

Introduction to Logic Programming

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Contents

- What is Logic Programming
- History of Logic Programming
- What is a logic
- Examples of Logic Programs

Aspects of Logic Programming

- Programs are written in the language of some logic.
- Execution of a logic program is a theorem proving process; that is, computation is done by logic inferences
- Prolog (PROgramming in LOGic) is a representative logic language

History of Logic Programming (LP)

- Formulated in 1974 by a professor at Univ. of Edinburgh.
- First system implemented in 1995 by a research group in France.
- First compiler built in 1997 by a PhD student also in Edinburgh.
- Japan's fifth generation computer project announced in 1980.
- Efficiency improved in recent years
- Interfaces with other languages such as C/Java.

Why Prolog is not as popular as C/Java

- Mistaken at first as some universal computer language
- Not yet as efficient as C
- Support to Prolog takes effort, resources; companies are not willing to pay for it
- Its value not recognized by industry.

What is a logic

- A logic is a language. It has syntax and semantics. More than a language, it has inference rules.
- **Syntax:** the rules about how to form formulas; this is usually the easy part of a logic.
- **Semantics:** about the meaning carried by the formulas, mainly in terms of logical consequences.
- **Inference rules** describe correct ways to derive conclusions.

Use logic to do reasoning

Example:

Given information about fatherhood and motherhood, determine grand parent relationship.

E.g. Given the information called *facts*

John is father of Lily

Kathy is mother of Lily

Lily is mother of Bill

Ken is father of Karen

Who are grand parents of Bill?

Who are grand parents of Karen?

Example of Prolog program

In Prolog, we write the following for the given facts:

```
father(john,lily).  
mother(kathy,lily).  
mother(lily,bill).  
father(ken, karen).
```

- In logic, words like father, mother are called *predicates*
- A statement like father(john,lily) is called an *atomic formula*, called *an atom*, stating a true fact

Programs as logic formulas

Express the grand parent relationship:

grandparent(X,Z) :- parent(X,Y), parent(Y,Z).

parent(X,Y) :- father(X,Y).

parent(X,Y) :- mother(X,Y).

These are called *conditional statements*.

Capital letters denote variables, meaning “for any”.

E.g., the first formula above reads:

For any X,Y,Z,

if X is a parent of Y, and Y is a parent of Z,
then X is a grand parent of Z.

A complete program

Putting all together, we have a Prolog program:

```
grandparent(X,Z) :- parent(X,Y), parent(Y,Z).  
parent(X,Y) :- father(X,Y).  
parent(X,Y) :- mother(X,Y).
```

```
father(john,lily).  
mother(kathy,lily).  
mother(lily,bill).  
father(ken, karen).
```

Ask Prolog to do something for you

Provide a query to Prolog; e.g.

```
?- grandparent(john,bill)
```

Prolog uses your program to do reasoning and answer the query, in this case, the answer by Prolog is YES.

If you post your query as:

```
?- grandparent(Q,karen)
```

Meaning who are grand parent of karen, Prolog answers NO

Ask Prolog to do something for you

You can ask Prolog the question: who are the grand parents of bill by posting a query

```
?- grandparent(Q,bill)
```

Prolog answers

Q = john

Q = kathy

Ask Prolog to do something for you

You can ask Prolog the question: who are the grand children of john by posting

?- grandparent(john,W)

Prolog answers

W = bill

Prolog programs

- In general, a Prolog program is a collection of clauses of the form

$$A :- B_1, B_2, \dots, B_n.$$

where A and B_i 's are atoms.

- $:-$ replaces logic implication (usually written as \leftarrow)
- If the right hand side of a clause is empty, we simply write
 $A.$

Another Example

Given a list of integers, get the sum.

We will define a predicate

`sum(L,R)`

Where `L` is a given list, and `R` will be used to hold the result.

For example, a query like

`?- sum([3,5,2],Q)`

to Prolog should return answer:

`Q = 10.`

Prolog program for sum

The program consists of two clauses

`sum([],0).`

`sum([A|L], R) :- R is A+R1, sum(L,R1).`

- R is A+R1 is Prolog's way of saying "R is the result of A+R1."
- [A|L] is a notation for a list whose first element is A and the rest of the list is L
- The two clauses read:
 - the first: the sum of an empty list is 0.
 - the second: the sum of the list [A|L] is the result of adding A with the sum of L.

Execution

With the program:

```
sum([ ],0).
```

```
sum([A|L], R) :- R is A+R1, sum(L,R1).
```

You may post a query

```
?- sum([3,5,2],Q).
```

Prolog will answer: Q=10.

Summary

In logic programming,

- Programs are logic formulas of certain form
- Computations are logic inferences.