LAB 1

Bibliography
Ivan Bratko. Prolog Programming for Artificial Intelligence, Pearson Education Canada, 4th Edition, 2011.

Prolog (**SWI** / Sicstus) is a symbolic programming language, suitable for solving problems that involve objects and relations between objects. A Prolog program is a knowledge base that can be questioned.

For local installation	https://www.swi-prolog.org/download/stable
For the online version	https://swish.swi-prolog.org/

Consider the following Prolog program (a text file with the extension **pl**):

```
parent(ion,maria).
parent(ana,maria).
parent(ana,dan).
parent(maria,elena).
parent(maria,radu).
parent(elena,nicu).
parent(radu,george).
parent(radu,dragos).
```

A Prolog program must first be consulted.

```
consult('c:\\prolog\\pro.pl').
```

In the query window, enter the following questions:

```
parent(ana,maria).
parent(ion,radu).
parent(X,maria).
parent(X,Y).
```

Observations:
1) alphanumeric constants (atoms) start with a lower-case letter;
2) variables start with an upper-case letter or an underscore character;
3) the answers are obtained in the order in which the information appears in the knowledge base;
4) if the question contains variables, Prolog finds the particular objects (instances) for which the answer is true.

To find out who Radu's grandfather is, we can ask

```
parent(X,Y), parent(Y,radu).
```

Prolog clauses
A clause has the general form R:-$C_1, C_2, \dots, C_N$, with the meaning:

$\forall X_1, X_2, \dots, X_k$ variables in the clause, R is true if $C_1, C_2, \dots, C_N$.

Example

```
child(X, Y):-parent(Y, X).
```

i.e. $\forall$ X,Y if Y is parent of X then X is child of Y.

Starting from the parent relation, define the following relations:

```
brother(X,Y) (X and Y are brothers)
grandparent(X,Y) (X is grandparent of Y).
```

To define a predecessor type relation, we need a recursive rule:

```
pred(X,Y):-parent(X,Y).
pred(X,Z):-parent(X,Y), pred(Y,Z).
```

Obs. The scope of a variable is the clause in which the respective variable appears.

Write a different version of the predecessor relation.

In Prolog, we can use **structures** – i.e., many components combined in one object. A structure can be generally described as:

functor(arg$_1$, arg$_2$, …, arg$_N$).

Obs.
1) A functor is an atom (it starts with a lower-case letter);
2) Arguments can be structures;
3) Each structure is well defined by the main functor and the arity (number of arguments).

Example

```
date(1,octomber,2019).
segment(point(1,2),point(6,7)).
point(1,2) and point(1,2,3) are different structures
```

Matching
It is the only operation allowed between Prolog terms.

Def It is called substitution the set

$\Theta=\{(X_i,t_i)_{i=1,n} \mid X_i \text{ variables, } t_i \text{ Prolog terms and } X_i\neq X_j \text{ if } i\neq j\}$

If T is a Prolog term, we denote by TQ the term resulted by simultaneous replacement in T of all appearances of X_i cu t_i, where $(X_i,t_i)\in\Theta$.
Def A term is completely instantiated if it does not contain any variable.
Def T1 matches T2 if $\exists\Theta$ so that T1Θ=T2Θ. Θ is called unifier.

Examples

1) T1=f(X,a)
   T2=f(b,Y)
   $\Theta=\{(X,b), (Y,a)\}$
2) T1=X
   T2=f(g(Y,Z),b)
   $\Theta1=\{(X, f(g(Y,Z),b))\}$
   $\Theta2=\{(Y,a), (Z,c), (X,f(g(a,c),b))\}$

$\Theta1$ is more general than $\Theta2$.

The predicate = tests if two Prolog terms match. If yes, the most general substitution is returned.

Test the following question

```
X=f(X).
```

Obs.
1) two atoms match iff they are identical;
2) a variable matches anything;
3) two structures match if they have the same main functor, the same arity and the corresponding arguments match.

Arithmetic in Prolog

```
= = equality of terms
1+2= = 2+1 no
=:= equality of the numerical values of two arithmetic expressions
1+2=:=2+1 yes
\= = different terms
X is Y variable X is instantiated with the value of Y.
X is 3+2.
```

Lists

A list is a sequence of any number of comma-separated items:

```
[1,2,3,4,5,a,b,c]
```

The empty list is denoted by [].
A non-empty list can be viewed as consisting of head and tail [A|B]. The head A is one item, the tail B is a list.
We can indicate several elements at the beginning of the list:

```
[A,B,C,…|T].
```

Example

```
[1,2,3]=[1|[2,3]]=[1,2|[3]]=[1,2,3|[]].
```

We can collect elements that satisfy a certain property with the help of 3 predefined predicates:
1) bagof(X,P,L) collects in the list L the items X that satisfy P. If there is no such element, the answer is no.
2) setof(X,P,L) similar as bagof, but it eliminates duplicates and the resulting list is sorted
3) findall(X,P,L) if there is no element satisfying P the result is yes and L=∅. It ignores variables that appear in P and do not appear in X.

Example:
Assuming we have relations boy(name, age), we calculate the sum of the ages of all the boys from the knowledge base.

```
ageboys(L):-findall(Age,boy(Name,Age),L).
sum(S):-ageboys(L),sum(L,S).
sum([],0).
sum([H|T],S):-sum(T,S1), S is S1+H.
```

The efficiency of the Prolog programs

The function

$$f(x) = \begin{cases} 0, x \leq 3 \\ 2, x \in (3,6] \\ 4, x > 6 \end{cases}$$

can be implemented in Prolog by the following clauses:

```
f(X,0):-X=<3.
f(X,2):-3<X, X=<6.
f(X,4):-6<X.
```

If we ask

```
f(1,Y),2<Y.
```

Prolog searches the solution on all three clauses, although logically it should have stopped after the first clause. We can prevent backtracking with the help of the predicate ! (cut). The program becomes as follows:

```
f(X,0):-X=<3,!.
f(X,2):-3<X, X=<6,!.
f(X,4):-6<X.
```

If X=<3 is true, the search stops (it cuts backtracking).
In the clause 2, the test 3<X it is redundant because it gets here only if the cut in the first clause has not been reached.
So, the program may be written as:

```
f(X,0):-X=<3,!.
f(X,2):-X=<6,!.
f(X,4).
```

Exercises

1) Write the max predicate that calculates the maximum between 2 values.

2) Write the *member* and *concat* predicates.

3) Calculate the alternate sum of the elements of a list.

4) Eliminate an element from a list (one/all the occurrences of that element).

5) Reverse a list; generate all the permutations of the elements of a list.

6) Find the number of occurrences of an element in a list.

7) Insert an element on a certain position in a list.

8) Merge two ascending ordered lists.