COMP4418: Knowledge Representation and Reasoning

Introduction to Prolog

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Prolog

- Prolog — Programming in Logic
- Invented early 70s by Alain Colmeraurer et al., University of Marseille

- Declarative language
  - Specify goal and interpreter/compiler will work out how to achieve it
  - Traditional (imperative) languages require you to specify how to solve problem

- Prolog program specifies:
  - facts about objects and their relationships
  - rules about objects and their relationships
Starting Prolog

$ prolog
iProlog (8 April 2001)
: ^D
$

$ prolog courses.pl
iProlog (8 April 2001)
: lectures(maurice, comp4418)?
** yes
: ^D
$


Relations

■ Prolog programs specify relationships among objects and properties of objects

■ When we say, “John owns the book”, we are declaring the ownership relation between two objects: John and the book

■ When we ask, “Does John own the book?”, we are querying the relationship

■ Relationships can also be rules such as:

   Two people are sisters if  
   both are female  
   they have the same parents

■ This is a rule that allows us to find out about a relationship even if the relationship isn’t explicitly declared
Programming in Prolog

- Declare facts describing explicit relationships between objects and properties of objects
- Define rules describing implicit relationships between objects or implicit object properties
- Ask questions about relationships between objects and object properties
Representing Regulations

The rules for entry into a professional computer science society are set out below:

An applicant to the society is acceptable if he or she has been nominated by two established members of the society and is eligible under the terms below:

- the applicant graduated with a university degree
- the applicant has two years of professional experience
- the applicant pays a joining fee of $200.

An established member is one who has been a member for at least two years.
Facts

- Properties of objects; relationships between objects

- Example
  - “Maurice lectures in course COMP4418”
  - Prolog: lectures(maurice, comp4418)

- Notice
  - Names of properties/relationships begin with lower-case character
  - Name of relationship appears as first term, objects appear as arguments
  - Fact terminated by ‘.’
  - Objects (atoms) also begin with lower-case characters

- lectures(maurice, 4418) also called a predicate
Facts

Let us return to the regulations example:

experience(fred, 3).
fee_paid(fred).
graduated(fred, unsw).
university(unsw).
nominated_by(fred, jim).
nominated_by(fred, mary).
joined(jim, 1998).
joined(mary, 1997).
current_year(2001).
Prolog Database

A collection of facts about a hypothetical computer science department:

% lectures(X, Y): person X lectures in course Y
lectures(tony, comp1001).
lectures(andrew, comp2041).
lectures(john, comp2041).
lectures(gernot, comp3231).
lectures(arun, comp4141).
lectures(sowmya, comp4411).
lectures(claude, comp4411).
lectures(maurice, comp4418).
lectures(adnan, comp4418).
lectures(adnan, comp9518).
lectures(wayne, comp4418).
lectures(arthur, comp9020).
% studies(X, Y): person X studies course Y
studies(mary, comp1001).
studies(jim, comp1001).
studies(jane, comp4411).
studies(jane, comp4418).
studies(jack, comp9518).
studies(jack, comp9020).

% year(X, Y): person X is in year Y
year(mary, 1).
year(jim, 1).
year(jane, 4).
year(jack, 4).

Together, these facts form Prolog’s database.
Queries

- Once we have a database of facts (and, soon, rules) we need to be able to ask questions of the information that is stored

- \texttt{lectures(maurice, comp4418)}?

- Notice:
  - Query is terminated by a question mark ‘?’
  - To determine answer (yes or no), Prolog consults database checking whether this is a known fact
  - For example, \texttt{lectures(bob, comp4418)}?
    **no**
  - If answer is yes, query succeeded; otherwise, if answer is no, query failed
Variables

- Suppose we want to ask, “What subject does John teach?”
- This could be phrased as:
  > Is there a subject, X, that John teaches?
- The variable X stands for an object that the questioner does not yet know about
- To answer the question, Prolog has to find the value of X, if it exists
- As long as we do not know the value of the variable, it is said to be unbound
- When a value is found, the variable is bound to that value
Variables

A variable must begin with a capital letter or ‘_’

To ask Prolog to find the subject that John teaches, type:

```
: lectures(john, Subject)?
```

Subject = comp2041

To ask which subjects that Adnan teaches, ask:

```
: lectures(adnan, X)?
```

X = comp4418

X = comp9518

Prolog can find all possible ways to satisfy a query
Conjunction in Queries

■ How do we ask, “Does Arthur teach Jack?”

■ This can be answered by finding out whether Arthur lectures in a subject that Jack studies:
  \[ \text{lectures}(\text{arthur}, \text{Subject}), \text{studies}(\text{jack}, \text{Subject})? \]

■ i.e., Arthur lectures in subject, Subject, and Jack studies subject, Subject.

