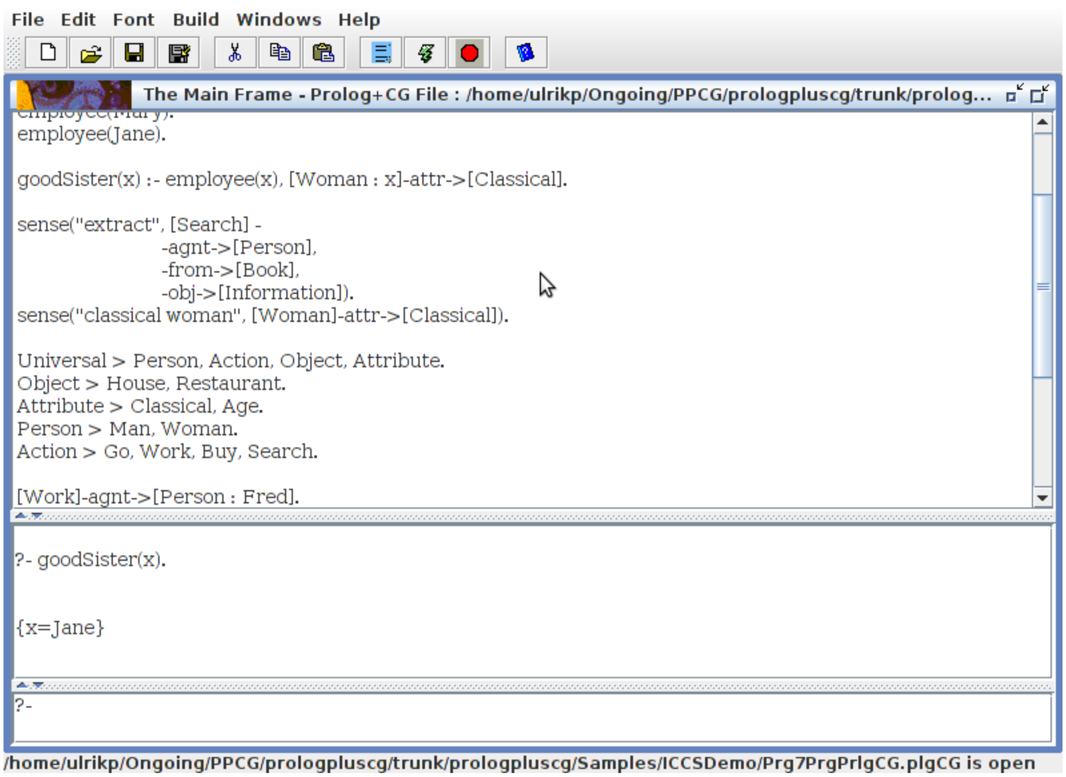


Figure 1.1: PROLOG+CG Environment

cessible from the Help menu).

Figure 1.1 gives a snapshot of the PROLOG+CG environment.

Some of the commands/buttons of the environment are the following (the others are the standards buttons for file and edition processing):

 Compile a Prolog+CG File to produce an object file (if it doesn't exist already)

 Execute the interpreter to answer a question

 Help

More information on the environment is provided in the next sections.

1.2.1 Installation of PROLOG+CG

Prolog+CG is implemented with JAVA 2. So the JRE of JAVA 2 should be installed first. Then you have to download the PrologPlusCG ZIP file and unzip it it somewhere on your harddrive (C for Windows for instance). Inside the directory that this creates (e.g., "PPCG"), PrologPlusCG can be executed with the following command (from the DOS Console):

```
java -classpath classes PrologPlusCG/PrologPlusCG
```

1.3 Elementary data types

Currently, the elementary data types are:

- **Number** (unsigned or negative integer or real : 23, -45, 02.45, -564.675, etc.)
- **Boolean** (true, false)
- A *string* is any sequence of characters surrounded by double-quotes.

  Example: `"this is a string"`.
- A *constant identifier* is any sequence of letters, digits or underscore (_) that begins with two letters.

  Examples of good identifiers: `pr32`, `papa`, `is_good`, `pp34_65`

  Examples of illegal identifiers: `p45`, `_rt`, `p_rt`, `_rrt`

1.3.1 Variables

The *identifier of a variable* can be either:

- An underscore followed optionally by a sequence of letters, digits or underscores.
- A letter.
- A letter followed by a digit or an underscore, and followed optionally by a sequence of letters, digits or underscores.

Examples of good variable identifiers:
`_var1`, `_`, `_324`, `_ce_ci`, `x`, `x3`, `x_var`
Note: The grammar of PROLOG+CG is given in Appendix A.

1.4 Composed data types overview

The composed data types of PROLOG+CG are:

- term,
- list,
- set,

- concept and
- CG.

They are introduced in the next sections (sets and concepts are considered in CG section, Section 2.3).

1.4.1 Example

Figure 1.2 shows a simple Prolog+CG program that introduces the basic data types of Prolog+CG: the program contains the fact "`prologCGData`" that has one argument: a list of different elements: an integer, a constant identifier, a string, a boolean, a image file name (see the remark below), a list, a predicate or term and a conceptual graph (CG). The program contains also a rule that defines the goal "`dataExple/1`": it search the fact "`prologCGData`" and call the primitive goal "`member`" to access (with backtracking) all the elements contained in the list.

The editor of Prolog+CG allows for some hypertext actions. For instance, when the data is a file name of a multi-media data, like "`ImgPrlg.png`", the user can see the content of this file in a separate window simply by selecting the whole name and by doing a click on the left-button of the mouse. Figure 1.2 shows the result of theses actions in the case "`ImgPrlg.png`".

Now, to ask some questions about the above program, you first have to compile it: choose "`Build/Compile`" from the menu or just press on the corresponding button . Then click in the bottom-most panel (the "Prompt panel") and write your request just after the prompt "`?- `". To activate the interpreter for responding to your request, press the key "`Rreturn/Enter`", or choose "`Build/Answer Question`" from the menu, or just press on the corresponding button .

Here is the result of one question about the above program:

```
?- prologCGData(L).
{L = (23, John, "John is the Hero", false, "ImgPrlg.png",
  (iccs,2000), book(John, KR, 2000),
      [Write]-
         -obj->[Book]-attr->[New],
         -agnt->[Man : John])}
```

1.5 Term

A term is an a constant identifier followed optionally by a list of arguments. An argument is either an elementary data type, a variable or a composed data type.

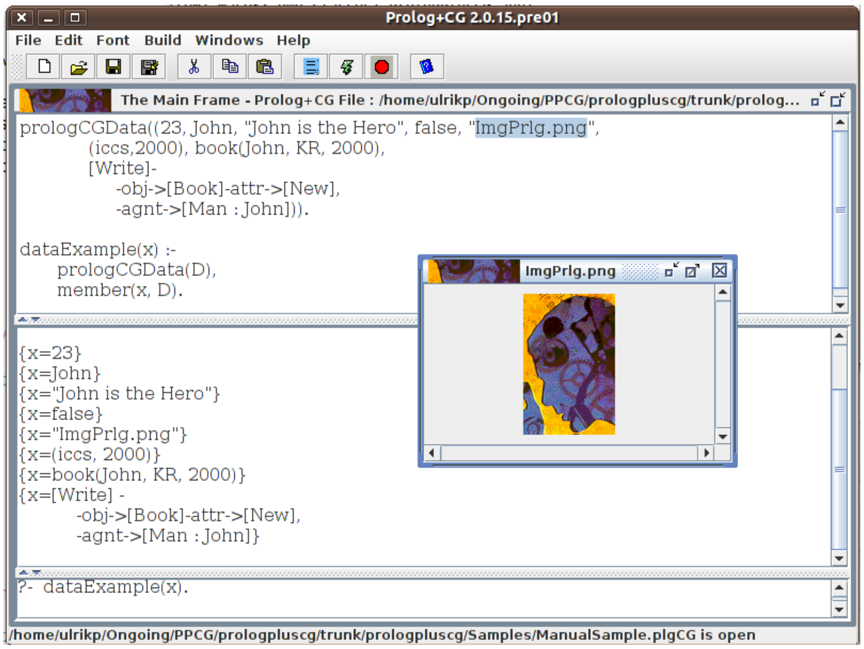


Figure 1.2: The "hyper-text editor" and basic data in PROLOG+CG

1.5.1 Examples of correct terms

```
Prop4,
Papa(Abdou),
Publisher(Addison, "Conceptual Structure", 1984),
like(Kim, (banana, tomato, juice),
     [Man: Kim]<-agnt-[Work]-manr->[Hard]),
phrase("kha eats banana",
       st(np("kha"), vp(vb("eats"), np("banana"))),
       [Man:kha]<-agnt-[Eat]-obj->[Banana])
```

1.6 List

A list can be composed of zero, one or several elements separated by comma. An element of a list is like an argument of a term; it is either an elementary data type, a variable or a composed data type.

Note: Prolog+CG uses (parentheses) around lists rather than [square brackets]. This is different from standard Prolog.

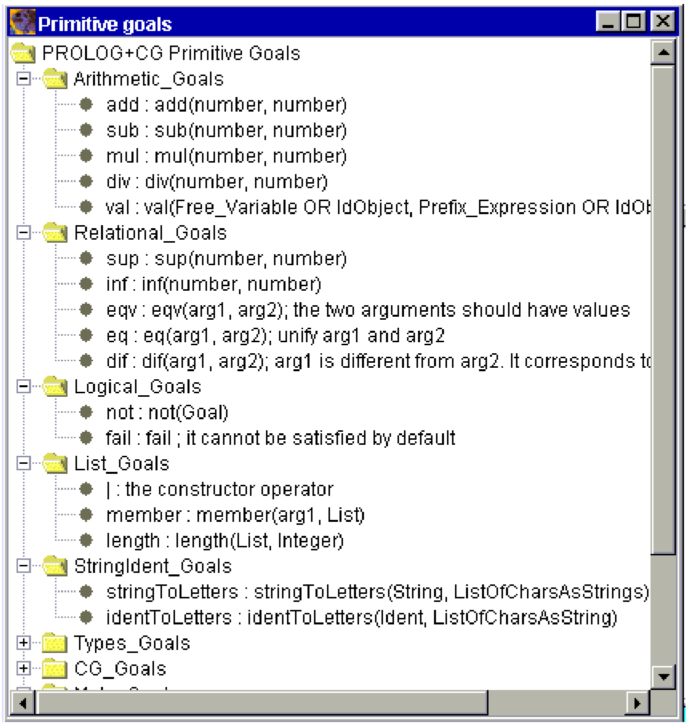


Figure 1.3: Primitive operations

1.6.1 Examples of correct lists

```
(),
(tati),
(titi, 34, (356, ps(note(67), (2, 4)), "ha ha")),
(exp32, [Dat = (23, 12, 84)]<-birthOf-[Boy:Cham], 54)
```

1.7 Primitive operations

Figure 1.3 shows the window that is given to the user when he asks for the primitives of the language, either by choosing the menu action Help/Primitives or Windows/Primitives. Each primitive operation is given with its signature (number and types of the arguments). In this section, we consider only the arithmetic, relational, logical, list, stringIdent and multi-media primitive operations. The other types of primitives are introduced later.

PROLOG+CG adopts a prefix notation to formulate an expression. Thus, the infix expression: `3 + (4 - 5)` should be formulated in PROLOG+CG as: `add(3, sub(4, 5))`. As shown below, the primitive goal "`val(Var, Expr)`" evaluates the expression Expr and associates its value to the variable Var. This is how arithmetic computation is done in PROLOG+CG.

```
?- val(x, add(4, mul(5,3))).
{x = 19}
```

Recall : the request must terminates with a point (.) . To activate the interpreter and get an answer, the user can either choose the menu action "`Build/Answer Question`", or press the button , or just press the "**`return`**" key on the keyboard. The interpreter returns

```
{x = 19}

?-val(x, mul(-4, add(6, 4.68))).

{x = -42.72}

?-eq(x, 34), val(y, div(765, x)).

{x = 34, y = 22.5}

?-eqv(x, 54).

Error: any variable in an expression should have a value.
```

Note the difference between the two primitives "`eq`" and "`eqv`": **eq** corresponds to the unification operation while **eqv** corresponds to the identity test; the two arguments of **eqv** should have a value.

```
?-eq(x, 54), eqv(x, 54).

{x = 54}

?-sup(43, -54).

{}

?-inf(-54, -34).

{}

?- eq(x, 34), eq(y, 54), dif(x, y).

{x = 34, y = 54}
```

```
?- eq(54, x), val(y, sub(56, 2)), not(eq(x, y)).

no.

?- eq(54, x), val(y, sub(56, 2)), not(dif(x, y)).

{x = 54, y = 54}

?- eq(papa(Hicham, x), papa(y,Nour)).

{x = Nour, y = Hicham}

?- eq((1, 2, 3, 4, 5),(x,y|z)).

{x = 1, y = 2, z = (3, 4, 5)}

?- dif(papa(Hicham, x), papa(y, Nour)).

no.

?- dif(papa(Hicham, x), papa(Wasouf, Nour)).

{}
```

Note the primitive goal **dif(x,y)** is equivalent to : **not(eq(x,y))**.

```
?-seed(100).

{}

?-rnd(0,24,X).

{X = 17}

?-rnd(0,20,X).

{X = 3}
```

The rnd/3 predicate takes two numbers and a free variable as arguments. The last argument must be the free variable, and the two others must be numbers between 0 and 2100000000 ($2.1*10^9$), with the first being less than or equal to the second. What is returned in the third argument is a pseudo-random number in the range from the first to the second argument (both inclusive), and what is returned is always an integer, even if the two first arguments are floating-point numbers.

seed/1 takes a number between 0 and 2100000000 ($2.1*10^9$) and seeds the pseudo-random number with the integer value of this number. The significance of this is that when one seeds the pseudo-random number generator with a specific number, then it will generate the same sequence of pseudo-random numbers after the next seeding with the same number.

Both seed/1 and rnd/3 always succeed, unless the constraints on the arguments mentioned above are not met, in which case an error is flagged and the resolution is stopped.

```
?-fail.

no.

?-concat("xx", "yy", "xxyy").

{}

?-concat(X, "yy", "xxyy").

{X = "yy"}

?-concat("xx", Y, "xxyy").

{Y = "yy"}

?- concat("xx", "yy", Z).

{Z = "xxyy"}

?-stringToLetters("papa", L).

{L = ("p", "a", "p", "a")}

?-stringToLetters(x, ("m", "a", "i")).

{x = "mai"}

?-identToLetters(papa, L).

{L = ("p", "a", "p", "a")}

?-identToLetters(c, ("p", "a", "p", "i")).

{c = papi}
```

1.7.1 Examples of List operations

```
?- member(3, (2, 3, 4, 5)).

{}

?- member(6, (2, 3, 4, 5)).

no.

?-member(x, (2, 3, 4)).

{x = 2}
{x = 3}
{x = 4}

?- length((4, 5, 6, 7), x).

{x = 4}

?- shuffle((1,2,3,4,5,6,7,8,9,10), x).

{x = (9,6,10,4,1,5,2,8,3,7)}
```

1.7.2 Multi-media primitives: show/2 and close/1

These two predicates have been removed in version 2.0.13.

1.8 Facts and inference Rules

As in PROLOG, a PROLOG+CG program is composed mainly of *facts* and *inference rules*.

A fact is a term or a CG followed by a point. *An inference rule* is composed of a head and a tail, separated by the if symbol "`:-`" and it terminates with a point. The *head* of a rule is a term or a CG and the *tail* is a conjunction of elements, an element can be a term, a CG or a variable. The next section gives a classic example of a Prolog program, formulated in Prolog+CG without the use of CGs. In later sections, we define CG and we present their use in Prolog+CG programs.

