Logic Programming

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Background

- Logic Programming is a different paradigm from either imperative or functional programming languages.
- The best known Logic Programming language is Prolog; it is like Haskell and other functional programming languages in having a declarative reading.
- According to an old joke, Logic Programming was invented in Edinburgh in 1974, and implemented in Marseille in 1972.
- The approach came out of connections observed between natural language parsing, general theorem proving in first-order logic, and AI planning.

The Idea

It would be great if:

> *Instead of writing an algorithm to solve a given problem, we can just specify the problem (in first-order logic) and let the machine solve the problem for us.*

Logic Programming achieves this —

to an extent, certainly not always; (and actually we know that this wish cannot be fully realised).

So languages like Prolog are practical solution, which given a good understanding of the approach, lets us solve (quite a lot of) problems quickly.

Course organisation

- Third year course, worth 10 points.
- The assessment is by exams (80%);
  and two assessed courseworks (20%).
- There are tutorials (from week 3), which are an integral part of the course.
- There will be two exams:
  - 1 hour on theoretical material
  - 2 hour programming exam in computer lab.

The course

Official descriptor:

http://www.drps.ed.ac.uk/15-16/dpt/cxinfr09031.htm

and course web page:

http://www.inf.ed.ac.uk/teaching/courses/lp/

Background, Aims

It will help if you have seen first-order logic before;
if not, see some resources on the course web page.

The aim is that you will

- Understand the principles of declarative specification.
- Be able to construct well crafted Prolog programs of moderate size and sophistication.
- To be able to interpret problems in a style that suits logic programming.

LP: Programming

Today we aim

- to get a general grasp of the main ideas behind Logic Programming;
- why you might use it;
- and how to get started programming in LP.

The Ideal

- Program specifications can be written in logic.
- Specifications are independent of computers.
- Rules of logic can prove that a specification can be realised, even if computers didn't exist.
- But proof can also be done by a computer smart enough to find the right proof.
- So specifications and programs are . . . the same.
- So specifications and programs are nearly the same.

Ideally

- Slogan (Kowalski): "Algorithm = Logic + Control"
- The program should simply describe what counts as a solution to the program.
- The computer then finds the solution.
- Programmers should be able to ignore how the solution is found.

In reality

- Purely declarative programming can only get you so far
- For efficiency/termination, sometimes need finer-grained control over search.
- I/O, interaction with outside world, seem inherently "imperative"

Prolog

- Prolog is the best-known LP language
  - Core based on first-order (predicate) logic
  - Algorithmic realisation via unification, search
- Many implementations that make it into a full-fledged programming language
  - I/O, primitive ops, & efficiency issues all complicate the declarative story

Why learn LP?

- LP often great for rapidly prototyping algorithms/search strategies
- "Declarative" ideas arise in many areas of CS
  - LP concepts very important in AI, databases, PL
  - SAT solvers, model-checking, constraint programming
  - Becoming important in program analysis, Semantic Web
- Learning a very different "way to think about problems" makes you a better programmer.

Well use **SICStus** Prolog.

- Available on all DICE machines
  - Tutorials, exams will be based on this version
- Windows, Mac version free for UofE students:
  - Can request through Computing Support
- On-line documentation

  http://www.sics.se/isl/sicstuswww/site/

Getting started

Prolog is an interactive language.

```
$ sicstus
?-
?- print( 'hello world').
hello world
yes
```

We see the result of the print command,
and also the response `yes`.

Atoms

An atom is:

- a sequence of alphanumeric characters
    - usually started with a lower case letter
- or a string enclosed in single quotes

Examples:

```
homer marge17 'Mr.  Burns'
```

Variables

A variable is a sequence of alphanumeric characters, usually starting with an uppercase letter.

Examples:

```
X Y Parent Foo
```

Predicates

A predicate has the form

```
p(t1,...,tn)
```

where `p` is an atom, and `t1,...,tn` are terms.

For now, a term is just an atom or variable

Examples:

```
father(homer, bart)

mother(marge, bart)
```

Predicates ctd

A predicate has

- a name – `father` in `father(homer, bart)`
- an arity – how many arguments: 2 in `father(homer, bart)`

Predicates with the same name, but different arity,
are different predicates.

We write `foo/1`, `foo/2`, ... to refer to these different predicates.

Facts

A fact is an assertion that an instance of the predicate is true:

```
father(homer, bart).

mother(marge, bart).
```

Notice the full stops!!

A collection of facts is sometimes called a knowledge base.

Goals

A goal is a sequence of predicates, connected by commas – we understand this as conjunction:

```
p(t1,...,tn), ..., q(t1',...,tn').
```

We read this as saying `p` holds of `t1,...,tn`, and also similarly for other predicates.

Predicates can be 0-ary (no arguments); there are some built-ins: `true, false, fail`

Answers

Given a goal, Prolog searches for answers:
the two possible answers are:

- `yes` (possible with answer substitution)
- `no`

Substitutions are bindings of variables that make goal true

Use ";" to see more answers.

Examples

Suppose have Prolog facts (here in `simpsons.pl`:

```
father(abe,homer).
father(homer, bart).
father(homer, lisa).
father(homer, maggie).
father(ned, rod).
father(ned, todd).
father(chief_wiggum,ralph).

mother(marge, bart).
mother(marge, lisa).
mother(marge, maggie).
...
```

Examples ctd

We can now query, and Prolog will search for possible answers:

```
?- father(X,bart).
X = homer ;
no

?- father(X,Z), mother(Y,Z).
X = homer, Y = marge, Z = bart ;
X = homer, Y = marge, Z = lisa ;
X = homer, Y = marge, Z = maggie ;
no
```

Rules

A Rule is an assertion of the form

```
p(ts1) :- q(ts2), ..., r(tsN).
```

where `ts1, ts2, ..., tsN` are sequences of terms.

This means:
`p(ts1)` holds if `q(ts2)` holds and ... and `r(tsN)` holds.

Example:

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

Is this a good definition of sibling?

- Comments:

```
% percent comments out rest of line

/* multiple
           line comment */
```

- To quit Sicstus, type

```
?- halt.
```

. . . or control-D.

Consulting

- A Prolog program is a collection of facts and rules; together these are known as clauses
  - stored in one or more files
- The predicate `consult/1` loads the clauses in a file:

  ```
  ?- consult('simpsons.pl').
  ```

  or without the `.pl` extension:

  ```
  ?- consult(simpsons). or
  ?- [simpsons].
  ```

A complete program

```
/* hello.pl
 * James Cheney
 * Sept.  20, 2010
 */

main :- print('hello world').
```

Tracing

Most Prolog implementations have good tracing facilities.

- `trace/0` turns on tracing
- `notrace/0` turns tracing off
- `debugging/0` shows tracing status

Further Reading

- Course text:
  "Learn Prolog Now!" (Blackburn et. al.): on-line at:
  http://www.learnprolognow.org/
- Quick Start Prolog notes (David Robertson):
  http://www.inf.ed.ac.uk/teaching/courses/lp/2008-9/prolognotes.pdf

Exercises

Using `simpsons.pl`, write goal bodies for:

- `classmate(X,Y)`
- `employer(X)`
- `parent(X,Y)`
- `grandparent(X,Y)`

Next Time

- Compound Terms
- Equality and Unification
- How Prolog searches for answers