■ Subject is a variable

■ The question consists of two goals

■ To find the answer, Prolog must find a single value for Subject that satisfies both goals
Conjunctions

- Who does Adnan teach:
  
  ```prolog
  : lectures(adnan, Subject), studies(Student, Subject)?
  Subject = comp4418
  Student = jane
  
  Subject = comp9518
  Student = jack
  ```

- Prolog solves problems by proceeding left to right and then backtracking

- Given the initial query, Prolog tries to solve
  ```prolog
  lectures(adnan, Subject)
  ```

- There are twelve lectures clauses but only two have adnan as first argument

- Prolog chooses the first clause containing a reference to adan i.e.,
  ```prolog
  lectures(adnan, 4418)
  ```
Proof Tree

- With Subject = 4418, it then tries to satisfy the next goal, viz studies(Student, 4418)
- After the solution is found, Prolog retraces its steps and looks for alternative solutions
- It may now go down the branch containing lectures(adnan, 9518) and try studies(Student, 9518)
The previous question can be restated as a general rule:

One person, Teacher teaches another person, Student if Teacher lectures subject, Subject and Student studies Subject

In Prolog this is written as the:

\[
\text{teaches}(\text{Teacher}, \text{Student}) :- \text{lectures}(\text{Teacher}, \text{Subject}), \text{studies}(\text{Student}, \text{Subject}).
\]

\[
\text{teaches}(\text{adnan}, \text{Student})?\]

Facts are unit clauses and rules are non-unit clauses
Rules

acceptable(Applicant) :-
    nominated(Applicant),
    eligible(Applicant).

nominated(Applicant) :-
    nominated_by(Applicant, Member1),
    nominated_by(Applicant, Member2),
    Member1 \= Member2,
    current_year(ThisYear),
    joined(Member1, Year1), ThisYear >= Year1 + 2,
    joined(Member2, Year2), ThisYear >= Year2 + 2,. 

eligible(Applicant) :-
    graduated(Applicant, University), university(University),
    experience(Applicant, Experience), Experience >= 2,
    fee_paid(Applicant).
Clause Syntax

- ‘:-’ means “if” or “is implied by”. Also called “neck”
- The left hand side of the neck is the head
- The right hand side is called the body
- The comma, ‘,’ separating the goals stands for and

  more_advanced(Student1, Student2) :-
    year(Student1, Year1),
    year(Student2, Year2),
    Year1 > Year2.

- Note the use of the predefined predicate ‘>’

  more_advanced(jane, mary)?
  more_advanced(jack, X)?
Structures

- Functional terms can be used to construct complex data structures
- E.g., to say that John owns the book *Foundation*, this may be expressed as:
  
  \[
  \text{owns(john, 'Foundation')}.
  \]

- Often objects have a number of attributes
- A book may have a title and an author:
  
  \[
  \text{owns(john, book('Foundation', asimov))}.
  \]

- To be more accurate we should give the author’s family and given names:
  
  \[
  \text{owns(john, book('Foundation', author(asimov, isaac))}).
  \]
Asking Questions with Structures

How do we ask:

“What books does John own that were written by someone called “Asimov”?

: owns(john, book(Title, author(asimov, GivenName)))?
Title = Foundation
GivenName = isaac

: owns(john, Book)?
Book = book(Foundation, author(asimov, isaac))

: owns(john, book(Title, Author))?
Title = Foundation
Author = author(asimov, isaac)
Databases

- A database of books in a library contains facts of the form:
  - book(CatNo, Title, author(Family, Given)).
  - member(MemNo, name(Family, Given), Address).
  - loan(CatNo, MemNo, Borrowed, Due).

- A member of the library may borrow a book

- A “loan” records:
  - the catalogue number of the book
  - the number of the member
  - the borrow date
  - the due date
Database Structures

- Dates are stored as structures:
  ```prolog
date(Year, Month, Day).
```
- E.g., `date(2001, 9, 8)` represents 8 September 2001
- Names and addresses are all stored as character strings
- Which books has a member borrowed?
  ```prolog
has_borrowed(MemFamily, Title, CatNo) :-
  memb(MemNo, name(MemFamily, _), _),
  loan(CatNo, MemNo, _, _),
  book(CatNo, Title, _).
```
- Which books are overdue?
Overdue Books

\[
\text{later}(\text{date}(Y, M, D1), \text{date}(Y, M, D2)) :\text{ D1 > D2}.
\]

\[
\text{later}(\text{date}(Y, M1, _), \text{date}(Y, M2, _)) :\text{ M1 > M2}.
\]

\[
\text{later}(\text{date}(Y1, _, _), \text{date}(Y2, _, _)) :\text{ Y1 > Y2}.
\]

\[
\text{later}(\text{date}(2001, 12, 3), \text{date}(1999, 8, 3))?
\]

\[
\text{overdue}(\text{Today}, \text{Title}, \text{CatNo}, \text{MemFamily}) :\text{-}
\]
\[
\begin{align*}
&\text{loan}(&\text{CatNo}, \text{MemNo}, _, \text{DueDate}), \\
&\text{later}(\text{Today}, \text{DueDate}), \\
&\text{book}(&\text{CatNo}, \text{Title}, _), \\
&\text{memb}(&\text{MemNo}, \text{name}(\text{MemFamily}, _), _).
\end{align*}
\]
Due Date

due_date(date(Y, M1, D), date(Y, M2, D)) :-
    M1 < 12,
    M2 is M1 + 1.
due_date(date(Y1, 12, D), date(Y2, 1, D)) :-
    Y2 is Y1 + 1.

■ is accepts two arguments

■ The right hand argument must be an evaluable arithmetic expression

■ The term is evaluated and unified with the left hand argument

■ It is not an assignment statement

■ Variables cannot be reassigned values

■ Arguments of comparison operators can also be arithmetic expressions