Prologue to Prolog 101
A Lecture for COSC-6421

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Prologue

Goal: Convert you to the way of Prolog, especially you Lisp heathens (*or to introduce you to Prolog and its many merits*).

I. The Genesis of Prolog

II. Prolog, the language

III. The Merits of Prolog

IV. Why Prolog?

A. Prolog vs. Lisp

B. Why Prolog for AI?

V. The Cannibals-and-Missionaries Problem

VI. Homework

Theorem Proving

$$
\begin{array}{ll}
\neg a \vee b & \neg b \vee \neg f \vee h \\
\neg a \vee c & \neg c \vee \neg d \vee h \\
\neg b \vee d \vee e & \neg e \vee \neg g \vee h \\
\neg c \vee f \vee g & \quad a \\
\hline
\end{array}
$$

Prove h.

Search can be hard. Theorem proving can be hard.

A *Horn clause* has one or no positive atoms in it.

$$a \vee \neg b \vee \neg c$$

can be rewritten as

$$a \; \leftarrow \; b, c.$$

`Procedural = Declarative`

Logic can be used as a programming language!

Prolog, the language

1. Clauses, Facts, and Queries

Clause: $a \leftarrow b\_1, \ldots, b\_n.$

Fact: $a.$

Query: $\leftarrow a\_1, \ldots, a\_n.$

2. Matching (unification)

3. Built-in control

- Proof by refutation
- One inference rule: resolution
- Choosing clauses: first in list to match to last in list to match
- Choosing goals: from left-to-right in goal list

4. Meta-predicates

`setof`	`clause`	`var`
`assert`	`retract`	`not` “\+”
`univ` “=..”	`equivalent` “==”	*meta-variables!*

5. Search Prunning/Commit

`cut` “!”

Grandmothers and Grandfathers

$$\begin{aligned} \mathit{grandmother}\,(GM,\ X) \leftarrow{} & \mathit{mother}\,(GM,\ P),\\ & \mathit{parent}\,(P,\ X). \end{aligned}$$

$$\begin{aligned} \mathit{grandfather}\,(GF,\ X) \leftarrow{} & \mathit{father}\,(GF,\ P),\\ & \mathit{parent}\,(P,\ X). \end{aligned}$$

$$\mathit{parent}\,(M,\ X) \leftarrow \mathit{mother}\,(M,\ X).$$

$$\mathit{parent}\,(F,\ X) \leftarrow \mathit{father}\,(F,\ X).$$

mother (judith, parke).

mother (ruby, judith).

mother (lallage, blan).

father (blan, parke).

father (alvin, judith).

father (albert, blan).

← *grandmother (G, parke).*

G = ruby;

G = lallage;

no

← *grandmother (lallage, X).*

X = parke;

no

Why Prolog?

Prolog vs. Lisp (a sibling rivalry)

- the not-invented-here syndrom
- relational vs. functional

Why Prolog for AI?

- ○ easy to write meta-programs
    - Prolog is its own meta-language!
    - `code = data`
- ○ is an “interpreted” language
    - good debugging facilities
    - needed for meta-programming
- ○ based on the recursion paradigm
- ○ no typing!
- Prolog is based on first-order logic

  `Logic is good for AI.`
- is *declarative*

  (not prescriptive)

The Merits of Prolog

Neat Features of Prolog

- **Non-determinism (backtracking)**
  - Can find alternate answers/solutions for free!
- **Invertability**
  - Call any predicate with any instantiation pattern!

    (Well, sometimes . . .)
- **Unification**
  - Pattern matching for free!
- **Built-in Search**
  - A free refutation proof system.
  - Specs *are* executable. (Well, kind of . . .)

    Do not have to write one's own search mechanism for every problem.
- **Built-in database features**
  - `assert` and `retract`

Meta-Predicates

a.k.a. Extra-Logical Predicates

setof/findall

$\leftarrow setof\,(GM,\ grandmother\,(GM,\ parke),\ GMs).$

$GMs = [lallage,\ ruby];$

no

assert

$\leftarrow student\,(X).$

no

$\leftarrow assert\,(student\,(parke)).$

yes

$\leftarrow student\,(X).$

$X = parke;$

no

meta-variables

$$exec\_list\,([X|Xs]) \leftarrow X,\ exec\_list\,(Xs).$$

$$exec\_list\,([\,]).$$

Executable Specifications

`Program = Logic + Control`

A goal of logic programming is to be able to execute specifications as code.

In Prolog, the *control* mechanism is built in.

