Prolog

In Text: Chapter 16

Prolog

- A logic programming language
- Prolog programs consist of collections of statements
- There are only a few kinds of statements in Prolog, but they can be complex
  - Fact statements, rule statements, and goal statements
- All prolog statements are constructed from terms

Fact Statements

- Correspond to Headless Horn clauses
- Fact statements are propositions that are assumed to be true, and from which new information can be inferred
- E.g., female(shelley).
  female(mary).
  mother(mary, shelley).

Rule Statements

- Correspond to Headed Horn clauses
- They describe implication rules between propositions, or logical relationship between them: if a set of given conditions are satisfied, what conclusion can be drawn
- The consequent of a statement is a single term, while the antecedent can be either a single term or conjunction

Conjunctions

- The AND operation in conjunctions is implied in Prolog
- The structures that specify atomic propositions in a conjunction are separated by commas
- The commas can be considered as AND operators

Rule Statements

- E.g., grandparent(X, Z) :- parent(X, Y), parent(Y, Z),
  where X, Y, and Z are universal objects
  - It states that if there are instantiations of X, Y, and Z such that parent (X, Y) is true, and parent (Y, Z) is true, then for those same instantiations of X, Y, and Z, grandparent(X, Z) is true

Goal Statements

- Also correspond to Headless Horn clauses
- **Goal statements** are propositions describing the theorem that we want the system to either prove or disprove
  - E.g., man(fred)
- Because goal statements and some nongoal statements have the same form, a Prolog implementation must have some means to distinguish between the two

Goal Statement

```
(assert(rainy(seattle))).
(assert(rainy(rochester))).
?- rainy(C).
```

The Prolog interpreter would respond with:

```
C = seattle
```

Seattle is returned first, because it comes first in the database

Goal Statement

- If we want to find all possible solutions, we can ask the interpreter to continue by typing a semicolon:

```
C = seattle ;
C = rochester.
```


Another Example

```
takes(jane_doe, his201).
takes(jane_doe, cs254).
takes(ajit_chandra, art302).
takes(ajit_chandra, cs254).
classmates(X, Y) :- takes(X, Z),
takes(Y, Z).
```

What does the following query return?

```
?- classmates(jane_doe, X).
```



```
X = jane_doe ;
X = jane_doe;
X = ajit_chandra.
```

How should we modify the rule so that the student is not considered as a classmate of himself or herself?

```
classmates(X, Y) :- takes(X, Z),
takes(Y, Z), X\=Y.
```


- Can we define propositions in the following way?

```
takes(jane doe, his201).
```

- No. The prolog interpreter will complain. Instead, we can define the proposition as below:

```
takes('jane doe', his201).
```

Prolog Programs

- ASSERT (define)
  - FACTS about OBJECTS
  - RULES("CLAUSES") that inter-relate facts
- Ask QUESTIONS about objects and their relationship
  - GOALS

Some Prolog FACTS

```
| ?- (assert (father (michael, cathy))).
| ?- (assert (father (chuck, michael))).
| ?- (assert (father (chuck, julie))).
| ?- (assert (father (david, chuck))).
| ?- (assert (father (sam, melody))).
| ?- (assert (mother (cathy, melody))).
| ?- (assert (mother (hazel, michael))).
| ?- (assert (mother (hazel, julie))).
| ?- (assert (mother (melody, sandy))).
| ?- (assert (made_of (moon, green_cheese))).
```


Some Prolog RULES

- A person's parent is their mother or father

| ?- (assert ((parent(X, Y) :- father(X, Y); mother (X, Y)))).

- A person's grandfather is the father of one of their parents

| ?- (assert ((grandfather(X,Y) :- father(X, A), parent(A, Y)))).

Some Prolog QUESTIONS

- Is chuck the parent of julie ?
  | ?- parent(chuck, julie).
- Is john the father of cathy ?
  | ?- father(john, cathy).

Note:
- **No "assert"s**
- **No use of variables**

Prolog Notes

- atoms: symbolic values of Prolog
  - father (bill, mike)
  - Strings of letters, digits, and underscores starting with a lower case letter
- variable: unbound entity
  - father (X, mike)
  - Strings of letters, digits, and underscores starting with an UPPER CASE letter
  - Variables are not bound to type by declaration

Prolog Notes

- FACTS: UNCONDITIONAL ASSERTIONS OF "TRUTH"

  (assert(mother(carol, jim))).
  - assumed to be true
  - contains no variables
  - stored in database

Prolog Notes

- RULES: ASSERTIONS from which conclusions can be drawn if given conditions are true
  (assert((parent(X, Y) :-father(X, Y); mother (X, Y)))).
  - contains variables for instantiation
  - also stored in database