1.9 Samples I

The following program can be found in Samples/Others/Meal.prlg. It is a classic example, proposed first by Colmerauer [Colmerauer, 85]. The user can load the example (by opening the file Meal.prlg) and compile it, or he can write and edit the program in the 'Program pane'.

```
meal(a, r, m, d) :-
        appetizer(a),
        main(r, m),
        val(x, add(3,4)),
        dessert(d).

main(r, m) :- drink(r), principal(m).
main(r, m) :- drink(r), meat(m).

principal((m, m2)) :- fish(m), fish2(m2).

drink(Coke).
drink(Beer).

appetizer(radishes).
appetizer(pate).

fish(sole).
fish(tuna).

fish2(titi).
fish2(tata).

meat(pork).
meat(beef).

dessert(cake).
dessert(fruit).

little_sum(1, _x, _y) :- little_successor(_x, _y).
little_sum(_x1, _y, _z1) :-
   little_successor(_x, _x1),
   little_sum(_x, _y, _z),
   little_successor(_z, _z1).

little_successor(1,2).
little_successor(2,3).
little_successor(3,4).
little_successor(4,5).
little_successor(5,6).
little_successor(6,7).
little_successor(7,8).
little_successor(8,9).
```

```
light_meal(a, m, d) :-
   meal(a, m, d),
   units(a, x),
   units(m, y),
   little_sum(x, y, u),
   units(d, z),
   little_sum(z, u, v).

// units with two arguments
units(beef, 3).
units(fruit, 1).
units(cake, 5).
units(pate, 6).
units(pork, 7).
units(radishes, 1).
units(sole, 2).
units(tuna, 4).



meal(a, m, d) :-
         appetizer(a),
```

Once the editing task has been done, the user should compile the program by pressing the button (or activating the menu action "`Build/Compile`"). At this time, the user can save the program (both the text format with the extension .prlg and the object format with the extension .obj) and/or activates the Console pane to ask questions.

Let us ask one question:

```
?- light_meal(a, m,d).

{a = radishes, m = sole, d = cake}
{a = radishes, m = sole, d = fruit}
{a = radishes, m = tuna, d = fruit}
{a = radishes, m = pork, d = fruit}
{a = radishes, m = beef, d = cake}
{a = radishes, m = beef, d = fruit}
{a = pate, m = sole, d = fruit}
```

Next time, when the file is opened and compiled directly; without any modification, the system will not recompile it again, it will rather load the object file. But if the text file is modified, the user should recompile and save it.

Chapter 2

Ontologies and Conceptual Graphs

2.1 Specialization (Generalization) rules

Before considering *conceptual graphs* (CGs) in detail, we will introduce two related notions: *concept types hierarchy* and*instantiation*. The two constitute the **support** for the manipulation of CGs. Indeed, as introduced later, CG unification and the other CG operations make use of these notions. Figure 2.1 gives the Prolog+CG primitives for support and CGs manipulation.

2.1.1 Concept types hierarchy

This describes the generalization/specialization relation between the concept types used in the CGs. It encodes the famous "`IsA`" relation, used in many semantic network formalisms. In PROLOG+CG, a concept type hierarchy is defined as a set of *specialization rules*. A specialization rule describes the immediate subtypes Type1, Type2, . . . , TypeN of a type Type. It has the following form :

```
Type > Type1, Type2, ..., TypeN.
```

2.1.2 Example

```
Universal > Person, Animal,
Action, Situation, Object, AbstractEntity, Attribute.
Person > Man, Woman.
Man > Boy, Employee.
Woman > Girl, Employee.
Employee > Supervisor.
Action > Drive, Love, Break, Rent, Begin, Press, Look.
Object > Vehicle, Machine, Key, Keyboard, Finger.
```

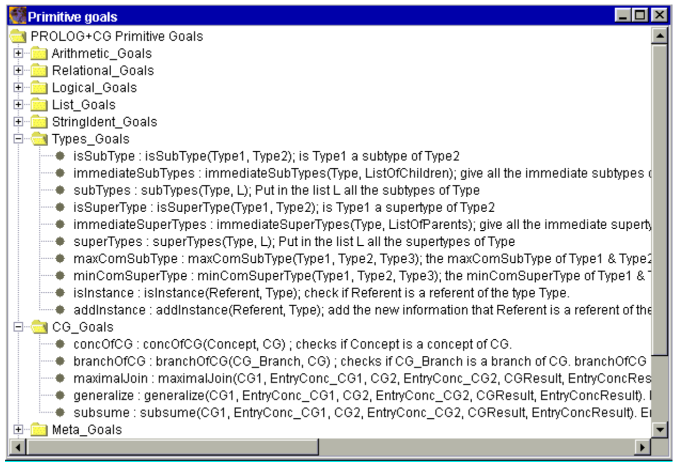


Figure 2.1: Prolog+CG primitives for support and CG manipulation

```
AbstractEntity > Society, Session, Years, Proposition.
Vehicle > Car, Truck.
Attribute > Fast, Color, Expensive, Big.
```

2.1.3 Operations on the concept types hierarchy

Currently, PROLOG+CG provides the following primitive operations on concept type hierarchies:

- **isSubType(Type1,Type2):** checks if a type Type1 is a subtype of a type Type2.
- **immediateSubTypes(Type, L):** returns in the list L all the immediate subtypes of a type Type.
- **subTypes(Type, L):** returns in the list L all the subtypes of a type Type. The types are given in the breadth-first order.
- **isSuperType(Type1, Type2):** checks if a type Type1 is a super-type of a type Type2.
- **immediateSuperTypes(Type, L):** returns in the list L all the immediate super-types of a type Type.
- **superTypes(Type, L):** returns in the list L all the super-types of a type Type. The types are given in the breadth-first order.
- **maxComSubType(Type1, Type2, T):** gives in T the maximum common subtype of the types Type1 and Type2.

- **maxComSubTypes(Type1, Type2, L):** gives in L the list of "maximal common subtypes". If the type hierarchy is not a strict lattice, this can be useful. If it is a strict lattice, then this is the same as maxComSubType, except that a list is returned (with only one element). The "maximum common subtypes" is defined as follows: If Type1 is a subtype of Type2, or vice versa, then the one that is the subtype is returned as the single element of the list. Otherwise, what is returned is the list of those common subtypes that do not have any supertypes in the list of all common subtypes of types Type1 and Type2.
- **minComSuperType(Type1, Type2, T):** gives in T the minimum common super-type of the types Type1 and Type2.
- **maxComSubTypes(Type1, Type2, L):** gives in L the list of "minimal common supertypes". If the type hierarchy is not a strict lattice, this can be useful. If it is a strict lattice, then this is the same as minComSuperType, except that a list is returned (with only one element). The "minimum common supertypes" is defined as follows: If Type1 is a supertype of Type2, or vice versa, then the one that is the supertype is returned as the single element of the list. Otherwise, what is returned is the list of those common supertypes that do not have any subtypes in the list of all common supertypes of types Type1 and Type2.

2.1.4 Examples

```
?- isSubType(Supervisor, Person).

{}

?-isSubtype(Supervisor, Girl).

no.

?-immediateSubTypes(Action, L).

{L = (Drive, Love, Break, Rent, Begin, Press, Look)}

?-subTypes(Person, L).

{L = (Man, Woman, Boy, Employee, Girl, Supervisor)}

?-isSuperType(Person, Supervisor).

{}

?-immediateSuperTypes(Employee, L).
```

```
{L = (Man, Woman)}

?-superTypes(Employee, L).

{L = (Man, Woman, Person, Universal)}

?- maxComSubType(Man, Woman, x).

{x = Employee}

?-maxComSubType(Person, Employee, x).

{x = Employee}

?-minComSuperType(Supervisor, Boy, x).

{x = Man}
```

2.2 Instantiation rules

The instantiation relation relates an instance to its type. In PROLOG+CG, **instances of a type** are described with an *instantiation rule*:

```
Type = Inst1, Inst2, ..., InstN.
```

Instantiation rules are specified as a complement to the specialization rules which describe the concept type hierarchy.

2.2.1 Examples

(we assume the concept type hierarchy introduced in Section 2.1):

```
Boy = John, Bob, Sam, Andre.
Girl = Sue, Mary.
Color = red.
Machine = res23.
Years = four.
Key = enter.
```

2.2.2 Operations on instances

PROLOG+CG provides two operations on type instances (figure 2.1):

- **isInstanceOf(Referent, Type):** checks if the referent Referent is an instance of a type Type.
- **addInstance(Referent, Type):** adds Referent as a new instance in the instances declaration of the type Type.

2.2.3 Examples

```
?- isInstance(Sue, Girl).

{}

?-isInstance(Sue, Person).

{}

?-isInstance(Sue, Boy).

no.

?-isInstance(Karl, Boy).

no.

?-addInstance(Karl, Boy).

{}

?- addInstance(Emp01, Employee).

{}
```

Note that following the two above operations, the instantiation rule for the type "Boy" is modified and a new instantiation rule is added for the type "Employee":

```
Boy = John, Bob, Sam, Andre, Karl.
Girl = Sue, Mary.
Color = red.
Machine = res23.
Years = four.
Key = enter.
Employee = Emp01.


(continue ...)


?-isInstance(Karl, Boy).

{}

?- isInstance(Karl, Person).
```

```
{}
```

2.3 Conceptual Graphs (CG)

As noted earlier, a composed data item in PROLOG+CG can be a term, a list, a *concept* or a **conceptual graph (CG)**.

- **CG.** A conceptual graph (CG), in Prolog+CG, is a graph of nodes that represent *concepts* and that are related by *conceptual relations*.

  Only binary relations are possible (this constraint is for simplicity and practical purpose only).

  Remark: Prolog+CG provides a large flexibility in the use of variables inside CG: a variable can stand for:

  – a whole CG,
  – a whole concept (like: `[Man]-agnt->X` ; X is a variable),
  – a relation (like: `[Man]-R->[Eat]` ; R is a variable),
  – a concept type or a concept referent (like: `[A : B]-agnt->[Eat]` ; A and B are variables).

  Such a flexible use of variables enhances the expressive power of the language, according to CG manipulation.

- **Concept.** A concept is composed of a type, an optional referent and an optional description.

  – A concept type can be a variable or an identifier that refers to a type defined in the concept type hierarchy.
  – A concept referent can be a variable, an instance (an identifier or a string) declared in instances declaration rules, a set of instances, a co-referent (represented by a variable) or a multi-referent.
  – A concept description is any Prolog+CG data: an elementary data like an integer, a real, a boolean, an identifier, a string or a composed data like a list, a term, a concept or a CG.

A multi-referent has the form "`*Number`" and it is only used in the linear notation to identify all occurrences of a concept. A multi-referent is not represented in the internal representation of the concept. Examples are given below.

2.3.1 Concept and CG Linear Notation

The linear notation used in PROLOG+CG to express CG is similar to the notation introduced first by Sowa. As introduced above, a concept has tree fields surrounded by brackets.

Examples of concepts

```
[Man],
[Man : John],
[Man : {John, Carl, Henry}],
[Cat : x],
[Human : *1],
[Integer = 25],
[List = (1, 2, 3)],
[Date : CurrentDate = (04,01,2000)],
[Term = papa(x, Hicham)],
[Proposition :propHenry = [Man : Carl]<-agnt-
            <-[Think]-obj->[Proposition =
                           [Man: Carl]-attr->[Crazy] ] ]
```

A relation R between two concepts C1 and C2 can be expressed as follows:

```
[C1]-R->[C2]
```

R of C1 is C2, or `[C2]<-R-[C1]` which is the same.

Example of a simple CG:

```
[Girl : Fouzia]<-agent-[Walk]

agent of Walk is Girl Fouzia.
```

If a concept is connected to several relations, writes the concept, then a dash followed by a sequence of relations description separated by comma (see the Appendix for the detailed definition of CG grammar). Also, the CGs given in this manual illustrates several cases of writing CG.

Example of CG — continued

```
[Extract]-
    -agnt->[Person],
    -obj->[Text],
    -target->[Book].
```

The role of the hyphen "-", the comma "," and the semi-colon ";": if a concept (like [**Extract**]) has several branches connected to it, then write the "-" after the concept, write the branches using "," to seperate between them, and use the ";" at the end to indicate the end of the specification of the branches. In this sense, the branches of a concept are enclosed by two delimiters: "-" and ";" and they are separated by the delimiter ",". Note that the delimiter ";" is optional if we are at the end of the CG, like the example above.Of course, a concept at the end of a relation can be connected itself to other relations and so on, forming a tree (and a graph as described below). This case is illustrated by the following example :

Example

```
[Work]-
      -agnt->[Person: Jane]-
                              -ageOf->[Age = 30],
                              <-poss-[House : *1];,
      -near->[House : *1].
```

In the example above, the delimiter "`;`" is used to specify the end of the specification of the branches of [**Person : Jane**] and the delimiter "`,`" that follows "`;`" is used to separate between the two branches of [**Work**].

Finally, note that the indentation and carriage-return are used only for "pretty-print"; they are not significant in the analysis of the notation.

A linear formulation of any graph (and hence, of a CG) provides in general a way to specify several occurrences of the same node (the same concept for CG). In PROLOG+CG, a referent and/or a multi-referent is used for this end. In the above example, the multi-referent "`*1`" is used to specify that the two concepts [**House : *1**] and [**House : *1**] are in fact two occurrences of the same concept.

Relations that are connected to a concept can be specified as relations connected to the occurrences of the same concept.

Example

```
[Extract]-
    -agnt->[Person],
    -obj->[Inanimate : *1]-matr->[Wood],
    -manr->[Strong],
    -target->[Inanimate]-on->[Inanimate :
*1]-priceOf->[Expensive].
```

Example of compound CG

```
[Person]<-agnt-[Perform]-obj->[Action = [Eat]-
           -obj->[Walnut = wal2]-part->[Shell:myShell = toto],
           -instr->[Spoon]-matr->[Shell : myShell]
]-instr->[Roulette].
```

Maybe a better formulation is as follows:

```
[Action = [Eat]-
           -obj->[Walnut = wal2]-part->[Shell : myShell = toto],
           -instr->[Spoon]-matr->[Shell : myShell]
]<-obj-[Perform]-
           -agnt->[Person],
           -instr->[Roulette].
```

Note that the two concepts "[**Shell : myShell = toto**]" and "[**Shell : myShell**]" are the same. They are identified by the referent (**myShell**). Thus, when the concept has a specific referent, this can be used (instead of a multi-referent) to specify the identity of several occurrences of the same concept.

2.3.2 Co-references

A **Co-reference** is represented with a variable. An example will illustrate this important notion:

```
[Man : x]<-agnt-[Begin]-srce->[Proposition =
                  [Person]<-pat-[Look]-dest->[Person : x] ]
```

The variable x plays a role of a co-reference between the two concepts [**Man : x**] and [**Person : x**]. Thus, the two concepts refere to the same entity.

With the above illustrations concerning CG notation, the user can combine them in order to formulate any CG.

2.3.3 The use of CG in PROLOG+CG

In PROLOG+CG, CG is a basic data structure, like a term or a list. CG can be an argument of a term, an element in a list, a value of a concept, the head of a rule (or a fact) or a goal in the tail of a rule.

2.4 Samples II

To illustrate the use of CG in PROLOG+CG, we give two programs in this section. The first has been proposed first by Fargues et al. [6] (which is a Prolog-based formulation of an example presented by Sowa, using Peirce Logic). In the first program, all the goals are formulated as CGs. In general however, we can have in one rule some goals that are represented by CGs and others that are represented by terms. The second program illustrates this point.

