

COMP219: Artificial Intelligence

Lecture 3: Introduction to Prolog

Notice

- Practical classes for the module begin **next week**.
- Check your timetable to see which class you have been allocated to.
- Exercise sheets (non-assessed) will be posted on the module web page.
- Demonstrators will be on hand to provide assistance and feedback.

Overview

- Last time
 - Techniques, applications and state-of-the-art in AI
- Today:
 - a brief *introduction* to Prolog and its uses
 - describe the use of *facts* and *rules* in Prolog programs
 - explain how Prolog evaluates *queries*.

– There will be four subsequent Prolog lectures
- Learning outcome covered today:

Understand and write Prolog code to solve simple knowledge-based problems.

Prolog



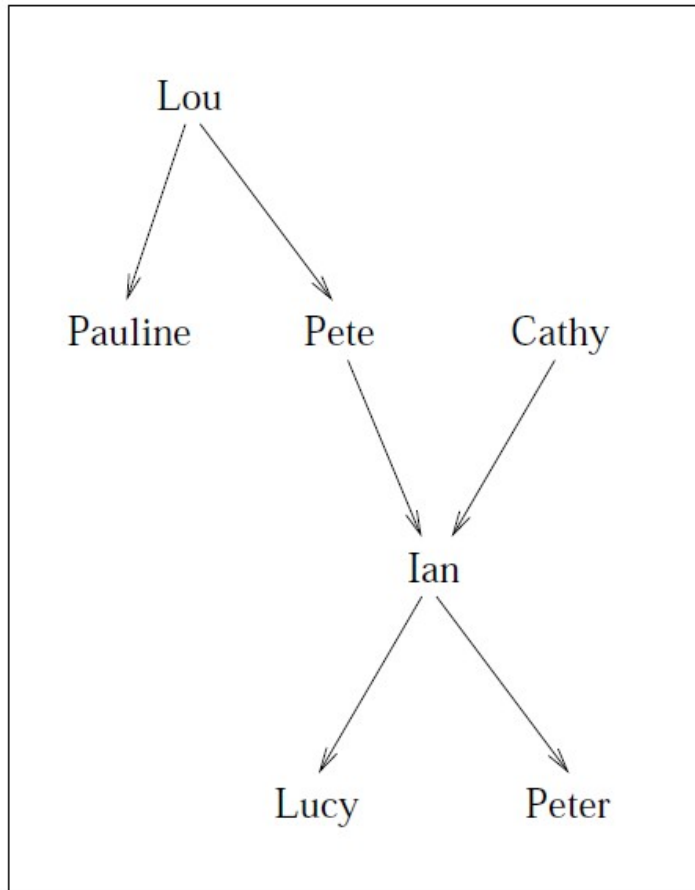
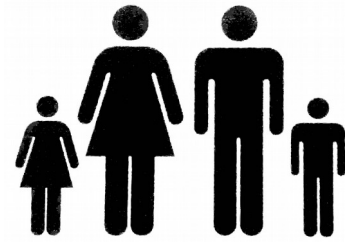
SWI Prolog

- Short for **P**rogramming in **L**ogic
- Based on an idea to use logic as a programming language (we'll see the connection later)
- Developed in the 1970s in Edinburgh and Marseilles
- Often thought of as an AI programming language
- Useful for solving problems involving objects and relations between them
- Not suitable for problems involving a lot of numeric calculation or GUIs
- “Deductive Database” with respect to which one can make deductive inferences. Can be used as the underlying logic of web applications

Books

- *Prolog Programming for Artificial Intelligence*, [Ivan Bratko](#), third edition, Addison Wesley
- *The art of Prolog: advanced programming techniques*, [Leon Sterling, Ehud Shapiro](#), MIT Press 1986
- *Introduction to programming in Prolog* [Danny Crookes](#) Prentice-Hall, 1988
- SWI Prolog Users' Manual available at
 - <http://www.swi-prolog.org/pldoc/index.html>
- SWI Prolog Web site
 - <http://www.swi-prolog.org>

Example: A Family Tree



- Lou is parent of Pete
- Pete is parent of Ian
- Ian is parent of Lucy

Facts

- To represent the previous family tree in Prolog we use *facts*, which are true without conditions
- Facts are clauses (a relation and arguments)
 - parent(pete,ian).
 - parent(ian,peter).
 - parent(ian,lucy).
- Note the **full stop** at the end of **every** line
- Relation names and arguments (constants or atoms) start with **a lower case**
- Compare to a database record: table *parent* with attributes for *parent* and *child*