An Example

FACTS
```
| ?- (assert(color(banana, yellow))).
| ?- (assert(color(squash, yellow))).
| ?- (assert(color(apple, green))).
| ?- (assert(color(peas, green))).
| ?- (assert(fruit(banana))).
| ?- (assert(fruit(apple))).
| ?- (assert(vegetable(squash))).
| ?- (assert(vegetable(peas))).
```

bob eats green colored vegetables

RULE
```
| ?- (assert((eats(bob, X) :- color(X, green), vegetable(X)))).
```


An Example

```
(assert ((eats(bob, X) :-
    color(X, green),
    vegetable(X)))).
```

Does bob eat apples ?
```
| ?- eats(bob, apple).
    color(apple, green) => match          false
    vegetable(apple)    => no
```

Does bob eat squash ?
```
| ?- eats(bob, squash).
    color(squash, green) => no            false
```

What does bob eat ?
```
| ?- eats(bob, X).                        therefore X = peas
    color(banana, green) => no
    color(squash, green) => no
    color(apple, green)  => yes
      vegetable(apple)   => no
    color(peas, green)   => yes
      vegetable(peas)    => yes
```


Prolog Notes

INSTANTIATION: binding of a variable to value (and thus, a type)

UNIFICATION: Process of finding an instantiation of a variable for which "match" is found in database of facts and rules

Instantiation & Unification

FACTS
- (assert (color (apple, red))).
- (assert (color (banana, yellow))).

color (X, yellow).

Ask the question (goal):
Does there exist (or, Give me) an X such that X is the color yellow

X = apple — color (apple, yellow)
instantiation — no matching pattern

X = banana — color (banana, yellow)
instantiation — match

X = banana — results in match of goal with database item

Prolog Notes

- DISJUNCTIVE RULES: X if Y or Z
  (assert ((parent(X, Y) :- father(X, Y)))).
  (assert ((parent(X, Y) :- mother(X, Y)))).

  or

  (assert ((parent(X, Y) :- father(X, Y); mother(X, Y)))).

Prolog Notes

- CONJUNCTIVE RULES: X if Y AND Z
  (assert((father(X, Y) :- parent(X, Y), male(X)))).
- NEGATION RULES: X if Not Y
  (assert((good(X) :- not(bad(X))))).
  (assert((mother(X, Y) :- parent(X, Y), not(male(X))))).

"Older" Example

```
older(george, john).
older(alice, george).
older(john, mary).
older(X, Z) :- older(X, Y), older(Y, Z).
```


- When we ask a query that will result in TRUE, we get the right answer:
  ?- older(george, mary).
  yes
- When we ask a query that will result in FALSE, we get into an endless loop
  ?- older(mary, john).

Left Recursion Problem

- The first element in older is the predicate that is repeatedly tried
- To solve the problem, remove the older rule and replace with:
  is_older(X, Y) :- older(X, Y).
  is_older(X, Z) :- older(X, Y), is_older(Y, Z).
- Now:
  ?- is_older(mary, john).
  false

Prolog Notes

- Prolog is more than "LOGIC"
  - Math
  - List manipulation

Consult File Format

[x]. or consult(x).

- File x.pl:
  husband(tommy, claudia).
  husband(mike, effie).
  mother(claudia, sannon).
  mother(effie, jamie).
  father(X, Y) :- mother(W, Y), husband(X, W).
  parent(X, Y) :-father(X, Y); mother(X, Y).
- Note: No assert's, but can still state **Facts and Rules**

Consult File

- Cannot state question/goal in a consult file

| ?- consult(x).

Suggested Approach to Specifying Solution

- Use a consult file to define facts and rules
  - Instantiate prolog
  - "consult" file interactively
  - Interactively ask questions to see if facts/ rules yield expected results
  - Change consult as needed
    - Need to reinitiate prolog and re"consult"

Suggested Approach to Specifying Solution

- Construct I/O redirected file to include
  - Consult file and queries, e.g.,
    swipl < input.fle
  - You may use ";" to ask "Is there another answer?"
    - The initial query CANNOT have anything on the line after the ".", and
    - There must be a blank line after ";"

input.fle

```
consult(cnslt).
query1.
;

query2.
```


SWI-Prolog: Access & Nuance

- SWI-Prolog on Rlogin is located in the directory:
  - /home/staff/arthur/bin/swipl
- swipl prints output to STDERR (file descriptor 2). To redirect output to a file you must precede ">" with a "2" :
  - swipl < input.fle 2> output.fle

Prolog – Issues/Limitations

- "Closed World"
  - the only truth is that known to the system
- Efficiency
  - theorem proving can be extremely time consuming
- Resolution order control
  - Prolog always starts with left side of a goal, and always searches database from the top. Have some control by choice of order in the propositions and by structuring database.

Prolog – Issues/Limitations

- Prolog uses backward chaining (start with goal and attempt to find sequence of propositions that leads to facts in the database).
- In some cases forward chaining (start with facts in the database and attempt to find a sequence of propositions that leads to the goal) can be more efficient.
- Prolog always searches depth-first, though breadth-first can work better in some cases.

Prolog – Issues/Limitations

- The Negation Problem -- failure to prove is not equivalent to a logical not
  - not(not(some_goal)) is not necessarily equivalent to some_goal