2.4.1 Program 1

(it can be found in Samples/Others/Citizen.prlg)

```
Universal > PERSON, BORN, NATURALIZE, COUNTRY.
PERSON > CITIZEN, GIRL.

GIRL = "Dorothy".
PERSON = "Tinman".
COUNTRY = "Oz".

[CITIZEN : x]<-MEMB-[COUNTRY : "Oz"] :-
   [PERSON: x]<-AGNT-[BORN]-LOC->[COUNTRY : "Oz"].
```

```
[CITIZEN : x]<-MEMB-[COUNTRY : "Oz"] :-
   [PERSON: x]<-CHLD-[PERSON: y],
   [CITIZEN : y]<-MEMB-[COUNTRY : "Oz"].

[CITIZEN : x]<-MEMB-[COUNTRY : "Oz"] :-
   [PERSON : x]<-RCPT-[NATURALIZE]-LOC->[COUNTRY : "Oz"].

[PERSON : "Tinman"]-
    -CHLD->[GIRL : "Dorothy"],
    <-AGNT-[BORN]-LOC->[COUNTRY : "Oz"].
```

Let us ask some queries:

```
?- [CITIZEN : x]<-MEMB-[COUNTRY : y].

{x = "Tinman", y = "Oz"}.

?- [CITIZEN : "Dorothy"]<-MEMB-[COUNTRY : "Oz"].

no.
```

2.4.2 Program 2

(it can be found in Samples/Others/GoodSister.prlg):

```
Universal > Person, Action, Object, Attribute.
Object > House, Restaurant, Walnut, Shell, Spoon.
Attribute > Classical, Age, Easily.
Person > Man, Woman.
Action > Perform, Go, Work, Buy, Eat, Search.

Man = Jo, Mark.
Woman = Mary, Jane.

// Prolog+CG rules. Notes that a goal can be a term or a CG.
// x, w and a are variables.
goodSister(x) :-
       employee(x),
       [Woman : x]-attr->[Classical].

[Woman : w]-attr->[Classical] :-
       [Work]-
             -near->[House]-poss->[Woman : w]-ageOf->[Age = a],
             -agnt->[Woman : w],
       inf(a, 40).
```

```
// *1 is a multi-referent.
[Work]-
      -agnt->[Person : Jane]-
                 -ageOf->[Age = 30],
                 <-poss-[House : *1]<-nearOf-[Restaurant];,
      -near->[House : *1].


employee(Mary).
employee(Jane).


// An example of compound CG
[Person]<-agnt-[Perform]-obj->
   [Action = [Eat]-
      -obj->[Walnut=wal2]-part->[Shell:myShell = toto],
      -instr->[Spoon]-matr->[Shell : myShell]
   ]-manr->[Easily].


sense("extract", [Search]-
                         -agnt->[Person],
                         -from->[Book],
                         -obj->[Information]).


sense("classical woman", [Woman]-attr->[Classical]).
```

Let us consider now some queries:

```
?- goodSister(x).

{x = Jane}

?-goodSister(Mary).

 no.

?- [Woman: x]-attr->[Classical].

{x = Jane}
```

The next two queries illustrate how the compound CG are naturally expressed and manipulated in PROLOG+CG (like simple CG). Note that an embedded CG is considered in PROLOG+CG as a *value* of the concept (*not as a referent*).

```
?- [Man]<-agnt-[Perform]-obj->[Action =
         [Eat]-obj->[Walnut]-part->[Shell : x] ].

{x = myShell}

?- [Man]<-agnt-[Perform]-obj->[Action = x].
{x = [Eat]-
       -obj->[Walnut = wal2]-part->[Shell:myShell = toto]-
               <-matr-[Spoon : *1];,
       -instr->[Spoon : *1]}

?- sense("extract", g).

{g = [Search]-
          -agnt->[Person],
          -from->[Book],
          -obj->[Information]}
```

In the next request, the variable x stand for the concept type. Thus we can reason and manipulate all the fields of a concept (the type, the referent and the value).

```
?- sense("extract", [x]<-obj-[Action]-agnt->[Person]).

{x = Information}

?- sense("extract", [x]<-obj-[Work]-agnt->[Person]).

no.
```

The following query is interesting: the second goal is a variable that will be unified, after the satisfaction of the first goal, to a CG. So the request is to search the CG associated to "classical woman" and then try to solve it (as the next goal of the request).

```
?- sense("classical woman", g), g.

{g = [Woman]-attr->[Classical]}
```

2.5 CG operations

Actually, PROLOG+CG provides the following operations on CG, for both simple and compound CG with sets and co-references (Figure 2.1):

- **concOfCG(c, g):** check if c is a concept of the CG g. Concept unification is used to search for such a concept. The primitive "`concOfCG/2`" is non-deterministic: it searchs by default for all the concepts in the CG g that could unify the concept c which could be totally determined, partially specified (the concept type or referent is a variable) or non-specified (a variable). If c is a free variable then the primitive, with the backtrack, will return all the concepts of the CG g.

- **branchOfCG(b, g):** check if the branch b (a branch is two concepts connected by a relation) is a branch of the CG g. The primitive is non-deterministic: it searches by default for all the branches in the CG g that could unify the branch b which could be totally determined, partially specified or non-specified (a variable). If b is a free variable then the primitive, with the backtrack, will return all the branches of the CG g.

- **maximalJoin(g1, g2, g3)**: returns in g3 the maximal join of the two CG g1 and g2. maximalJoin joins in g3 any information contained in g1 and g2. The join is guided of course by the matching of the two graphs g1 and g2.

- **generalize(g1, g2, g3)**: returns in g3 the generalization of the two CG g1 and g2. generalize puts in g3 the common information found in g1 and g2. Again, the generalize operation is guided by the matching of the two CG.

- **subsume(g1, g2)**: checks that g1 subsumes g2 ; checks that g1 is more general than g2. subsume checks that the information contained in g1 is more general than the information contained in g2.

- **subsume(g1, g2, g3)**: checks that g1 subsumes g2 and return in g3 the image of g1 in g2 (the sub-graph of g2 that is ismorph to g1).

These operations are provided also with entry points which are very usefull in natural language processing, as illustrated in section 2.6 (sample III).

2.5.1 Examples of calling CG operations

(it can be found in Samples/ExpleCGs.prlg)

To facilitate the demo, the program contains already the specification of some CGs.

```
Universal > Person, Animal, Action, Situation, Object,
            AbstractEntity, Attribute.
Person > Man, Woman, Employee.
Man > Boy.
Woman > Girl.
Employee > Supervisor.
Action > Drive, Love, Break, Rent, Begin, Press, Look.
Object > Vehicle, Machine, Key, Keyboard, Finger.
AbstractEntity > Society, Session, Years, Proposition.
Vehicle > Car, Truck.
```

```
Attribute > Fast, Color, Expensive, Big.

Boy = John, Bob.
Girl = Sue, Mary.
Color = red.
Machine = res23.
Years = four.
Key = enter.

// cg(cg12, g1, g2) , maximalJoin(g1, g2, g3).
cg(cg12, [Person]<-agnt-[Drive]-obj->[Car],
         [Boy: John]<-agnt-[Drive]-manr->[Fast]).

// cg(cg34, g1, g2) , generalize(g1, g2, g3).
cg(cg34, [Boy: John]<-agnt-[Drive]-obj->[Car]-chrc->[Color: red],
         [Girl: Sue]<-agnt-[Drive]-
                              -obj->[Truck],
                              -manr->[Fast]).

// cg(cg56, g1, g2) , subsume(g2, g1).
// cg(cg56, g1, g2) , subsume(g2, g1, g3).
cg(cg56, [Man: John]-child->[Boy: Bob]<-agnt-[Love]-
                         ->obj->[Girl: Mary],
         [Person]-child->[Person]).
cg(cg70, [Break]-
             -agnt->[Employee],
             -obj->[Machine]-attr->[Expensive],
         [Situation]-mainActOf->[Break]-
                      -agnt->[Supervisor],
                      -obj->[Machine: res23]-qlte->[Big]).

// cg(cg910, g1, g2) , maximalJoin(g1, g2, g3).
cg(cg910,
       [Person: John]<-agnt-[Begin]-
                      -obj->[Session],
                      -srce->[Proposition =
                   [Person: John]<-agnt-[Press]-
                      ->obj->[Key: enter]-part->[Keyboard] ];,
      [Man]<-agnt-[Begin]-srce->[Proposition =
                   [Person]<-agnt-[Press]-
                           -obj->[Key],
                           -manr->[Fast] ]).

// cg(cg1011, g1, g2) , maximalJoin(g1, g2, g3).
cg(cg1011,
   [Person]<-agnt-[Begin]-
```

```
            -obj->[Session],
            -srce->[Proposition =
                [Person]<-agnt-[Press]-obj->[Key: enter]-
                           ->part->[Keyboard] ],
      [Man]<-agnt-[Begin]-srce->[Proposition =
            [Person]<-pat-[Look]-dest->[Person] ]).
```

Let us asks some queries:

Examples of calling the primitive concOfCG/2

```
?- concOfCG([Drive], [Drive]-obj->[Car]).

{}

?- concOfCG(c,
            [Man : John]-child->[Boy : Bob]-
                     <-agnt-[Love]-obj->[Girl : Mary]).
{c = [Man : John]}
{c = [Boy : Bob]}
{c = [Love]}
{c = [Girl : Mary]}

?- concOfCG([Person : x],
            [Man : John]-child->[Boy : Bob]-
                  <-agnt-[Love]-obj->[Girl : Mary]).
{x = John}
{x = Bob}
{x = Mary}
```

Examples of calling the primitive branchOfCG/2

Gives the children of the person x: note that the whole concept (the target of the relation child) is represented by the variable C.

```
?- branchOfCG([Person : x]-child->C,
              [Man : John]-
                          -child->[Boy : Bob],
                          -attr->[Color :black],
                          -child->[Girl : Mary],
                          <-agnt-[Eat] ).

{x = John, C = [Boy : Bob]}
{x = John, C = [Girl : Mary]}
```

Search the relations that relate two persons x and y: note that the relation is represented by a variable.

```
?- branchOfCG([Person : x]-R->[Person : y],
            [Man : John]-
                        -child->[Boy : Bob],
                        -attr->[Color :black],
                        -child->[Girl : Mary],
                        <-agnt-[Eat]
                        ).

{x = John, R = child, y = Bob}
{x = John, R = child, y = Mary}
```

Gives all the branches of a CG:

```
?- branchOfCG(b, [Man : John]-
                             -child->[Boy : Bob],
                             -attr->[Color :black],
                             -child->[Girl : Mary],
                             <-agnt-[Eat] ).

{b = [Man : John]-child->[Boy : Bob]}
{b = [Man : John]-attr->[Color : black]}
{b = [Man : John]-child->[Girl : Mary]}
{b = [Eat]-agnt->[Man : John]}
```

2.5.2 Unification

eq/2 is the unification operator.

- **eq(Concept c1, Concept c2)**and **eq(CG g1, CG g2):**

Unification on concepts

Concepts are considered to be Prolog+CG data structures on a par with all other data structures.

```
?- eq([Person : John], [Man : x]).

{x = John}

?- eq([Person : John], [Woman : x]).

no.

? member([Person : x],
         ([Man : John], [Color : red], [Woman : Mary])).

{x = John}
{x = Mary}
```

Unification on simple CGs with sets

It fails since Andre is not specified in the set {John, Bob, Sam}.

```
?- eq([Person : Andre]<-agnt-[Drive]-obj->[Vehicle : myCar],
      [Boy : {John, Bob, Sam}]<-agnt-[Drive]-
                                              -obj->[Car :x],
                                              -manr->[Fast]).

no.

?- eq([Person : Bob]<-agnt-[Drive]-obj->[Vehicle : myCar],
      [Boy : {John, Bob, Sam}]<-agnt-[Drive]-
                                              -obj->[Car :x],
                                              -manr->[Fast]).
{x = myCar}
```

Unification on compound CGs with co-referents

The unification succeeds since, apart from the unification of the other components of the two CGs, the co-reference ‘x’ between [**Person : x**] and [**Man : x**] in the first CG can be unified with the co-reference ‘Andre’ between [**Man : Andre**] and [**Boy : Andre**] in the second CG. Indeed, the concepts [**Person : x**]/[**Man : x**] refer to the same entity and this is also the case for the concepts [**Man : Andre**]/[**Boy : Andre**].

```
?-eq([Person : x]<-agnt-[Begin]-srce->[Proposition =
             [Man : x]<-agnt-[Action]-obj->[Object]],
     [Man : Andre]<-agnt-[Begin]-
             -obj->[Session],
             -srce->[Proposition =
                  [Boy:Andre]<-agnt-[Press]-
                      ->obj-> [Key :enter]-part->[Keyboard]]).

{x = Andre}
```

Unification on compound CGs with co-referents

here, the unification fails since the co-reference ‘x’ in the first CG can’t be unified.

```
?- eq([Person : x]<-agnt-[Begin]-srce->[Proposition =
            [Man : x]<-agnt-[Action]-obj->[Object]],
      [Man : Andre]<-agnt-[Begin]-
            -obj->[Session],
            -srce->[Proposition =
                [Boy : John]<-agnt-[Press]-
```

```
                    -> obj->[Key:enter]-part->[Keyboard]]).

no.
```

Unification on compound CGs with co-referents

here, the unification fails too since the co-reference 'x' in the first CG has no corresponding co-reference in the second CG.

```
?- eq([Person : x]<-agnt-[Begin]-srce->[Proposition =
          [Man : x]<-agnt-[Action]-obj->[Object]],
      [Man]<-agnt-[Begin]-
          -obj->[Session],
          -srce->[Proposition =
                [Boy]<-agnt-[Press]-
                     ->obj->[Key : enter]-part->[Keyboard]]).

no.
```

2.5.3 Subsume operation

```
?- subsume(
      [Person]-child->[Person],
      [Man:John]-child->[Boy:Bob]<-agnt-[Love]-obj->[Girl:Mary]).

{}

?- subsume(
    [Person]-child->[Person],
    [Man:John]-child->[Boy:Bob]<-agnt-[Love]-obj->[Girl:Mary],
    g3).

{g3 = [Man :John]-child->[Boy : Bob]}
```

Subsume on simple CGs with sets

```
?- subsume([Person]-child->[Person : {John, Sam}],
           [Man : John]-child->[Boy : {Bob, John, Andre, Sam}]-
                <-agnt-[Love]-obj->[Girl : Mary]).

{}
```

The same request but we specify the third argument to get the image of the first argument

```
?- subsume(
     [Person]-child->[Person : {John, Sam}],
```

```
     [Man : John]-child->[Boy : {Bob, John, Andre, Sam}]-
              <-agnt-[Love]-obj->[Girl : Mary];,
     g).

{g = [Man : John]-child->[Boy : {Bob, John, Andre, Sam}]}
```

Subsume fails since the set John, Sam is not included in the set {Bob, John, Andre}

```
?-subsume(
     [Person]-child->[Person : {John, Sam}],
     [Man : John]-child->[Boy : {Bob, John, Andre}]-
             <-agnt-[Love]-obj->[Girl : Mary]).

no.
```

Subsume on compound CGs without co-references

```
?- subsume(
     [Person ]<-agnt-[Begin]-srce->[Proposition =
              [Person]<-agnt-[Action]-obj->[Object]],
     [Man]<-agnt-[Begin]-
              -obj->[Session],
              -srce->[Proposition =
                 [Boy]<-agnt-[Press]-
                    ->obj->[Key:enter]-part->[Keyboard]];,
     g).

{g = [Begin]-
            -srce->[Proposition = [Press] -
                                             -obj->[Key : enter],
                                             -agnt->[Boy]],
            -agnt->[Man]}
```

Subsume on compound CGs with co-reference

The same request as the precedent but a co-reference ‘x’ is added in the first argument. Subsume fails in this case since the co-reference ‘x’ is not mapped to a co-reference in the second CG : the first CG doesn’t totally subsume the second CG; the information that the two concepts [Person : x] and [Person : x] refers to the same entity is not found in the second CG since the corresponding concepts in the second CG [Man] and [Boy] could refer to different entities.

```
?- subsume(
    [Person :x]<-agnt-[Begin]-
         ->srce->[Proposition =
                   [Person:x]<-agnt-[Action]-obj->[Object]];,
```

```
    [Man]<-agnt-[Begin]-
          -obj->[Session],
          -srce->[Proposition =
                     [Boy]<-agnt-[Press]-
                         ->obj->[Key:enter]-part->[Keyboard]];,
    g).

no.
```

Subsume on compound CGs with co-reference

The same request as the precedent but a co-reference ‘y’ is added to the second CG. Subsume is possible in this case since the constraint imposed by the co-reference in the first CG is verified by a corresponding co-reference in the second CG.

```
?- subsume([Person :x]<-agnt-[Begin]-srce->[Proposition =
           [Person:x]<-agnt-[Action]-obj->[Object]],
           [Man : y]<-agnt-[Begin]-
                -obj->[Session],
                -srce->[Proposition =
                        [Boy: y]<-agnt-[Press]-
                          ->obj->[Key :enter]-part->[Keyboard]];,
           g).

{x = FREE,
 y = FREE,
 g = [Begin] -
             -srce->[Proposition = [Press] -
                           -agnt->[Boy : y],
                           -obj->[Key : enter]],
                           -agnt->[Man : y]
```

2.5.4 maximalJoin operation

```
?- cg(cg12, g1, g2), maximalJoin(g1, g2, g3).

{g1 = [Drive] -
              -obj->[Car],
              -agnt->[Person],
 g2 = [Drive] -
              -manr->[Fast],
              -agnt->[Boy : John],
 g3 = [Drive] -
              -agnt->[Boy : John],
              -obj->[Car],
              -manr->[Fast]}
```