More Facts

- We could store information about the gender of people in the family tree as follows
 - `female(cathy)`.
 - `female(lucy)`.
 - `male(ian)`.
- Any kind of facts we want
 - `lives_in(lucy,walford)`.
- Any number of arguments
 - `lived_from(lou,1890,1992)`.
- No data-type declaration is needed (e.g. for characters, digits, strings)

The Family Tree Program

```
/* Family Tree */
```

```
parent(pete,ian).           % Pete is a parent of Ian
```

```
parent(ian,peter).         
```

```
parent(ian,lucy).          
```

```
parent(lou,pete).          
```

```
parent(lou,pauline).       
```

```
parent(cathy,ian).         
```

```
female(cathy).             % Cathy is female.
```

```
female(lucy).              
```

```
female(pauline).           
```

```
female(lou).                
```

```
male(ian).                  % Ian is male.
```

```
male(pete).                 
```

```
male(peter).                
```

Comment symbols

Relations grouped together



Comments

- As with all programming languages, it is a good idea to include comments
- In Prolog there are two ways to do this

`% Ian is male`

`%` is a comment on this line only

- Extended comment

`/*`

Family Tree

Describes family relationships

`*/`

where

`/*` denotes the beginning of the comment and

`*/` denotes the end of the comment

Querying the Family Tree Program

- Assume the previous facts have been stored as a Prolog program and interpreted. A Prolog query is a clause
 - Is Ian a parent of Lucy?
?- `parent(ian,lucy)`.
true.
 - Is Ian a parent of Pauline?
?- `parent(ian,pauline)`.
false.
 - Is Cathy a parent of Peggy? *NB: Peggy does not appear at all in our program*
?- `parent(cathy,peggy)`.
false.
- 'true' here means 'have found a fact in the program that matches the query'
- 'false' here means 'have not found a fact in the program that matches the query'

Querying the Family Tree Program

- Can use variables as well to check facts
- Who is Lucy's parent?
?- parent(X,lucy).
X = ian.
- Starting from top of program, Prolog matches `parent` relation with `lucy` as second argument, finds `parent(ian,lucy)`, binds X to ian, and returns the result
- Variables begin with `upper case` letters (here X)

Querying the Family Tree Program

- If there are several answers, the next solution can be requested by typing a **semi-colon**

Who are Lou's children?

```
?- parent(lou,X).
```

```
X = pete ;
```

```
X = pauline .
```

- The order of the answers follows the order of facts in the program

Querying a program: summary

- Relations and arguments
 - **Relations**, e.g. parent (lower case)
 - concrete objects and constants, known as **atoms**, e.g. ian or cathy (lower case)
 - **variables**, e.g. X, Father, or Child (upper case)
- Questions to the system are *goals* (go and find the answer)
 - If a positive answer to the question is found, we say the goal was **satisfiable**, and the goal **succeeded**
 - If we get a negative answer, the goal was **unsatisfiable**, and the goal **failed**



Rules



- Rules describe what holds depending on a certain condition: conclusion if condition satisfied
- With rules, we can define complex relations in terms of simpler relations
- Mothers are female parents
`mother(X,Y) :- parent(X,Y),female(X).`
- For all X and Y, X is the mother of Y if X is the parent of Y and X is female - implicit universal quantification
- The left side of the rule (the conclusion part) is known as the **head** of the clause. The right side of the rule (the condition part) is known as the **body** of the clause
- Commas between clauses are understood as conjunction

Evaluating Rules

- Is Cathy the mother of Ian?
?- mother(cathy,ian).
true.
- There are no facts about mothers in the program so we must use the rule about mothers
mother(X,Y) :- parent(X,Y),female(X).
- We work from what we can satisfy to see if we can get a conclusion
 - Start with a body clause, parent(X,Y), match to a fact, bind variables, use the bound variables for female(X)
 - If both clauses are satisfied, then we get a conclusion
 - Otherwise, try binding the variables with respect to another fact
 - Continue until satisfaction or failure

How It Works

```
/* Family Tree */
```

```
parent(pete,ian).    % Pete is a parent of Ian
parent(ian,peter).
parent(ian,lucy).
parent(lou,pete).
parent(lou,pauline).
parent(cathy,ian).
```

```
female(cathy).      % Cathy is female.
female(lucy).
female(pauline).
female(lou). ←
```

```
male(ian).          % Ian is male.
male(pete).
male(peter).
```

```
?- mother(X,Y).
```

Find a value for X and a value for Y which satisfies
mother(X,Y)

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

Considers the goals in order (left to right) with respect to the
facts (top down)

```
parent(X,Y)
```

Matches X = pete, Y = ian. Binding of variables is applied to
other clauses

```
mother(pete,ian) :- parent(pete,ian),female(pete).
```

First body clause is OK, but female(pete) fails (not a fact)