Problem with Specs

Some specs are more equal than others.

$$\begin{aligned} \mathit{sort}\,(\mathit{As},\ \mathit{Zs}) \leftarrow{} & \mathit{same\_length}\,(\mathit{As},\ \mathit{Zs}),\\ & \mathit{perm}\,(\mathit{As},\ \mathit{Zs}),\\ & \mathit{ordered}\,(\mathit{Zs}). \end{aligned}$$

$$\begin{aligned} \mathit{perm}\,(\mathit{As},\ [A\,|\,\mathit{Zs}]) \leftarrow{} & \mathit{choose}\,(A,\ \mathit{As},\ \mathit{Rest}),\\ & \mathit{perm}\,(\mathit{Rest},\ \mathit{Zs}). \end{aligned}$$

$$\mathit{perm}\,([\,],\ [\,]).$$

$$\mathit{same\_length}\,([\_\,|\,\mathit{As}],\ [\_\,|\,\mathit{Zs}]) \leftarrow \mathit{same\_length}\,(\mathit{As},\ \mathit{Zs}).$$

$$\mathit{same\_length}\,([\,],\ [\,]).$$

$$\mathit{choose}\,(A,\ [A\,|\,\mathit{As}],\ \mathit{As}).$$

$$\mathit{choose}\,(A,\ [B\,|\,\mathit{As}],\ [B\,|\,\mathit{Zs}]) \leftarrow \mathit{choose}\,(A,\ \mathit{As},\ \mathit{Zs}).$$

$$\mathit{ordered}\,([A,\ B\,|\,\mathit{As}]) \leftarrow A < B,\ \mathit{ordered}\,([B\,|\,\mathit{As}]).$$

$$\mathit{ordered}\,([A\,]).$$

$$\mathit{ordered}\,([\,]).$$

Problem with Specs [cont.]

A better sort of sort.

$$\begin{aligned}
\mathit{sort}\,([A\,|\,As],\ Zs) \leftarrow\ & \mathit{divide\_list}\,(A,\ As,\ Fs,\ Ls),\\
& \mathit{sort}\,(Fs,\ \mathit{OrdFs}),\\
& \mathit{sort}\,(Ls,\ \mathit{OrdLs}),\\
& \mathit{append}\,(\mathit{OrdFs},\ [A\,|\,\mathit{OrdLs}],\ Zs).
\end{aligned}$$

$$\mathit{sort}\,([\,],\ [\,]).$$

$$\begin{aligned}
& \mathit{divide\_list}\,(A,\ [F|As],\ [F|Fs],\ Ls) \leftarrow\\
& \qquad A > F,\\
& \qquad \mathit{divide\_list}\,(A,\ As,\ Fs,\ Ls).\\
& \mathit{divide\_list}\,(A,\ [L\,|As],\ Fs,\ [L\,|Ls]) \leftarrow\\
& \qquad A =< L,\\
& \qquad \mathit{divide\_list}\,(A,\ As,\ Fs,\ Ls).\\
& \mathit{divide\_list}\,(A,\ [\,],\ [\,],\ [\,]).
\end{aligned}$$

Pragmatics

\+	is	*not*	
,	is	*and*	
;	is	*or*	(also used to enumerate answers)
!	is	*cut*	
:-	is	*if*	(←)

[*Head*|*Tail*] is a list.

Head is the first term in list. (*car* for you Lispites)

Tail is the first term in list. (*cdr* for you Lispites)

[*First*, *Second*|*Tail*] is valid notation too. [ ] is the empty list.

[*First*, *Second*, *Third*] is a completely enumerated list.

Variables names always start CAPITALIZED.

Constants begin with lowercase (or are single-quoted).

How do you load clauses from a file?

In the Prolog session, type: *consult* ($\langle filename \rangle$).

Every clause (rule, query, or fact) must end in a period!

Books on Prolog

Prolog Books (On reserve in AVW Library)

[1] W. F. Clocksin and C. S. Mellish. *Programming in Prolog.* Springer-Verlag, Berlin, third, revised and extened edition, 1987.

[2] L.S. Sterling and E.Y. Shapiro. *The Art of Prolog.* MIT Press, 1986.

Manuals

The *SICSTUS* Manual.

Logic for Problem Solving

[1] R.A. Kowalski. *Logic for Problem Solving.* Artificial Intelligence Series. North-Holland, New York, 1979.

[2] Nils J. Nilsson. *Principles of Artificial Intelligence.* Morgan Kaufmann Publishers Incorporated, 1980.

Books on Logic Programming

[1] John W. Lloyd. *Foundations of Logic Programming.* Symbolic Computation—Artificial Intelligence. Springer-Verlag, Berlin, second edition, 1987.

[2] Jorge Lobo, Jack Minker, and Arcot Rajasekar. *Foundations of Disjunctive Logic Programming.* M.I.T. Press, Cambridge, Massachusetts, 1992.