MaximalJoin on simple CGs with sets

```
?- maximalJoin(
      [Person : {Bob, Andre}]<-agnt-[Drive]-obj->[Car],
      [Boy : {John, Bob, Sam}]<-agnt-[Drive]-manr->[Fast],
      g).

{g = [Drive] -
             -agnt->[Boy : {John, Bob, Sam, Andre}],
             -obj->[Car],
             -manr->[Fast]}
```

MaximalJoin on simple CGs with coercion and set

```
?- maximalJoin(
     [Person : Andre]<-agnt-[Drive]-obj->[Car],
     [Boy :{John, Bob, Sam}]<-agnt-[Drive]-manr->[Fast],
     g).

{g = [Drive] -
             -agnt->[Boy : {John, Bob, Sam, Andre}],
             -obj->[Car],
             -manr->[Fast]}
```

Maximal Join failure: coercion impossible since Mary is not conform to Boy

```
?- maximalJoin(
   [Person : Mary]<-agnt-[Drive]-obj->[Car],
   [Boy : {John, Bob, Sam}]<-agnt-[Drive]-manr->[Fast],
   g).

no.
```

Maximal join on compound CGs

```
?- cg(cg910, g1, g2), maximalJoin(g1, g2, g3).
{g1 = [Begin] -
        -obj->[Session],
        -srce->[Proposition = [Press] -
                    -obj->[Key : enter]-part->[Keyboard],
                    -agnt->[Person : John]],
        -agnt->[Person : John],
 g2 = [Begin] -
        -srce->[Proposition = [Press] -
                    -obj->[Key],
                    -manr->[Fast],
```

```
                  -agnt->[Person]],
        -agnt->[Man],
 g3 = [Begin] -
        -srce->[Proposition = [Press] -
                    -obj->[Key : enter]-part->[Keyboard],
                    -agnt->[Person : John],
                    -manr->[Fast]],
        -agnt->[Man : John],
        -obj->[Session]}
```

Concerning the next request, note that the maximalJoin of the embedded graphs:

```
   [Press] -
           -obj->[Key : enter]-part->[Keyboard],
           -agnt->[Person]
```

and

```
   [Look] -
          -dest->[Person],
          -pat->[Person]
```

will discover that the two graphs have nothing in common except the [Person] concept. Thus, the maximalJoin will be done around the concept [Person] of the first graph and one concept [Person] of the second.

```
?- cg(cg1011, g1, g2), maximalJoin(g1, g2, g3).
{g1 = [Begin] -
        -obj->[Session],
        -srce->[Proposition = [Press] -
                  -obj->[Key : enter]-part->[Keyboard],
                  -agnt->[Person]],
        -agnt->[Person], g2 = [Begin] -
                  -srce->[Proposition = [Look] -
                            -dest->[Person],
                            -pat->[Person]],
                  -agnt->[Man], g3 = [Begin] -
                            -srce->[Proposition =
                  [Press] -
                      -agnt->[Person]<-pat-[Look]-dest->[Person],
                      -obj->[Key : enter]-part->[Keyboard]],
                        -agnt->[Man],
                        -obj->[Session]}
```

maximalJoin on compound CGs with co-references

To illustrate the interplay between co-references and maximal join, we will change, in the above program the fact cg(cg1011, ...) as follows: we add a co-reference, represented by the variable x, between the two concepts [Person **: x**] and [Person **: x**] in the first CG.

```
cg(cg1011,
    [Person : x]<-agnt-[Begin]-
       -obj->[Session],
       -srce->[Proposition =
          [Person: x]<-agnt-[Press]-
                ->obj->[Key: enter]-part->[Keyboard] ];,
    [Man]<-agnt-[Begin]-srce->[Proposition =
                   [Person]<-pat-[Look]-dest->[Person] ]).
```

As shown by the following request, the CG g3 that results from the maximalJoin of the two CG g1 and g2 will contain the above coreference. In fact, **coreference is considered as an implicit relation** between the two concepts. So, in the maximalJoin, such a relation will remain.

```
?- cg(cg1011, g1, g2), maximalJoin(g1, g2, g3).
{g1 = [Begin] -
         -obj->[Session],
         -srce->[Proposition = [Press] -
                  -obj->[Key : enter]-part->[Keyboard],
                  -agnt->[Person : x]],
                  -agnt->[Person : x],
g2 = [Begin] -
         -srce->[Proposition = [Look] -
                  -dest->[Person],
                  -pat->[Person]],
         -agnt->[Man],
g3 = [Begin] -
         -srce->[Proposition = [Press] -
                  -agnt->[Person : x]<-pat-[Look]-dest->[Person],
                  -obj->[Key : enter]-part->[Keyboard]],
                  -agnt->[Man : x],
                  -obj->[Session]
```

Now and to illustrate *the impact* of *co-references on maximal join*, we will change, in the above program the fact cg(cg1011, ...) as follows:

```
cg(cg1011, [Person : x]<-agnt-[Begin]-
               -obj->[Session],
               -srce->[Proposition =
                    [Person: x]<-agnt-[Press]-
```

```
                        ->obj->[Key: enter]-part->[Keyboard] ],
  [Man : y]<-agnt-[Begin]-srce->[Proposition =
                   [Person]<-pat-[Look]-dest->[Person : y]]).
```

The variable x is a co-reference between the two concepts [Person : x] and [Person :x] and the variable y is a co-reference between the two concepts [Man : y] and [Person : y].

To make the above change effective, we have to recompile the program and then ask the same request:

```
?- cg(cg1011, g1, g2), maximalJoin(g1, g2, g3).
{g1 = [Begin] -
             -obj->[Session],
             -srce->[Proposition = [Press] -
                          -obj->[Key : enter]-part->[Keyboard],
                          -agnt->[Person : x]],
                          -agnt->[Person : x],
g2 = [Begin] -
            -srce->[Proposition = [Look] -
                                  -dest->[Person : y],
                                  -pat->[Person]],
            -agnt->[Man : y],

 g3 = [Begin] -
             -srce->[Proposition =
               [Press] -
                 -agnt->[Person : x]<-dest-[Look]-pat->[Person],
                 -obj->[Key : enter]-part->[Keyboard]],
             -agnt->[Man : x],
             -obj->[Session]}
```

If you look at the result g3 and especially at the embedded graph:

```
    [Press] -
            -agnt->[Person : x]<-dest-[Look]-pat->[Person],
            obj->[Key : enter]-part->[Keyboard]
```

you will note that it is different from the previous one: the maximalJoin between the two initial graphs has been done around the destination (dest) of [Look], not the patient. The reason is this: since the concept [Person : x] in g1 (in the first level of g1) has been joined with the concept [Man : y] in g2 and since the embedded graphs that contain the concepts [Person : x] and [Person : y] will be joined, then we must begin their maximalJoin by joining the concept [Person : x] with the [Person : y]. Note also that the resulting graph g3 contains the co-reference x that relates the concept that results from the join of [Person : x] and [Man : y] with the concept that results from the join of [Person : y] and [Person : y].

2.5.5 Generalize operation

```
?- cg(cg34, g1, g2), generalize(g1, g2, g3).

{g1 = [Drive] -
             -obj->[Car]-chrc->[Color : red],
             -agnt->[Boy : John],
 g2 = [Drive] -
             -obj->[Truck],
             -manr->[Fast],
             -agnt->[Girl : Sue],
 g3 = [Drive] -
             -obj->[Vehicle],
             -agnt->[Person]}
```

generalize on simple CGs with sets:

the case of intersection between sets

```
?- generalize([Person : {John, Sam, Sue, Mary}]<-agnt-[Drive]-
                     ->obj->[Car]-chrc->[Color : red],
              [Girl : {Sue, Mary, Katy}]<-agnt-[Drive]-
                     -obj->[Truck],
                     -manr->[Fast],
               g).

{g = [Drive] -
            -obj->[Vehicle],
            -agnt->[Person : {Sue, Mary}]}
```

Generalize on simple CGs with sets

The case of membership of an element to a set

```
?- generalize([Person : {John, Sam, Sue, Mary}]<-agnt-[Drive]-
                    -obj->[Car]-chrc->[Color : red],
              [Girl : Sue]<-agnt-[Drive]-
                    -obj->[Truck],
                    -manr->[Fast],
              g).
{g = [Drive]-
        -obj->[Vehicle],
        -agnt->[Person : Sue]}
```

generalization of compound CGs with co-references

Generalize treats co-references as it does with relations : in this example, since the co-reference ‘x’ in the first argument g1 has no corresponding co-reference in the second argument, then no co-reference is added to the resulted graph g.

```
?- generalize([Person: x]<-agnt-[Begin] -
                -obj->[Session],
                -srce->[Proposition = [Press] -
                           -obj->[Key : enter]-part->[Keyboard],
                           -agnt->[Person : x] ],
             [Man]<-agnt-[Begin]-srce->[Proposition =
                [Boy]<-agnt-[Action]-dest->[Person] ],
             g).

{x = FREE, g = [Begin] -
                -srce->[Proposition = [Action]-agnt->[Person]],
                -agnt->[Person]}
```

Impact of co-references on generalize

In the current definition and implementation of generalize, we consider the following heuristic about treatment of co-references: if both the first and the second arguments (let's call them g1 and g2) contain co-referents, like in this example (represented by variable 'x' and 'y' respectively), and if the generalization of the first level of the two CGs involves a common generalization of the two co-references (i.e. generalization of [Person : x] in g1 with [Man : y] in g2 producing [Person : c01] in the resulting CG g), and if the context [Proposition : ...] in g1 is being generalized with the context [Proposition : ...] in g2, then the generalization of the contain of these two contexts will be constrained by the generalization of the co-references 'x' and 'y' : the concept [Person : x] in the context embedded in g1 MUST BE generalized with the concept [Person : y] in the context embedded in g2. The result is the concept [Person : c01] which is in co-reference with the concept [Person : c01], the two are concepts of the resulted CG g. Note that this graph is different from the resulted CG of the precedent example. As this example shows, with the above heuristic, we preserve the specific information that the two contexts [Proposition ...] and [Proposition ...] contains the same entity, refereed in the first context by [Person : x] and in the second by [Person : y]. However, we loose other information like that the two contexts contain the information : [Action]-agnt-¿[Person]. A better solution may be a conjunction of the two information: [Person : c01] and [Action]-agnt-¿[Person]. Further study is required for the treatment of co-references by the generalization operation (depending on the interpretation given to it).

```
?- generalize([Person: x]<-agnt-[Begin] -
                     -obj->[Session],
                     -srce->[Proposition = [Press] -
                     -obj->[Key : enter]-part->[Keyboard],
                     -agnt->[Person : x] ],
             [Man: y]<-agnt-[Begin]-srce->[Proposition :
                     [Boy]<-agnt-[Action]-dest->[Person : y] ],
```

```
              g).

{x = FREE, y = FREE, g = [Begin] -
                      -srce->[Proposition: [Person : c01]],
                      -agnt->[Person : c01]}
```

2.6 Sample III: Semantic analyzer

This example illsutrates the expressive power that results from the integration of CG to PROLOG and also the possibility to manipulate directly CG from a programming language perspective. For instance, this example shows how variables can be used to stand for concept type, concept referent, concept value, for the whole concept or even for a relation. The example illustrates also how a CG can be constructed by successive calls to maximal join on other CGs. Finally, it is our hope the convince the reader that PROLOG+CG is very well suited for natural language processing. See SHRDHLCom for a detailed description of the program.

```
Personne > Homme.
Objet > PYRAMIDE, CUBE.
Action > METTRE.
Attribut > TAILLE, COULEUR.
COULEUR = bleu, rouge.

TAILLE = petite, grand.
Homme = john.

dictionnaire("mets", verbe, METTRE).
dictionnaire("pyramide", nom, PYRAMIDE).
dictionnaire("cube", nom, CUBE).
dictionnaire("petite", adj, tailleDe, TAILLE, petite).
dictionnaire("rouge", adj, couleurDe, COULEUR, rouge).
dictionnaire("grand", adj, tailleDe, TAILLE, grand).
dictionnaire("bleu", adj, couleurDe, COULEUR, bleu).
dictionnaire("sur", prep, sur).
dictionnaire("la", art, x).
dictionnaire("le", art, x).

Verbe((v|P), P, V) :- dictionnaire(v, verbe, V).
Prep((v|P), P, V) :- dictionnaire(v, prep, V).
Art((v|P), P, V) :- dictionnaire(v, art, V), /.
Art(P, P, undefined).
Nom((v|P), P, V) :- dictionnaire(v, nom, V).
Adj(A, R, T, V) :- dictionnaire(A, adj, R, T, V).
```

```
semantic_analyzer :-
      read_sentence(P),
      phrase_imperative(P, G),
      writenl(G), /.

phrase_imperative(P, G) :-
      Verbe(P, P1, V),
      GN(P1, P2, N1, E_GN1, S1),
      eq(G1, [V]-obj->[N1]),
      eq(G1, [V]-obj->E_N_G1),
      maximalJoin(G1, E_N_G1, S1, E_GN1, G1_S1, _),
      Prep(P2, P3, s_prep),
      GN(P3, ("."), N2, E_GN2, S2),
      eq(G2, [V]-s_prep->[N2]),
      eq(G2, [V]-s_prep->E_N_G2),
      maximalJoin(G2, E_N_G2, S2, E_GN2, G2_S2, _),
      eq(E_V_GS1-obj->x, G1_S1),
      eq(E_V_GS2-s_prep->y, G2_S2),
      maximalJoin(G1_S1, E_V_GS1, G2_S2, E_V_GS2, G, _).

GN(P, P1, N, E, G) :-
      Art(P, P2, A1),
      AdjsSynt(P2, P3, L_Adjs),
      Nom(P3, P4, N),
      SemAdjs(L_Adjs, N, A1, S, E1),
      AdjsSynt(P4, P1, L_Adjs2),
      SemAdjs(L_Adjs2, N, A1, S1, E11),
      maximalJoin(S, E1, S1, E11, G, E).

AdjsSynt((A|P), P1, (A|L_Adjs)) :-
      dictionnaire(A, adj, _, _, _),
      AdjsSynt(P, P1, L_Adjs), /.
AdjsSynt(P, P, ()).

SemAdjs((A|P), N, A1, S, E_N_S) :-
      Adj(A, R1, T1, V1),
      eq(G, [N : A1]-R1->[T1 = V1]),
      eq(G, E_N-R1->x),
      SemAdjs2(P, G, E_N, N, A1, S, E_N_S), /.
SemAdjs((), N, A1, G, E) :-
      eq(G, [N : A1]),
      eq(G, E-rel->[Universal]), /.

SemAdjs2((A|P), G, E_N, N, A1, S, E_S) :-
      Adj(A, R, T, V),
      eq(G1, [N : A1]-R->[T = V]),
```

```
      eq(G1, E_N1-R->x),
      maximalJoin(G, E_N, G1, E_N1, G2, E_N2),
      SemAdjs2(P, G2, E_N2, N, A1, S, E_S), /.
SemAdjs2((), G, E, _, _, G, E).
```

Let us run the code:

```
?- semantic_analyzer.
|:mets la petite pyramide rouge sur le grand cube bleu.

[METTRE] -
         -obj->[PYRAMIDE] -
                          -tailleDe->[TAILLE = petite],
                          -couleurDe->[COULEUR = rouge];,
         -sur->[CUBE] -
                      -tailleDe->[TAILLE = grand],
                      -couleurDe->[COULEUR = bleu];
{}
```

Chapter 3

Advanced topics

3.1 Meta-operations

Figure 3.1 presents the current meta-operations of PROLOG+CG:

- cut : "/",
- free,
- findall,
- read,
- read_sentence,
- write,
- writenl,
- nl,
- clearConsole,
- asserta, assertz,
- retract, suppress,
- term_list,
- set_list, and
- createInstance (this operator is introduced later, in Section 4.5).

Except createInstance, meta-operations are similar to the corresponding ones in the other PROLOG versions. Of course we have extended them to consider CG as another basic data structure. For instance, the fact to assert may be represented by a CG (not only a term).