Backtracks to try another way of satisfying the body clauses

```
parent(ian,peter) is no good as female(ian) fails
```

```
parent(ian,lucy) is no good as female(ian) fails (again)
```

```
parent(lou,pete) succeeds as female(lou) succeeds
```

```
mother(X,Y) succeeds where X=lou, Y=pete. Others?
```

More queries

```
/* Family Tree */
```

```
parent(pete,ian).    % Pete is a parent of Ian
```

```
parent(ian,peter).
```

```
parent(ian,lucy).
```

```
parent(lou,pete).
```

```
parent(lou,pauline).
```

```
parent(cathy,ian).
```

```
female(cathy).    % Cathy is female.
```

```
female(lucy).
```

```
female(pauline).
```

```
female(lou).
```

```
male(ian).    % Ian is male.
```

```
male(pete).
```

```
male(peter).
```

Can instantiate a variable:

```
?-mother(cathy,Child).
```

This will bind the other variables in the body:

```
mother(cathy,Child):-
```

```
parent(cathy,Child),female(cathy).
```

parent(cathy,ian) succeeds, binds Child to ian, Child=ian, and female(cathy) matches. So the following succeeds:

```
mother(cathy,ian).
```

Others:

```
?-mother(pete,Y).
```

Y=ian. But, fails since female(pete) fails

```
?-mother(lou,pauline).
```

Succeeds

```
?-mother(lucy,Y).
```

Fails since parent(lucy,Y) fails as it is never a fact for any binding of Y

```
?-mother(Parent,ian).
```

Succeeds with Parent=cathy. Will try Parent=pete first, but fail

More Rules – complex relations from facts or defined relations

- Grandparents are parents of parents
`grandparent(X,Z) :- parent(X,Y),parent(Y,Z).`
- Siblings are people with the same parent
`sibling(X,Y) :- parent(Z,X),parent(Z,Y).`
`sister(X,Y) :- female(X), parent(Z,X),parent(Z,Y).`
- Careful on interpretation of clauses – what do `grandparent(X,Z)` or `sister(X,Y)` mean? X has grandparent Z, or X is grandparent of Z? Is it X is sister of Y, or X has sister Y?
- Can use relations defined in rules in other rules
`grandmother(X,Z) :- mother(X,Y),parent(Y,Z).`
`sister(X,Y) :- sibling(X,Y),female(X).`

Exercise

- What relationship does the *unknown* describe?
unknown(X,Y):- parent(X,Y),female(Y).
- How would we define *brother*?
- What answers will Prolog find for the following query?
?- grandparent(X,Y).

Running Prolog under UNIX/LINUX

- On a unix/linux system enter the word `swipl`

```
$ swipl
```

```
Welcome to SWI-Prolog (Multi-threaded, 32 bits, Version 6.6.6)
```

```
Copyright (c) 1990-2013 University of Amsterdam, VU Amsterdam
```

```
SWI-Prolog comes with ABSOLUTELY NO WARRANTY. This is free software,  
and you are welcome to redistribute it under certain conditions.
```

```
Please visit http://www.swi-prolog.org for details.
```

```
For help, use ?- help(Topic). or ?- apropos(Word).
```

```
?-
```

Loading Programs

- Create the program (facts and rules) using any text editor
- If the program is saved in the same directory, type

```
?- consult(familyTree).
```

```
% familyTree compiled 0.00 sec, 15 clauses
```

```
true.
```

```
?-
```

- An alternative is to type

```
?- ['familyTree.pl'].
```

```
% familyTree compiled 0.00 sec, 15 clauses
```

```
true.
```

```
?-
```

Now you can type in your queries.

To exit the program type

```
?- halt.
```

Running Prolog under Windows

- Choose SWI-Prolog from

Start -> All Programs -> Programming Resources -> SWI-Prolog -> Prolog

- To load a program, in the console type

```
['h:\\familyTree']
```

making sure you specify the correct path to the location of the familyTree program within your filestore.

Summary (I)

- A Prolog program is constructed from **facts** and **rules**
- Facts describe things that are true without conditions
 - like data in a database
- Rules describe things that hold depending on certain conditions. The conditions are defined in rules and facts
 - Ultimately all rules unfold to facts
- Prolog programs can be **queried**
- Prolog clauses are facts, rules, and queries
- Queries are answered by solving each goal in turn by matching clauses (perhaps in the body of a rule) against facts (whether given or derived), binding variables, and backtracking where necessary until either the query is satisfied or it fails

Summary (II)

- Today
 - Introduction to Prolog
 - Facts, rules, queries
 - Running Prolog
- Next time
 - A brief history of AI
 - AI and intelligent agents