Programming Languages (CSCI 4430/6430)
History, Syntax, Semantics, Essentials, Paradigms

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The first programmer ever
Ada Augusta, the Countess of Lovelace, the daughter of the poet Lord Byron
Circa 1843
Using Babbage’s Analytical Engine

The first “high-level” (compiled) programming language
FORTRAN
1954
Backus at IBM
It was called “an automatic coding system”, not a "programming language"
Used for numerical computing

The first functional programming language
Lisp
1958
McCarthy at Stanford
For LISts Processing—lists represent both code and data
Used for symbolic manipulation

The first object oriented programming language
Simula
1962
Dahl and Nygaard at University of Oslo, Norway
Used for computer simulations

The first logic programming language
Prolog
1972
Roussel and Colmerauer at Marseilles University, France
For "PROgrammation en LOGique".
Used for natural language processing and automated theorem proving
The first concurrent programming language

Concurrent Pascal
1974
Hansen at Caltech
Used for operating systems development

PLASMA
1975
Hewitt at MIT
Used for artificial intelligence (planning)

The first concurrent actor programming language

The first scripting language

REXX
1982
Cowlishaw at IBM
Only one data type: character strings
Used for "macro" programming and prototyping

The first multi-paradigm programming language

Oz
1995
Smolka at Saarland University, Germany
A logic, functional, imperative, object-oriented, constraint, concurrent, and distributed programming language
Used for teaching programming and prototyping

Other programming languages

Logic Programming (PLP 11)
Horn Clauses
Introduction to Prolog: Resolution, Unification
An Early (1971) “Conversation”

USER: Cats kill mice.
Tom is a cat who does not like mice who eat cheese.
Jerry is a mouse who eats cheese.
Max is not a mouse.
What does Tom do?
COMPUTER: Tom does not like mice who eat cheese.
Tom kills mice.
USER: Who is a cat?
COMPUTER: Tom.

Another Conversation

USER: Every psychiatrist is a person.
Every person he analyzes is sick.
Jacques is a psychiatrist in Marseille.
Is Jacques a person?
Where is Jacques?
Is Jacques sick?
COMPUTER: Yes.
In Marseille.
I don’t know.

Logic programming

• A program is a collection of axioms, from which theorems can be proven.
• A goal states the theorem to be proved.
• A logic programming language implementation attempts to satisfy the goal given the axioms and built-in inference mechanism.

Horn clauses

• A standard form for writing axioms, e.g.:
  \[ \text{father}(X,Y) \leftarrow \text{parent}(X,Y), \text{male}(X). \]
• The Horn clause consists of:
  – A head or consequent term \( H \), and
  – A body consisting of terms \( B_i \)
    \[ H \leftarrow B_1, B_2, \ldots, B_n. \]
• The semantics is:
  \[ \text{If } B_1, B_2, \ldots, B_n \text{, then } H. \]

Terms

• Constants
  rpi
troy
• Variables
  University
  City
• Predicates
  located_at(rpi,troy)
  pair(x, pair(y,z))

Resolution

• To derive new statements, Robinson’s resolution principle says that if two Horn clauses:
  \[ H_1 \leftarrow B_1, B_2, \ldots, B_m \]
  \[ H_2 \leftarrow B_1, B_2, \ldots, B_{m+1}, B_{m+2}, \ldots, B_n \]
  are such that \( H_1 \) matches \( B_{m+1} \), then we can replace \( B_{m+1} \) with \( B_1, B_2, \ldots, B_m \):
  \[ H_2 \leftarrow B_1, B_2, \ldots, B_{m+1}, B_{m+2}, \ldots, B_{n-1}, B_{n} \]
• For example:
  \[ C \leftarrow A, B \]
  \[ D \leftarrow C, D \]
  \[ T \leftarrow A, B, D \]
**Resolution Example**

father(X,Y) :- parent(X,Y), male(X).
grandfather(X,Y) :- father(X,Z), parent(Z,Y).
grandfather(X,Y) :-
  parent(X,Z), male(X), parent(Z,Y).

:- is Prolog’s notation (syntax) for \( \iff \).

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**Unification**

- During resolution, free variables acquire values through unification with expressions in matching terms.
- For example:
  
  | male(carlos). |
  | parent(carlos, tatiana). |
  | parent(carlos, catalina). |
  | father(X,Y) :- parent(X,Y), male(X). |
  | father(carlos, tatiana). |
  | father(carlos, catalina). |

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**Unification Process**

- A constant unifies only with itself.
- Two predicates unify if and only if they have
  - the same functor,
  - the same number of arguments, and
  - the corresponding arguments unify.
- A variable unifies with anything.
  - If the other thing has a value, then the variable is instantiated.
  - If it is an uninstantiated variable, then the two variables are associated.

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**Backtracking**

- Forward chaining goes from axioms forward into goals.
- Backward chaining starts from goals and works backwards to prove them with existing axioms.

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**Backtracking example**

rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), cold(X).

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**Backtracking example**

rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), cold(X).

\[ \text{AND} \]

\[ \text{OR} \]

\[ \text{snowy(C)} \]

\[ \text{rainy(X)} \]

\[ \text{cold(X)} \]

\[ \text{rainy(seattle)} \]

\[ \text{rainy(rochester)} \]

\[ \text{cold(rochester)} \]
Backtracking example

rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), cold(X).

success
_C = _X
snowy(C)
cold(seattle)
cold(rochester)

AND

X = seattle
rainy(X)
OR
rainy(rochester)
cold(X)

fails; backtrack

Backtracking example

rainy(seattle).
rainy(rochester).
cold(rochester).
snowy(X) :- rainy(X), cold(X).

X = seattle
rainy(X)
OR
rainy(rochester)
cold(X)

fails; backtrack

X = rochester

success

Exercises

1. Download SWI Prolog and install it in your laptop.
2. Execute the "snowy(City)" example. Use "tracing" to follow backtracking step by step.
3. Create a knowledge base with Prolog facts about your family members using predicates and constants. Create Prolog rules using variables to define the following: brother, sister, uncle, aunt, nephew, niece, grandfather, grandmother, etc. Query your program for family relationships.