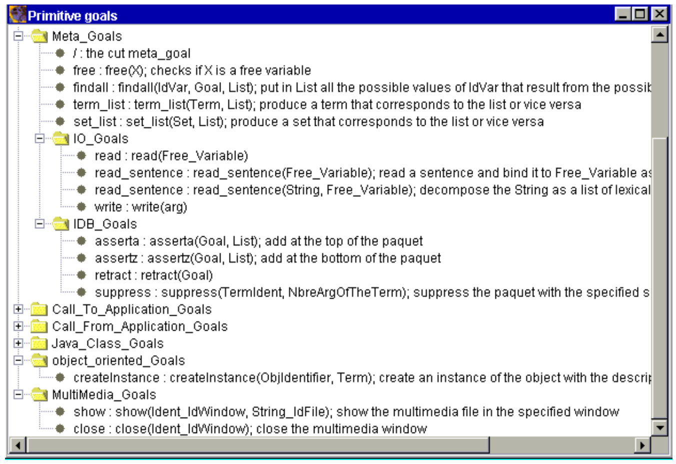


Figure 3.1: Meta-Goals of PROLOG+CG

3.1.1 Operator Cut/0 : "/"

To control the resolution process and to get a more efficient search engine, PROLOG+CG, like most other Prolog versions, provides the cut operator (represented often by "/" or "!"). The cut operator "/" is considered as a term with a special identifier ("/") and no arguments. It can be used as a goal in the tail of an inference rule.

Example

```
OurMember(e, (e | _)) :- /.
OurMember(e, (_ | x)) :- OurMember(e, x), /.

?- OurMember(x, (1, 3, 5, 7)).

{x = 1}
```

3.1.2 Operator free/1

free(Variable)
Checks if the variable is free. Succeeds if it is, fails if it isn't.

Example

```
?- free(x).

{}
```

```
?- eq(x, 45), free(x).

no.
```

3.1.3 Operator findall/3

findall(Variable, Goal, List)
Return in List all the values of Variable that result from all the possible resolutions of Goal

Example

```
donnee(4, jjj).
donnee(5, hhh).
donnee(6, kkkk).

data(10, kkk).
data(20, ddd).
data(30, ffff).
data(40, rrrr).

datum(x) :-
    donnee(x, _).
datum(x) :-
    data(x, _).

ex(m) :-
    findall(a, datum(a), L),
    moyenne(L, m), /.

moyenne(L, m) :-
    length(L, n),
    somme(L, 0, s),
    val(m, div(s, n)), /.

somme((x|L), s1, s2) :-
    val(s3, add(x, s1)),
    somme(L, s3, s2), /.
    somme((), s, s).
```

And to query:

```
?-ex(m).

{m = 16.428571428571427}
```

3.1.4 Operator read

read(Free_Variable)

The argument of "`read`" should be a free variable at the moment of its execution. When a read operation is executed, the system will prompt the user with the symbol "`|:`" and the user should give his data which could take several lines (a simple data like a number, a boolean, an identifier, a string or a composed data like a term, a list or a CG) and it should terminate with a point "`.`". Once his data is edited, the user should end with a period ("`.`") and press the key "`Enter`".

Example

```
?- read(x).
|: papa(Ahmed, Goerge).

{x = papa(Ahmed, Goerge)}
```

3.1.5 Operator read_sentence/1

read_sentence(Free_Variable)

read_sentence/1 reads a sentence (i.e. a sequence of characters) and returns the list of "`words`" that composes it. The sentence should be endede with a period ("`.`"), which will be the last "`word`".

You **cannot** use `read_sentence` from within a Java applet.

Example

```
?- read_sentence(p).
|: this is a simple sentence, with a comma inside.

{p = ("this", "is", "a", "simple", "sentence", ",", "with", "a",
 "comma", "inside", ".")}
```

3.1.6 Operator read_sentence/2

read_sentence(Sentence, Free_Variable)

read_sentence/2 returns in its second argument the list of words that compose its first argument (which is a String).

You cannot use read_sentence/2 from within a Java applet.

Example

```
?- read_sentence("this is another sentence", L).

{L = ("this", "is", "another", "sentence")}
```

3.1.7 Operator write

write(Data)

The argument of write/1 is any PROLOG+CG data. A newline is not added after the data has been written. Strings and variables containing strings will get their "double quotes" stripped. write/1 always succeeds.

3.1.8 writenl

writenl(Data)

The argument of writenl is any PROLOG+CG data. A newline IS added after the data has been written. Strings and variables containing strings will get their "double quotes" stripped. Writenl/2 always succeeds.

3.1.9 nl

nl

nl/0 takes no arguments, and prints a newline to the console either in the normal Prolog+CG application GUI or in the Prolog+CG applet. It always succeeds.

3.1.10 clearConsole

clearConsole

clearConsole/0 takes no arguments, and clears the console either in the normal Prolog+CG application GUI or in the Prolog+CG applet. It always succeeds.

3.1.11 asserta and assertz

asserta(Goal,List_Of_Goals), assertz(Goal,List_Of_Goals)

Asserta adds to the current program a new rule at the top of the packet (if it exists) while assertz adds the rule at the bottom of the packet. The first argument of asserta (and assertz) represents the head of the new rule while the second argument represents the tail expressed as a list. Of course, when the new rule is a fact, the list is empty.

3.1.12 retract/suppress

retract(Goal) & suppress(TermId, NumberOfArguments)

Retract eliminates from the current program any rule with a head that can be unified with its argument.

Suppress eliminates a whole packet of rules. The two arguments of suppress (an identifier and an integer) enables the identification of the packet.

3.1.13 term_list

term_list(Term, List)
term_list transforms a term to a list and vice versa.

Example

```
?- eq(x, papa), term_list(t, (x, Ahmed, y)).

{x = papa, t = papa(Ahmed, y), y = FREE}
```

Now, suppose that we have a program that contains this packet:

```
papa(Ahmed, Soumia).
papa(Sahir, Fatine).
papa(Ahmed, Khalid).
```

We ask again the previous question but in addition, we want to execute the new composed term t:

```
?- eq(x, papa), term_list(t, (x, Ahmed, y)), t.

{x = papa, t = papa(Ahmed, Soumia), y = Soumia}
{x = papa, t = papa(Ahmed, Khalid), y = Khalid}
```

3.1.14 set_list

set_list(Set, List)
`set_list` transforms a set to a list and vice versa.

Example

```
?- set_list(s, (Karim, Ahmed, Hicham)).

{s = {Karim, Ahmed, Hicham}}

?- set_list({Karim, Ahmed, Hicham}, L).

{L = (Karim, Ahmed, Hicham)}
```

3.2 The visual debugger of PROLOG+CG

PROLOG+CG provides a powerful debugger that visualizes the inference or resolution process as a construction or deconstruction (due to a backtrack) of the inference tree. Figure 3.2 gives a snapshot that shows the debugger in action. The figure shows also an auxiliary window: “a variable inspection window”. This type of window is introduced next.

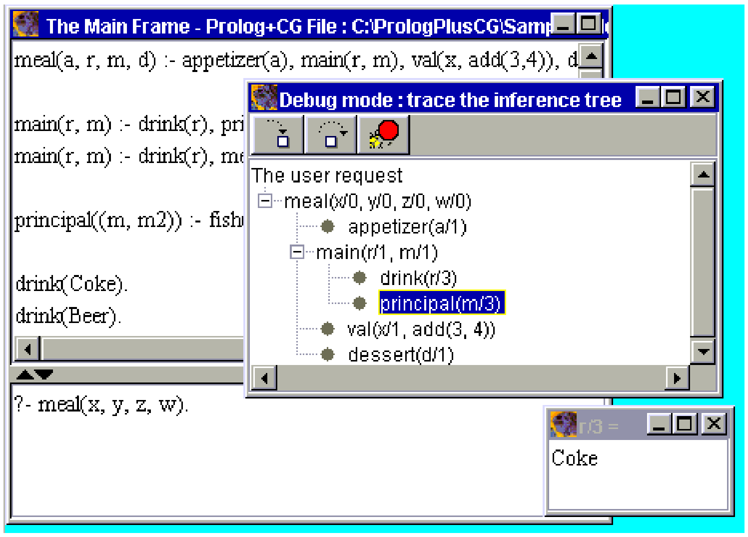
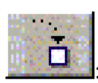
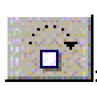
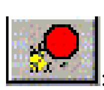


Figure 3.2: The visual Debugger of PROLOG+CG

To debug (or trace, follow) the resolution/satisfaction of a request (we assume that the program has been compiled), choose from the menu the option "`Build/Debug`" and then activate the interpreter as usual. The debug window appears. The current goal is the selected node in the visual tree. Next, you must guide the debugger. Three main actions are provided for that (they are represented by the three icons in the toolBar of the debug window):

- "`Inside`" iconified by : "`Inside the current step`" means debug the current goal. If the fact is a fact, a message will annonce it, otherwise the debugger will expand the visual tree and the new current goal is the first "`child`" of the list. If the current goal can't be resolved and the resolution process backtracks, the debugger will backtrack also to the previous node.

- "`Skip`" iconified by : "`Skip`" means not debug the current goal. Again, if the current goal can't be resolved and the resolution process backtracks, the debugger will backtrack also to the previous node.

- "`Stop`" iconified by : Stop the debugger; the resolution process will continue without his compagnon !

3.2.1 Visualization of backtracking

The normal resolution process expands the inference tree; the debugger will expand also the visual tree. A backtrack step done by the resolution process involves contraction and backward move in the visual tree. Also, once the resolution process finds one solution and writes it in the console panel, it will continue (by default) to search for other solutions and the user can continue to use the debugger to follow it.

3.2.2 Goal/Variable inspection facility

While debugging, it is very usefull to inspect the instanciation form of a goal and/or the value of a specific variable (if the user wants to do so). The visual debugger of PROLOG+CG allows the two:

- **inspect the instanciated form of a node:** click on the node (left-right, or right-left) to get the instanciated view of the node. The content of the node is changed. You can click again to come-back to the previous content of the node. So a sequence of alternative left/right clicks will switch the content of the node from the generic view to the instanciated one. You can also double-click to get the instanciated view in an auxiliary window.
- *inspect a specific variable:* select from the main menu the menu-item "`Build|Inspect variable`" , specify in the text field the identifier of the variable (like "`a/1`" , without the double quotes) and press on "`OK`". An auxiliary window will then appear with the value of the variable. An example of such an auxiliary window is given in Figure 3.2.

3.3 The Expert System Mode

The Expert System Mode was removed in version 2.0.13 due to bugginess.

Chapter 4

Object-Orientation

4.1 Objects, messages and OOP

Sometime and especially for a big knowledge-base system (written in Prolog), it is useful to partition the base in several partitions, contexts or objects, each one includes a set of packets. Of course, such a partition will be really useful only if the inference engine (i.e., the resolution process) is adapted accordingly; resolution of a goal will be restricted to the object where it is defined. The definition of objects and the contextual resolution of goals form the basis for logic object-based programming.

4.1.1 Objects in PROLOG+CG

An object is a set of rules prefixed by terms with an identical signature. An object has the following form:

```
T1::R1
T2::R2
...
Tn::Rn
```

Where T1, T2, . . . , Tn represent terms with the same signature and R1, R2, . . . , Rn stand for PROLOG+CG inference rules. The common signature to the T1, T2, . . . , Tn constitutes the *descriptor of the object*.

Sending a message to an object will correspond to a contextual resolution of a goal.

Sending a message

Sending a message to an object is expressed as a *composed goal*: T::G, where T represents a term and G a goal (i.e., which could be a term, a CG or a variable). T::G can be read: "send a message to the object OT to execute (satisfy) the goal G". OT is the object which its descriptor is the same as the signature of T.

To satisfy a composed goal T::G, the interpreter locates first an object with a descriptor that corresponds to the signature of the term T. Then it searches *inside* the object for a prefixed rule Ti::Ri such that T::G can be unified with Ti::HeadOf(Ri): the interpreter tries to unify T with Ti and the goal G with the head of the rule Ri.

Remark

A rule can be prefixed also by a CG: **CG::R**. In this case, all the rules of the program that are prefixed by CG constitute one object. Also, a composed goal can have the form : **CG::Goal**.

4.2 Samples IV

This section presents two programs that illustrate the object-based level of PROLOG+CG.

4.2.1 Example 1

(can be found in Samples/Others/Hamza.prlg):

```
Universal > PERSON, BIRTH, DATE.

hamza::[PERSON]-DateOfBirth->[BIRTH]-ptime->[DATE=(5,04,1995)].
hamza::Age(A) :-
    currentDate(D1),
    hamza::[PERSON]-DateOfBirth->[BIRTH]-ptime->[DATE = D2],
    diffDate(D1, D2, A).

currentDate((14, 12, 1999)).

diffDate((x_Day2, y_month2, z_year2),
         (x_Day1, y_month1, z_year1),
         (x_Day, y_month, z_year)) :-
    val(x_Day, sub(x_Day2, x_Day1)),
    val(y_month, sub(y_month2, y_month1)),
    val(z_year, sub(z_year2, z_year1)), /.
```

Let us ask some questions:

```
?-  hamza::[BIRTH]-ptime->[DATE = d].

{d = (5, 4, 1995)}
```

```
?- hamza::Age(x).

{x = (9, 8, 4)}
```

4.2.2 Example 2

(it can be found in Samples/Others/ConcStrs.prlg):

```
Universal > Animate, Inanimate, Action.
Action > Extract.
Animate > Person.
Person > Student, Employee.
Student > ResearchAssistant.
Employee > ResearchAssistant.
Inanimate > Text.
Text > Book.

// Conceptual structures for the type Extract
// constitutes an object
Extract(canon)::[Extract]-
                     -agnt->[Person],
                     -obj->[Inanimate].

Extract(schema)::[Extract]-
                    -agnt->[Person],
                    -obj->[Text],
                    -target->[Book].

Extract(schema)::[Extract]-
                     -agnt->[Person],
                     -obj->[Inanimate : *1],
                     -manr->[Strong],
                     -target->[Inanimate]-on->[Inanimate : *1].
```

The next goal definition involves some comments:

checkSchemas(v_type)::G: check if the given information in G can be unified with a schema for the type v_type. First, create a term v_term from the list (v_type, schema), i.e. v_type (schema), v_type will be replaced by its value. Second, search a schema v_schema for the type v_type: v_term::v_schema. Third, check that G can be unified with v_schema.

```
checkSchemas(v_type)::G :-
       term_list(v_term, (v_type, schema)),
       v_term::v_schema,
       eq(v_schema, G).
```

Please note how the expressive power of PROLOG+CG allows for a very abstract but “effective” formulation; search all the schema of a type T so that they verify an information G. Note also how the message (**v_term::v_schema**) is dynamically constructed; constructed from two variables: the object descriptor is a variable (**v_term**) and the content of the message is a variable (**v_schema**).

Let us ask some questions:

Get all the schemas of the type Extract:

```
?- Extract(schema)::G.

{G = [Extract]-
              -agnt->[Person],
              -obj->[Text],
              -target->[Book]}
{G = [Extract]-
              -agnt->[Person],
              -obj->[Inanimate]<-on-[Inanimate : *1],
              -manr->[Strong],
              -target->[Inanimate : *1]}
```

Check if the given information ([Extract]-target-¿[Inanimate]) can be unified with one of the Extract schemas:

```
?- checkSchemas(Extract)::[Extract]-target->[Inanimate].

{}
{}
```

And check for another information:

```
?-checkSchemas(Extract)::[Inanimate]<-from-[Extract]-
                   ->obj->[Person].

no.
```

4.3 Inheritance rules and Object-oriented programming

The object-oriented level of PROLOG+CG is based on the approach proposed by McCabe [15]. Inheritance between objects is defined by *inheritance rules*.

4.3.1 Inheritance rule

It has the following form:

```
Term1 <- Term2
```

where Term1 and Term2 are two terms that represent two objects. The rule means: the object identified by Term1 is a specialization of the object identified by Term2. If a message that is send to an object can not be satisfied, the interpreter will search an inheritance rule for that object (if it has) in order to delegate the message to its super-object.

The next section gives an example that illustrates object-oriented programming in PROLOG+CG.

4.4 Samples V

The following example can be found in **Samples/Others/OORectSqre.prlg**. It illustrates how a class (as a set of attributes and a set of methods) can be defined in PROLOG+CG. Let us consider for instance the definition of the class Rectangle. Rectangle is defined as an object (in the sense of PROLOG+CG; an object in this language can represent a class like Rectangle and/or a specific object like Hamza) identified by the term **Rectangle(H, W)**. Its static part (set of attributes) is described by the first rule, represented by a CG. Notes that the definition can have some semantic constraints, like the one expressed in this example: the width should not be inferior to the height of the rectangle. The constraints are formulated in the tail of the rule in order to be evaluated when needed.

The two methods of Rectangle (Perimeter and Surface) are defined as goals inside the object Rectangle(H, W).

Then, another class is defined: Square. This class is defined as a subclass of the class Rectangle. Notes the use of terms arguments to precise the modality of such a relation between the two classes.

```
Universal > Form, Attribute.
Form > Rectangle.
Rectangle > Square.
Attribute > Perimeter, Surface, Width, Heigth, Beautiful.

Rectangle(H, W)::[Rectangle]-
                            -permOf->[Perimeter],
                            -surfOf->[Surface],
                            -widthOf->[Width = W],
                            -heigthOf->[Heigth = H]
   :- not(inf(W, H)).

Rectangle(H, W)::Perimeter(P) :-
   val(P, mul(2, add(H, W))).

Rectangle(H, W)::Surface(S) :-
   val(S, mul(H, W)).
```

```
// An inheritance rule.
Square(C) <- Rectangle(C, C).

Square(_)::[Square]-attr->[Beautiful].
```

Let us consider some queries:

```
?- Rectangle(4,5)::G.

{G = [Rectangle] -
                 -permOf->[Perimeter],
                 -surfOf->[Surface],
                 -widthOf->[Width = 5],
                 -heigthOf->[Heigth = 4]}
{G = Perimeter(18)}
{G = Surface(20)}
```

The next question illustrates the use of constraints. The question is: is it possible to construct a rectangle with Width = 5 and Height = 4 ? The answer to the question is no because the associated constraint is not verified.

```
?- Rectangle(5,4)::[Width=5]<-widthOf-[Rectangle]-
                  ->heigthOf->[Heigth=4].

 no.
```

Finally, the next request illustrates method inheritance:

```
?- Square(4)::Perimeter(P).

{P = 16}
```

4.5 The primitive goal createInstance

PROLOG+CG provides the primitive goal **createInstance(Ident, Term)** which enables the creation of an instance Ident from an object identified by Term.

When executed, **createInstance(Ident, Term)** will add the following inheritance rule to the program:

```
Ident <- Term.
```

The following request illustrates the use of createInstance (assuming the previous program of Rectangle and Square):

```
?- createInstance(sq1, Square(6)), sq1::Surface(S).

{S = 36}
```

Chapter 5

Prolog+CG and JAVA

5.1 Prolog+CG as a JAVA Applet

5.1.1 Introduction

Prolog+CG can be embedded in an HTML page as a JAVA Applet. This section describes how to do so.

5.1.2 What's provided?

Basically, Prolog+CG as an applet has three GUI elements:

1. A number of input text fields (from 0 to 5) where the end-user can write their input.

2. A number of push buttons that can execute goals (from 1 to 5).

3. A console area where the Prolog+CG program can communicate with the end-user.

Figure 5.1 shows an example.

The console area can be written to with the usual write/1, writenl/1, and nl/0 built-in primitives, and can be cleared with clearConsole/0.

Error messages from Prolog+CG are printed on the console. However, results from goals are not printed as in the normal Prolog+CG console area. Instead, the applet program is expected to communicate any results to the user using the primitives just mentioned.

This design choice was made because the applet was envisaged as a dialogue between a non-Prolog-programmer (a "web user") and the Prolog+CG program. Thus the applet is designed to be useful as a demonstration of Prolog+CG for users who may not know Prolog.

The Prolog+CG program can use asserta/2 and assertz/2 and expect the results to be remembered between the user's clicks on the buttons.

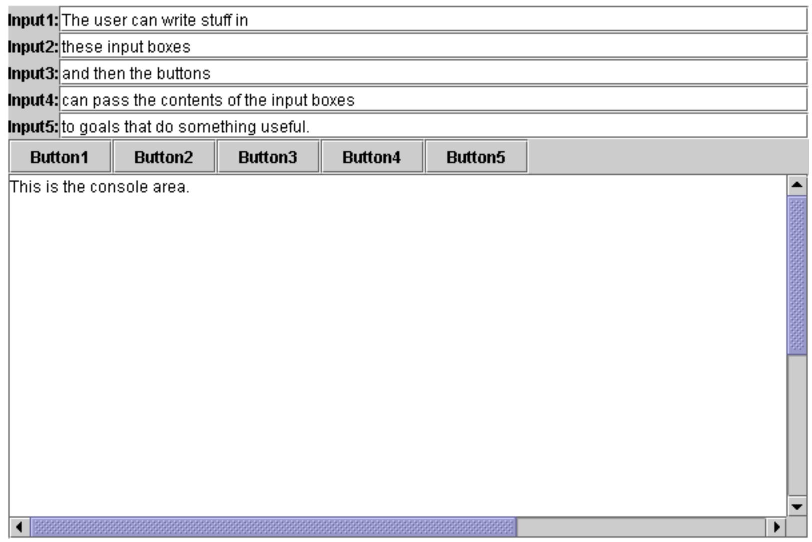


Figure 5.1: PROLOG+CG as a Java applet

5.1.3 Deploying an applet

Once you have written your applet application as a Prolog+CG program, go to "`File|Deploy Applet`". If you haven't saved the Prolog+CG program, you will be asked to do so. Then a dialog will appear, which looks like something like Figure 5.2:

You can define:

1. The title of the applet. This will appear as a ¡H1¿ title over the applet in the HTML that is written. It will also appear in the ¡TITLE¿ tag in the header of the HTML.
2. The width and the height.
3. How many input boxes you want (from 0-5).
4. The label next to each input box.
5. How many buttons you want (from 1-5).
6. The label of each button.
7. The goal executed by each button.

The four push-buttons at the bottom do the following:

- **OK:** Calls up the save procedure and, if the save procedure is successful, closes the dialog.

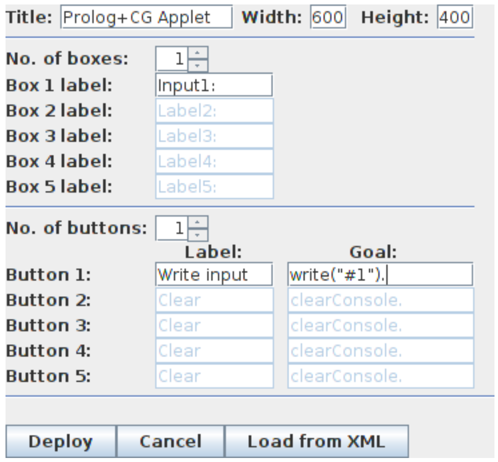


Figure 5.2: Applet deployment dialog

- **Cancel:** Closes the dialog without saving.
- **Load from XML:** Loads the dialog's parameters from an XML file previously saved by the dialog.

What happens when click OK?

Well, a "`Save`" dialog box appears, which lets you choose a file name for your program. At the same time, you will, of course, choose a directory in which the Prolog program, along with all the files of the Applet, will be saved.

Once you have chosen the prolog filename (and thus the directory), the following four files will be created in that directory:

- **index.html**: A simple HTML file containing a correctly formatted and filled `<APPLET>...</APPLET>` tag with all the necessary parameters.
- **ppcgapplet.xml**: The applet parameters in XML, for easy loading with the "`Load from XML`" push-button.
- **XXX.plgCG**: A copy of the Prolog+CG program which you had open when you called up the "`Deploy Applet`" dialog. This must be the Prolog+CG program which implements the application.
- **PPCGApplet.jar**: The .jar file containing Prolog+CG and the implementation of the applet.

Loading from XML

Once you have saved an applet, its parameters will be saved in the XML file "`ppcgapplet.xml`". You can reload this at any point in time by choosing the menu-item "`File|Load Applet from XML`". If there is a program in memory, you will be asked to save it, since it will be replaced by the applet's program.

You can also load an applet from XML from the "`Deploy applet`" dialog, by pressing the "`Load from XML`" button.

Testing the applet

To test the applet, open the "`index.html`" file in your webbrowser. On Windows, this can be done by navigating to the directory where you saved the applet and then opening "`index.html`".

Copying to the webserver

In order to fully deploy the applet, you should deploy the applet to your "public_html" directory on your webserver, using the Deploy Applet dialog directly.

You may also be able to just copy the about four files to the webserver. Check with your webspace provider for how to upload files. This may or may not work.

If it works, you only need to upload three files, namely all but ppcgapplet.xml. You can upload the ppcgapplet.xml file if you want to, but it won't be used by the webserver.

5.1.4 Writing an applet application

Introduction

You can write your applet Prolog+CG program in the normal Prolog+CG interface and test it there. You will get results printed in the console area as well as the output from your application, but the results won't be printed when you run the program as an applet.

The main key

The key to writing the applet is to define from 1 to 5 goals that serve as entry points into your application. For example, you might have a main/1 predicate that takes input from one of the input boxes. This main/1 predicate then does something useful with the input, and prints some results. For example:

```
main(X) :- write("The input was: "), write(X), nl.
```

Binding buttons to goals

Then you can bind one of the buttons to this goal. For example, to bind button 1 to call main with the contents of input-box 1, write the following in the "`goal`" edit-box of the "`Deploy Applet`" dialog box for Button 1:

```
main(#1).
```

The `#<number>` syntax works with `#1`, `#2`, `#3`, `#4`, and `#5` to mean "whatever is in the input box with the same number at the time of pressing the button."

You can also write a predicate that takes two input-boxes:

```
main(X,Y) :- write("Input 1 is: '"), write(X), writenl("'."),
             write("Input 2 is: '"), write(X), writenl("'.").
```

Then you can bind a button to input box 1 and input box 2 like this:

```
main(#1,#2).
```

This syntax works to any number of times and in any order:

```
main(#1,#2,#3,#4,#5,#4,#3,#2,#1).
```

If you wish to make a parameter into a string, do this:

```
main("#1").
```

Please note that if the user then enters a "double quote" in input-box 1, Prolog+CG will give a syntax error. This is because quotes are not escaped before passing the contents of the input box.

Help button

It may be helpful for your end-users (the users of the applet) if you include a button that says "`Help`". This button can then call a predicate which:

1. Clears the console area with the clearConsole/0 built-in predicate.
2. Writes a helpful help-message on what the applet does and how to use it, using a combination of write/1, writenl/1, and nl/0.

Clear

It may also be helpful (but not always) if you add a button which clears the console area using clearConsole/0. This button could be labelled "`Clear`".

5.1.5 Writing the HTML yourself

Introduction

The "`File|Deploy Applet`" procedure will write an HTML file which works. You can either take this file and customize it, or write your own from scratch. This section explains how.

Applet Basics

A JAVA Applet is defined by some HTML tags embedded in a larger HTML file. Specifically, the `<APPLET> ... </APPLET>` tag is used. Inside the `<APPLET> ... <APPLET>` tag, the parameters to the applet are given.

APPLET-tag attributes

The opening APPLET tag has some attributes, including the width, the height, the name of the class file that implements the applet, and the name of the .jar file that contains the applet class. The `<APPLET>` tag can look like this:

```
<APPLET  code="PrologPlusCG/PrologPlusCGApplet.class"
   codebase="."
   archive="PPCGApplet.jar"
   width="600"
   height="400"
>
```

Of these, only the width and the height should be touched, unless you know what you are doing.

Applet parameters

Inside the APPLET tag, one finds the parameters to the applet. These are given as single tags like this:

```
<PARAM name="parameter_name" value="parameter_value"  >
```

The "`paremeter_name`" must be replaced by one of the parameter names in the table below, and the "`parameter_value`" must be given as the desired value.

The parameters which the Prolog+CG applet understands are listed in Table 5.1:

5.2 PROLOG+CG and JAVA

(in collaboration with Prof. Dr. Bernard Moulin and his students: Jeremi Gancet, David Nadeau and Olivier Rouleau, from Laval university)

In the current version of Prolog+CG, PROLOG+CG can be activated from a Java program and inversely, Java components (i.e. methods and attributes of classes/objects) can be activated from a Prolog+CG program. Figure 5.3 gives the part of the primitive goals hierarchy that concerns this side of PROLOG+CG.

5.2.1 Calling Prolog+CG from Java programs

The Prolog language provides powerful reasoning and symbolic manipulation capabilities, but it is not well suited to implement the interface functionalities (windows, menus, link to data bases, etc.) that object-oriented languages provide. Hence, a good development strategy consists in using each Prolog+CG programming paradigm to implement the functionalities that it best supports. It is recommended to develop programs using Java and to call the Prolog+CG

Name	**Type**	**Comment**	**Default value**
box1label box2label box3label box4label box5label	String	The five labels of the five input boxes.	`""`
noofboxes	integer	The number of input boxes (values: 0-5).	1
noofbuttons	integer	The number of push-buttons (values: 1-5).	1
button1label button2label button3label button4label button5label	String	The five labels of the five push-buttons.	`"Clear"`
button1goal button2goal button3goal button4goal button5goal	String	The five goals of the five push-buttons.	`"clearConsole."`
prologfile	String	The name of the Prolog+CG program file as it appears on the webserver.	`""`
prologdir	String	The name of the directory where the Prolog+CG program can be found, relative to the index.html file. If you just leave this as `"."`, then the program can reside together with the HTML file. If you make it empty or omit it, then `"."` will be used by default.	`"."`

Table 5.1: Applet parameters

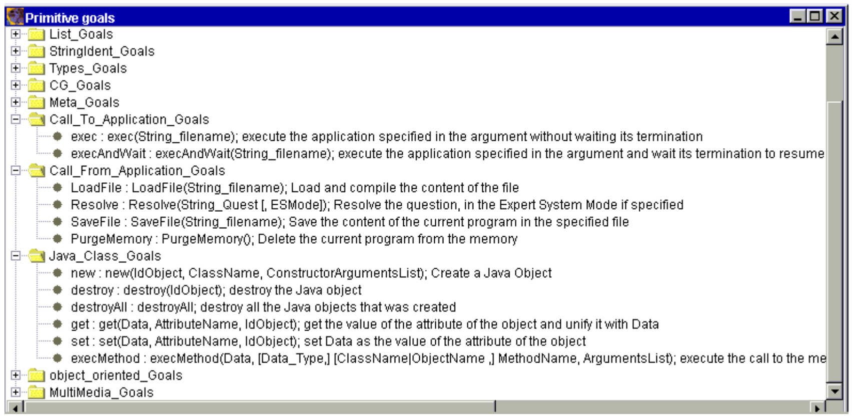


Figure 5.3: Primitives of PROLOG+CG related to the relation with JAVA

modules when it is appropriate. This section presents a set of primitives that Prolog+CG 2.0 provides in order to call Prolog+CG modules from Java programs. The use of these primitives is illustrated using a simple example.

Four primitives are used to exploit a Prolog+CG program from a Java program

- **void LoadFile(String fileName)**

  "`fileName`" is the name of a Prolog+CG program. The role of this primitive is to load a Prolog+CG program contained in the file *"`fileName`"*.

- **Vector Resolve(String Quest [, boolean ConvertResult] [, boolean ExpertSystemMode])**

  the parameter *"`Quest`"* is the request that Prolog+CG should resolve. The optional parameter *"`ConvertResult`"* specifies if the result should be converted to string or not (it is set to true by default). The parameter *"`ExpertSystemMode`"*, if it is specified, is a boolean that indicates if Prolog+CG should behave like an expert system shell or like a Prolog interpreter. This argument is set to false by default. The primitive goal Resolve/3 returns all the solutions in a Vector of hashtables; one solution being represented by a hashtable. Since a solution is a set of couples ¡VariableIdentifier, VariableValue¿, it is natural to represent it as a hashtable with VariableIdentifier as a key. To get the value of a variable in a solution, one has to use the hashtable method "`get(key)`" where key stands for a variable identifier. Any value of a variable is returned as a string (unless the parameter *"`ConverseResult`"* is set to false). The examples below illustrate this feature.

- **void SaveFile(String fileName)**

  saves the current program in the Prolog+CG file *"`fileName`"*.

- **void PurgeMemory()**

  deletes the current Prolog+CG program from memory.

5.2.2 Example 1

Assume that we have a Prolog+CG program *"FamilyRelations.plgCG"* which contains, among other things, the following facts and rules:

```
[Man : John]-fatherOf->[Man : Peter].
[Woman : Deborah]-fatherOf->[Man : Peter].
[Man : John]-motherOf->[Woman : Clara].
[Person : x]-parentOf->[Man : y] :-
    [Person : x]-fatherOf->[Man : y].
[Person : x]-parentOf->[Woman : y] :-
    [Person : x]-motherOf->[Woman : y].
```

From a Java program, we can assert new facts and retract existing facts from the above Prolog+CG program and we can ask questions and get answers.

Here is an example of such an interaction.

```
import PrologPlusCG.gui.PrologPlusCGFrame;
...
PrologPlusCGFrame prologFrame; // Must be initialized somwhere...
                               // See the next example for more information
...
public void example() {
    ... any Java code
    // Load a Prolog+CG File
    prologFrame.LoadFile("FamilyRelations.plgCG");
    ... any Java code
    // Resolve a question
    Vector solutions =
        prologFrame.Resolve("[Person : x]-parentOf->[Person : y]");
    // Make access to the solutions and to their content
    Hashtable solution;
    String valX, valY;
    For (Enumeration e = solutions.elements();
         e.hasMoreElements();) {
        // make access to a solution
        solution = (Hashtable) e.nextElement();
        // make access to the variable's value for the solution
        valX = (String) get("x");
        valY = (String) get("y");
        // make use of the variable's value
        ...
    };
```

```
...
// assert a new fact in the Prolog+CG program
prologFrame.Resolve("asserta([Man : Marc]-fatherOf->[Man : Clark], ())");
...
// Save the current program in a new file
prologFrame.SaveFile("FamilyRels1.plgCG");
// Purge the current program from the memory
prologFrame.PurgeMemory();
...
```

5.2.3 Example 2

A simple syntactic analyzer

The Prolog+CG program file "`AnalyseSynt.plgCG`"

```
sentence(p, ph(_np, _vp)) :-
    read_sentence(p, L),
    np(L, L1, _np),
    vp(L1, (), _vp), /.

np((_det, _adj, _noun|L), L, np(det(_det),
   adj(_adj), noun(_noun))) :-
    det(_art),
    adj(_adj),
    noun(_noun), /.

vp((_verb|L), L1, vp(verb(_verb), _np)) :-
    verb(_verb),
    np(L, L1, _np), /.


det("the").
det("a").
adj("beautiful").
noun("girl").
noun("apple").
verb("eat").
verb("eats").
```

The Java program

File "FrmAnalyseSyntaxique.java"

```
import javax.swing.*;
import java.awt.*;
import java.util.*;
```

```
import java.awt.event.*;
import javax.swing.JTree.*;
import javax.swing.tree.*;
import PrologPlusCG.gui.PrologPlusCGFrame;
import PrologPlusCG.prolog.PPCGEnv;
import PrologPlusCG.gui.PPCGIO_GUI;

public class FrmAnalyseSyntaxique extends JFrame {
  JTextArea jTextArea1 = new JTextArea();
  JScrollPane jspTextArea = new JScrollPane(jTextArea1);

  JButton BtAnalyse = new JButton();
  JButton BtNouvPhrase = new JButton();
  JButton BtFin = new JButton();

  JPanel jpnl = new JPanel();
  JTree jTree1;
  JScrollPane jspArbre;

  PPCGEnv env;
  PrologPlusCGFrame prologFrame;

  public static void main(String [] args) {
    FrmAnalyseSyntaxique unFrm = new FrmAnalyseSyntaxique();
  }

  public FrmAnalyseSyntaxique() {
    super();
    env = new PPCGEnv();
    prologFrame = new PrologPlusCGFrame(env, false);
    PPCGIO_GUI io = new PPCGIO_GUI(env, prologFrame);
    env.io = io;

    try {
      jbInit();
      this.show();
    }
    catch (Exception e) {
      e.printStackTrace();
    }
  }

  private void jbInit() throws Exception {
    setTitle("Analyse Syntaxique");
    getContentPane().setLayout(new BorderLayout());
    setSize(new Dimension(400, 500));
```

```
    jspTextArea.setMinimumSize(new Dimension(400,350));
    jspTextArea.setMaximumSize(new Dimension(400,350));
    jspTextArea.setBackground(SystemColor.info);
    jTextArea1.setText(" ");

    BtAnalyse.setLabel("Analyse");
    BtAnalyse.setPreferredSize(new Dimension(100,100));
    BtAnalyse.addActionListener(
           new java.awt.event.ActionListener() {
      public void actionPerformed(ActionEvent e) {
        BtAnalyse_actionPerformed(e);
      }
    });
    BtNouvPhrase.setLabel("Nouvelle Phrase");
    BtNouvPhrase.setPreferredSize(new Dimension(100,100));
    BtNouvPhrase.addActionListener(
              new java.awt.event.ActionListener() {
      public void actionPerformed(ActionEvent e) {
        BtNouvPhrase_actionPerformed(e);
      }
    });
    BtFin.setLabel("Fin");
    BtFin.setPreferredSize(new Dimension(100,100));
    BtFin.addActionListener(new java.awt.event.ActionListener() {
      public void actionPerformed(ActionEvent e) {
        BtFin_actionPerformed(e);
      }
    });

   jpnl.setPreferredSize(new Dimension(400, 350));
   jpnl.setBackground(SystemColor.info);

   getContentPane().add(jspTextArea, BorderLayout.NORTH);
   getContentPane().add(BtAnalyse, BorderLayout.WEST);
   getContentPane().add(BtNouvPhrase, BorderLayout.CENTER);
   getContentPane().add(BtFin, BorderLayout.EAST);
   getContentPane().add(jpnl, BorderLayout.SOUTH);
}

void BtAnalyse_actionPerformed(ActionEvent e) {
   prologFrame.LoadFile("AnalyseSynt.plgCG");
   Vector vect = prologFrame.Resolve("sentence(\""
                 + jTextArea1.getText() + "\", x).", false);
   // false in Resolve: indicates that the result shouldn't be
   // converted to String
```

```
  if (vect == null)
    JOptionPane.showMessageDialog(this,
           "The sentence is ungrammatical.",
           "Warning", JOptionPane.OK_OPTION);
  else { // Draw the syntactic tree
    Hashtable solution = (Hashtable) vect.firstElement();
    getContentPane().remove(jpnl);
    jTree1 = new JTree((Vector) solution.get("x"));
    jspArbre = new JScrollPane(jTree1);
    getContentPane().add(jspArbre, BorderLayout.SOUTH);
    show();
  };
}

void BtNouvPhrase_actionPerformed(ActionEvent e) {
  jTextArea1.setText(\verb|""|);
  try {
    this.getContentPane().remove(jspArbre);
    jspArbre.remove(jTree1);
    jTree1.removeAll();
    jTree1 = null;
    jspArbre = null;
    this.getContentPane().add(jpnl, BorderLayout.SOUTH);
  } catch(Exception ex) {};
  show();
}

void BtFin_actionPerformed(ActionEvent e) {
  System.exit(0);
  }
}
```

Figure 5.4 shows a snapshot of the directory and the DOS console just before the execution of the above Java file.

Figure 5.5 shows the result of the execution of the above Java file.

The following four primitives are are "*external*" primitives of Prolog+CG: "`LoadFile`", "`Resolve`", "`SaveFile`" and "`PurgeMemory`". This means that they are used in a Java Program to make use of a Prolog+CG program. These simple external commands may look like details but they are a tremendous step forward in making the Prolog+CG language a concrete development tool. The interface inability to convey a sense of usability and user-friendliness has long been a major obstacle in using logic programs in real end-user developments. For instance, it is not unusual to have many lines of Prolog code to enter before making a useful query. In addition, a lot of parameters in these lines of code are very sensible to error and require that the user know the program's internal workings fairly well to be able to get any valuable information from the system.

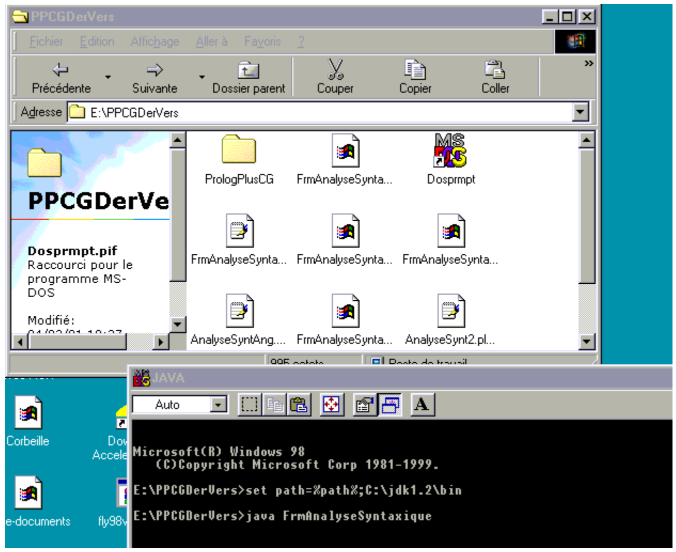


Figure 5.4: Snapshot of the directory and the DOS console just before the execution of the above Java file

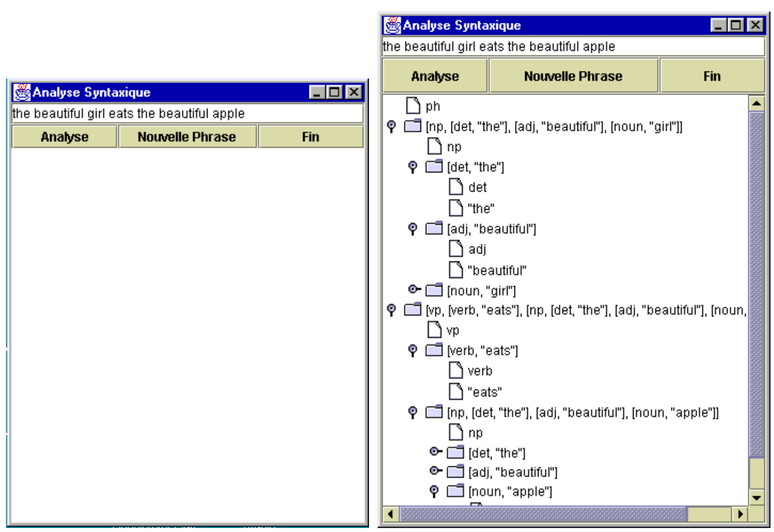


Figure 5.5: (a) before the analysis (b) after the analysis

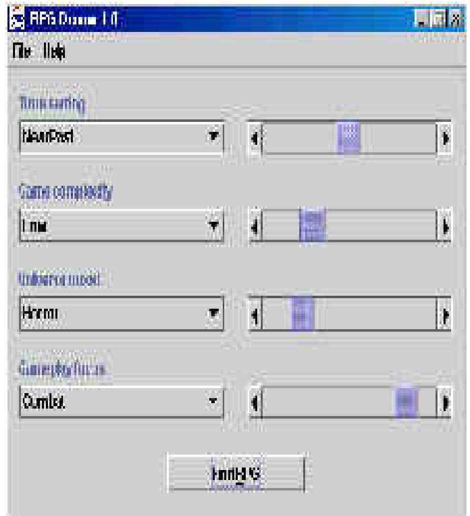


Figure 5.6: Front-end interface for a Prolog+CG program (Input screen)

In addition, the answer has the typical Prolog form (an output list) and it is sometimes very hard to read. The output list (i.e. the solution) is neither sorted alphabetically nor numerically. Finally, if the user wants additional information on one of the listed items, an additional query is necessary.

All these considerations find an elegant solution using the *Java/Prolog+CG* interface. We have used this interface to develop a simple Prolog+CG program (Figures 5.6 and 5.7). The front-end interface has been implemented using Java and the reasoning part using Prolog+CG. The input screen (Figure 5.6) offers lists and slider bars and actually writes in the Prolog+CG program four assertions for the user, using his selections. A results-screen (Figure 5.7) then presents the output list which can be sorted using any criteria. Additional information on a given list item can be obtained with the simple press of a button (Figure 5.7).

Using this example, we wanted to emphasize the importance of having interfaces between languages thus allowing each to be used for what it is best at. This Prolog+CG functionality makes it a concrete development tool easily usable in real projects. By allowing evolved logic reasoning to be used in simple user-friendly applications as well as complex Java code, the language moves beyond the traditional academic boundaries.

Note

The The Expert System Mode of Prolog+CG can be exploited from a Java program by using the primitives described in this Section. In this case, the second argument of the primitive "`Resolve/2`" should be used and should be

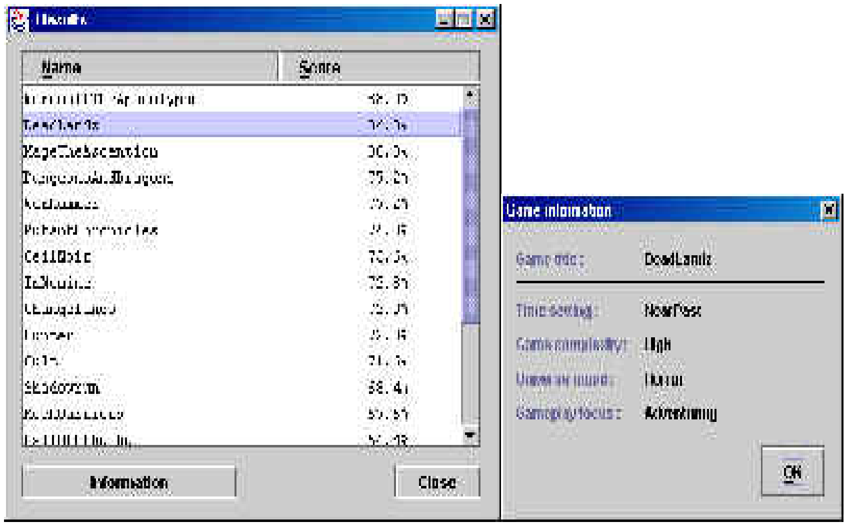


Figure 5.7: front-end interface for a Prolog+CG program (Output screen)

set to “`true`”.

5.2.4 Calling applications from a Prolog+CG program

Prolog+CG 2.0 provides two primitives which allow calling an executable application from a Prolog+CG program. This is another way to make use of Prolog+CG 's capabilities to work as a component of a larger system.

- **exec(ExecFileName):** starts the execution of the application given by *“ExecFileName”* and continues the current resolution.
- **execAndWait(ExecFileName):** starts the execution of the application *“ExecFileName”* and waits for its termination. Then it resumes the current resolution of the Prolog+CG program.

Example

```
ex1 :-
   eq(x, 45),
   exec("Synergy.exe"),
   writenl("Continue without waiting for the end of Synergy..."),
   /.

ex2 :-
   eq(x, 45),
   execAndWait("Synergy.exe"),
```

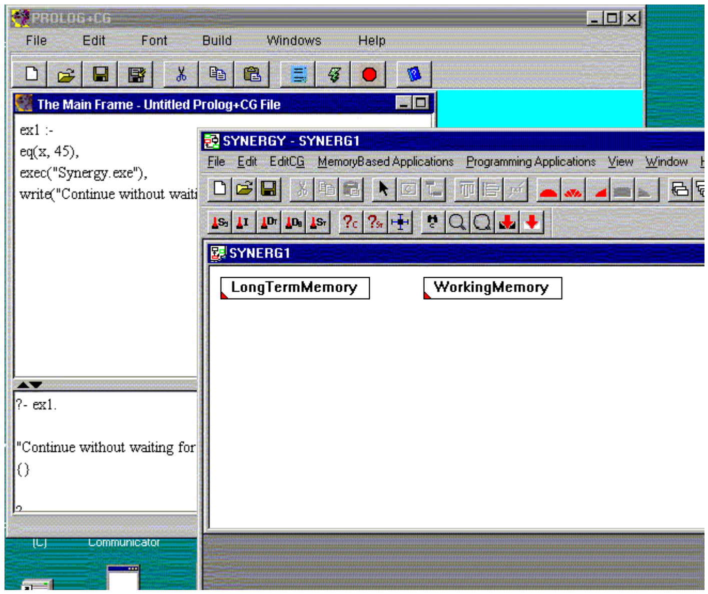


Figure 5.8: Result of execution of ex1

```
writenl("Continue after the end of Synergy ..."), /.
```

The result of the execution of ex1 can be seen in Figure 5.8.

5.2.5 Using Java code from Prolog+CG

Prolog+CG 2.0 provides several primitives allowing the use of Java code and providing access to object-oriented capabilities. Indeed, new Java objects can be created, used and destroyed from a Prolog+CG program. These objects are considered as "`global objects`" of a Prolog+CG program.

This section presents these primitives and briefly illustrates their use.

- **new(NewObjectIdent, JavaClass, ConstructorArguments):** this primitive goal enables the creation of a new Java object. It corresponds to the following Java instruction:

```
JavaClass NewObjectIdent =
          new JavaClass(ConstructorArguments);
```

- **destroy(ObjectIdent)**: this primitive goal destroys the Java object identified by *"ObjectIdent"*.

- **destroyAll**: this primitive goal destroys all the Java objects that have been created in the current program.

- **get(Data, AttributeIdent, ObjectIdent)**: this primitive goal can be used to get the value of the attribute *"AttributeIdent"* of the object *"ObjectIdent"*. The value is then unified with the first argument *"Data"*.

- **set(Data, AttributeIdent, ObjectIdent)**: this primitive goal can be used to set *"Data"* as the value of the attribute *"AttributeIdent"* of the object *"ObjectIdent"*.

- **execMethod(Data_Or_void, JavaClass_Or_ObjectIdent, MethodIdent, MethodArguments):** this primitive goal can be used to call a method "`MethodIdent`", of a Java class (in the case of a static method) or of a Java object "`JavaClass_Or_ObjectIdent`" with the argument list "`MethodArguments`". If the method is of type void then the first argument of the primitive execMethod should be the keyword "`void`". Otherwise, the returned value is unified with the first argument "`Data_Or_void`".

- **val(VariableIdent_Or_ObjectIdent, Expression_Or_ObjectIdent) :** this primitive goal determines the value of its second argument, which could be an expression or an object identifier. The value of the expression (or the object) is then associated to the variable (or to the object).

- **objectify(JavaObject, ObjectIdent):** this primitive goal adds the first parameter (which must be a variable unified to a JavaObject) to the global hash table of objects using ObjectIdent as the identifier. You must call destroy(ObjectIdent) or destroyAll in order to delete the object and be able to reuse the ObjectIdent.

With calling Java code from Prolog+CG predicates and calling Prolog+CG from Java code, the loop is closed and the language offers both a powerful new representational programming paradigm and an integrated way to access it conveniently.

Example 1

this simple example shows how an object (of a primitive or a defined Java class) can be created and how the object methods can be invoked.

```
explePPCGToJava(x,y) :-
    new(vct, "java.util.Vector", ()),
    execMethod(void, vct, "addElement", (4)),
    execMethod(void, vct, "addElement", (6)),
    execMethod(void, vct, "addElement", (10)),
    execMethod(void, vct, "addElement", (14)),
    execMethod(x, vct, "size", ()),
    execMethod(y, vct, "elementAt", (2)).
```

And to use:

```
?- explePPCGToJava(x,y).

{x = 4, y = 10}

?-
```

The next example shows the extendable feature of Prolog+CG. Suppose for instance that someone needs a primitive to convert a string to an integer. Instead of adding a new primitive to Prolog+CG to do that, the user can use Java directly for that. It corresponds to a call to a method of a class in Java that do such a job:

```
?- execMethod(c, "java.lang.Integer", "valueOf", ("345")),
   sup(c, 300).

{c = 345}
```

Example 2

An application that calls Java code: SHRDLU-PCG To illustrate the expressive power of Prolog+CG and to show its usefulness for the development of natural language processing applications, we developed SHRDLU-PCG, a reformulation in Prolog+CG of some aspects of the classic SHRDLU program [10]. In the Prolog+CG program (see below), one can note the natural use of CG as a data structure, beside term and list, and also the very use of variables in CG: a variable can hold for a CG, a concept, a concept type, a referent, a coreferent, a concept description (or value) and a relation. This flexibility is very important from a programming perspective. SHRDLU-PCG also illustrates how Java classes (and their attributes and methods) can be used from a Prolog+CG program. SHRDLU-PCG simulates a very restricted natural language dialog between a user and a robot that operates in a block-world. The robot can create, move, push and pop 3D blocks. The robot is able to “understand” declarative, imperative and interrogative sentences and to react accordingly. The 3D animation that results from such a dialog is monitored thanks to the “cooperation” of the Prolog+CG program SHRDLU-PCG with a Java3D program which provides the capability to create a 3D canvas, to fill it with 3D objects (cube, cylinder, sphere, pyramid) and to do some actions on them.

First, let us consider how the semantic analysis of a sentence and especially the analysis of an imperative sentence is carried out. Examples of imperative sentences are “create a red pyramid pyramid4.”, “push the red pyramid on the big cube.” and “move the blue sphere at the left of cube1.”. As the components of the sentence are analyzed, CGs that represent their semantic meaning are constructed and then joined. This dynamic construction of CGs is in itself an important feature of Prolog+CG.

```
// lexicon(Word, SyntacticCategory, TypeOrCGCanon)
lexicon("push", verb,[Push]-
```

```
     -obj->[Object],
     -on->[Object] ).
lexicon("create", verb,
[Create]-obj->[Object]-colorOf->[Color]).
Lexicon("sphere", noun, Sphere).

Verb(V, _CGCanon) :- lexicon(V, verb, _CGCanon).

// Syntax of imperative-sentence = Verb NP Complement.
// Complement = [Prep NP].
imperative_sentence((V|P1),
[Proposition: G]-mode->[Modality : imperative]) :-
    Verb(V, G_V),
    NP(P1, P2, E_NP1, S1),
    eq([T_Verb]-obj->E_N_G1, G_V),
    maximalJoin(G_V, E_N_G1, S1, E_NP1, G1_S1,_),
    complement(P2, T_Verb, G1_S1,G).
```

Comment on Verb/2

checks if V is a verb, if so, return the canon of the verb.

Comment on imperative_sentence/2

imperative_sentence(P, G) receives a sentence P, as a list of words, and produces a CG G that represents its meaning. It starts by recognizing the verb and then the noun phrase. The canon of the verb (G_V) is then joined with the CG corresponding to the noun phrase (S1). This maximal join should satisfy however the following constraint : the concept that represents the head of the noun phrase has to be joined with the concept that represents the object of the verb. So we have to locate these two concepts in the two CGs respectively and then we have to consider them as "entry concepts" for the maximal join in question; this later should start by the join of the two entry concepts. The entry concept for the CG G_V that represents the semantic meaning of the verb is located by the following goal :

```
eq([T_Verb]-obj->E_N_G1, G_V).
```

To understand the effect of the above goal, let's consider this request:

```
?- eq(G_V,[Create]-obj->[Sphere:sphere1]),
   eq([T_Verb]-obj->E_N_G1, G_V).

{G_V = [Create]-obj->[Sphere:sphere1], T_Verb = Create,E_N_G1 =
[Sphere:sphere1]}
```

As a result of the above unification eq/2, the variable "`E_N_G1`" refers to the concept in "`G_V`" that represents the object of the verb. Note how the variable

"T_Verb" stands for the type of the concept and the variable "E_N_G1" stands for the whole concept. The defined goal NP/4 : NP(P1, P2, E_NP1, S1) returns the graph S1 that represents the meaning of the noun phrase as well as the entry concept E_NP1 in S1.

After the analysis of the verb and the noun phrase, the maximal join of their semantic representations is done, producing a CG G1_S1 and then, the semantic analysis of the complement is initiated. If the complement is specified, its semantic representation will be computed and then joined with the CG G1_S1.

After the semantic analysis of an imperative sentence, the "robot" will consider its meaning as an order to be executed. Hence and as a result of such an execution, the knowledge of the "robot" will change (for instance, the position of an object has to be modified) as well as the 3D animation that shows the visual simulation of the robot behavior. The following Prolog+CG code shows how all these aspects are related.

```
Shrdlu :-
    new(aShrdlu_Canvas3D, "PrologPlusCG.Shrdlu_Canvas3D", ()),
    read_sentence(_sentence),
    ShrdluDialog(_sentence), /.

ShrdluDialog(("end", ".")) :- /.
ShrdluDialog(_sentence) :-
    Semantic_Analysis(_sentence, _CG),
    _CG,
    read_sentence(_s),
    ShrdluDialog(_s), /.
```

Comment on the main goal Shrdlu: this goal initiates the 3D simulation as well as the restricted natural language dialog. In particular, it specifies a call to the primitive goal "new" in order to create an instance of the defined Java 3D class Shrdlu_Canvas3D. Such a creation will involve, among other actions, the display of a frame that contains a "robot" (Figure 5.9).

Comment on the goal ShrdluDialog: in the above definition of the goal "ShrdluDialog", note how the meaning of the sentence (i.e. the CG "_CG" that results from the semantic analysis of "_sentence") is put as a goal to be interpreted. Thus, in the case of an imperative sentence, the goal-variable "_CG" will be bound to the following CG :

[Proposition : G]-mode-¿[MODALITY : imperative]The proposition G (the variable G will be bound to a CG) is interpreted as an order that should be satisfied. Here is the Prolog+CG rule that naturally formulates this interpretation :

```
[Proposition : G]-mode->[MODALITY : imperative] :-
    G.
```

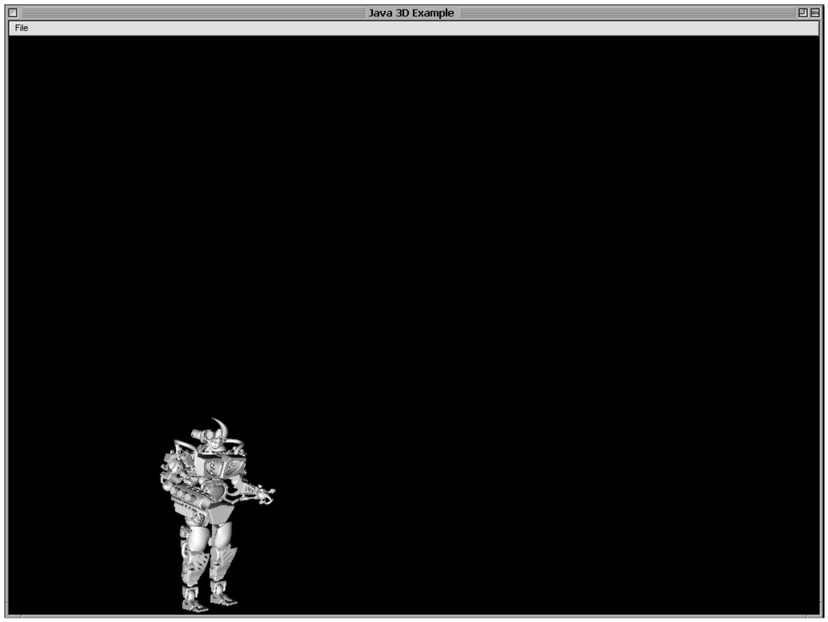


Figure 5.9: SHRDLU_PCG in action

Each order is then executed according to its semantic interpretation. For instance, the order to create an object with a specific name and color is defined as follows : first assert the existence of the object in the data base, then create a physical object in the 3D canvas. Each kind of object (Cube, Sphere, Pyramid) is created by a corresponding method in the defined Java class "Shrdlu_Canvas3D" (Figure 5.10).

```
[Create]-obj->[T_Obj : _IdObj]-colorOf->[Color : C] :-
    asserta(object([T_Obj : _IdObj]-colorOf->[Color : C]), ()),
    execMethod(void, "PrologPlusCG.Shrdlu_Canvas3D",
               T_Obj, (_IdObj, C)),
    /.

?- Shrdlu.
|:create the green sphere sphere1.
```

Example 3

Example with objectify:

```
sendLogURL(_query) :-
        new(uri, "java.net.URI", ("http", "127.0.0.1:8000", "/logapp/log", _query, ""))
```

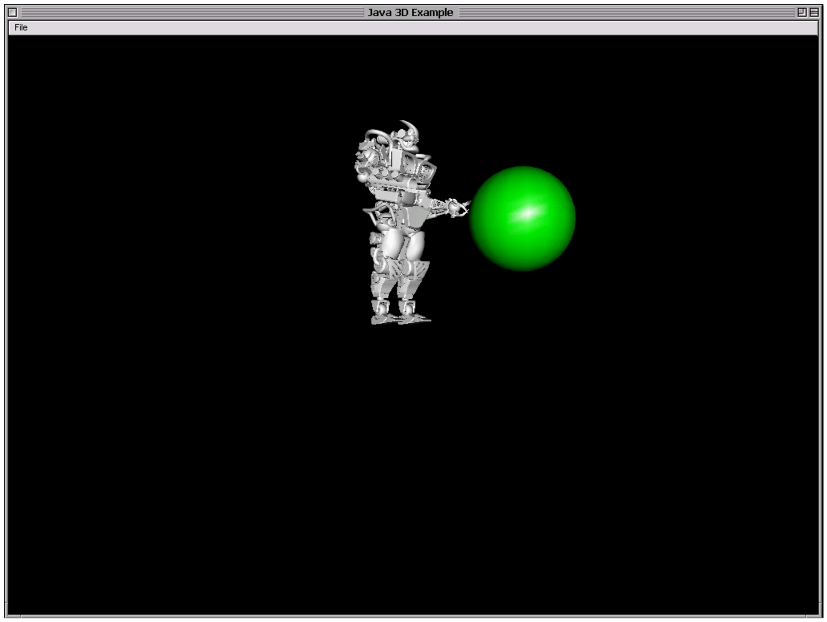


Figure 5.10: SHRDLU_PCG in action

```
execMethod(_url, uri, "toURL", ()),
objectify(_url, url),
execMethod(_urlconnection, url, "openConnection", ()),
objectify(_urlconnection, urlconnection),
execMethod(void, urlconnection, "connect", ()),
execMethod(_object, urlconnection, "getContent", ()),
destroy(urlconnection),
destroy(url),
destroy(uri).
```

This little example shows how to use objectify/2 with objects that are bound to a variable, but which must be given an identifier name in order to be able to be used with execMethod.

As can be seed, the call to execMethod with the "uri" object and the "toURL" method name instantiates a new object, which is bound to _url. In reality, it is a java.net.URL object. We then objectify this object with `objectify(_url,url)`, which means that we can then use url.openConnection in the next line in the call to execMethod. And so on.

Also note that the objects are destroyed at the end.

objectify/2 is new in Prolog+CG version 2.0.14.

Appendix A

The grammar of PROLOG+CG

```
Prolog+CGProgram = (Rule | Comment) {(Rule | Comment)} .
Rule = Specialization_Rule | Instantiation_Rule
     | Generalization_Rule | Inference_Rule .
Specialization_Rule = TypeIdentifier ">" TypeIdentifier
       {"," TypeIdentifier} "." .
Instantiation_Rule = TypeIdentifier "=" ReferentIdentifier
       {"," ReferentIdentifier} "." .
Generalization_Rule = ObjDescriptor "<-" ObjDescriptor "." .
Inference_Rule = Head [":-" Tail] "." .
Tail = Goal {"," Goal} .
Goal = SimpleGoal ["::" SimpleGoal] .
SimpleGoal = Term | CG | Variable .
Head = SimpleHead ["::" (SimpleHead | Variable)] .
SimpleHead = (Term | CG) .
ObjDescriptor = Term .
Term = Identifier [ "(" PrlgCGData {"," PrlgCGData} ")" ] .
List = "(" [ PrlgCGData {"," PrlgCGData} [ "|" Variable ] ] ")" .
PrlgCGData = Number | Boolean | Identifier | String
          | Variable | List | Term | CG .
CG = Concept [OutBranch | InBranch | Branches] .
Branches = "-" (OutBranch | InBranch)
         {"," (OutBranch | InBranch) } [","] .
OutBranch = "-" RelationIdentifier "->" CG .
InBranch = "<-" RelationIdentifier "-" CG .
Concept = "[" Type [":" Referent] ["=" Value] "]" .
Type = TypeIdentifier | Variable .
Referent = ReferentIdentifier | Multi_Referent | Variable.
Value = PrlgCGData .
```

```
Comment = "//" {Character} .
TypeIdentifier = Identifier .
ReferentIdentifier = Identifier .
RelationIdentifier = Identifier .
Multi_Referent = "*" {Digit} .
Number = Digit { Digit } .
Boolean = "true" | "false" .
Identifier = Letter Letter { Letter | Digit | "_" } .
String = \verb|"""| { Letter | Digit | "_" } \verb|"""| .
Variable = ("_" { Letter | Digit | "_" }) | Letter
         | (Letter (Digit | "_") { Letter | Digit | "_" } ) .
```

Appendix B

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