Programming Languages (CSCI 4430/6969)

History, Syntax, Semantics, Essentials, Paradigms

Carlos Varela

Rensselaer Polytechnic Institute

January 24, 2011

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

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

Imperative

Algol (Naur 1958)
Cobol (Hopper 1959)
BASIC (Kennedy and Kurtz 1964)
Pascal (Wirth 1970)
C (Kernighan and Ritchie 1971)
Ada (Whitaker 1979)

Functional

ML (Milner 1973)
Scheme (Sussman and Steele 1975)
Haskell (Hughes et al 1987)

Object-Oriented

Smalltalk (Kay 1980)
C++ (Stroustrop 1980)
Eiffel (Meyer 1985)
Java (Gosling 1994)
C# (Hejlsberg 2000)

Actor-Oriented

PLASMA (Hewitt 1975)
Act (Lieberman 1981)
ABCL (Yonezawa 1988)
Actalk (Briot 1989)
Erlang (Armstrong 1990)
E (Miller et al 1998)
SALSA (Varela and Agha 1999)

Scripting

Python (van Rossum 1985)
Perl (Wall 1987)
Tcl (Ousterhout 1988)
Lua (Ierusalimschy et al 1994)
JavaScript (Eich 1995)
PHP (Lerdorf 1995)
Ruby (Matsumoto 1995)

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.

USER:

What does Jerry eat?

COMPUTER:

Cheese.

USER:

Who does not like mice who eat cheese?

COMPUTER:

Tom.

USER:

What does Tom eat?

COMPUTER:

What cats who do not like mice who eat cheese eat.

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.:

```
father(X,Y) ⇐ parent(X,Y), male(X).
```

- The Horn clause consists of:
  - A *head* or consequent term H, and
  - A *body* consisting of terms B_i

$$H \Leftarrow B_0 , B_1 , \ldots, B_n$$

- The semantics is:

« If B_0 , B_1 , …, B_n, then H »

Terms

- Constants

```
rpi
troy
```

- Variables

```
University
City
```

- Predicates

```
located_at(rpi,troy)
pair(a, pair(b,c))
```

Can be nested.

Resolution

- To derive new statements, Robinson's resolution principle says that if two Horn clauses:

$$H_1 \Leftarrow B_{11}, B_{12}, \ldots, B_{1m}$$
$$H_2 \Leftarrow B_{21}, B_{22}, \ldots, B_{2n}$$

are such that $\mathbf{H_1}$ matches $\mathbf{B_{2i}}$, then we can replace $\mathbf{B_{2i}}$ with $\mathbf{B_{11}, B_{12}, \ldots, B_{1m}}$:

$$H_2 \Leftarrow B_{21}, B_{22}, \ldots, B_{2(i-1)}, \underline{B_{11}, B_{12}, \ldots, B_{1m}}, B_{2(i+1)} \ldots, B_{2n}$$

- For example:

$$\frac{\begin{array}{l} C \Leftarrow A,B \\ D \Leftarrow C \end{array}}{D \Leftarrow A,B}$$

Resolution Example

```
father(X,Y) :- parent(X,Y), male(X).
ancestor(X,Y) :- father(X,Y).
```

```
ancestor(X,Y) :- parent(X,Y), male(X).
```

`:-` is Prolog's notation (syntax) for $\Leftarrow$.

Unification

- During *resolution*, free variables acquire values through *unification* with expressions in matching terms.
- For example:

```
male(carlos).
parent(carlos, tatiana).
father(X,Y) :- parent(X,Y), male(X).
```

```
father(carlos, tatiana).
```

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*.

Backtracking

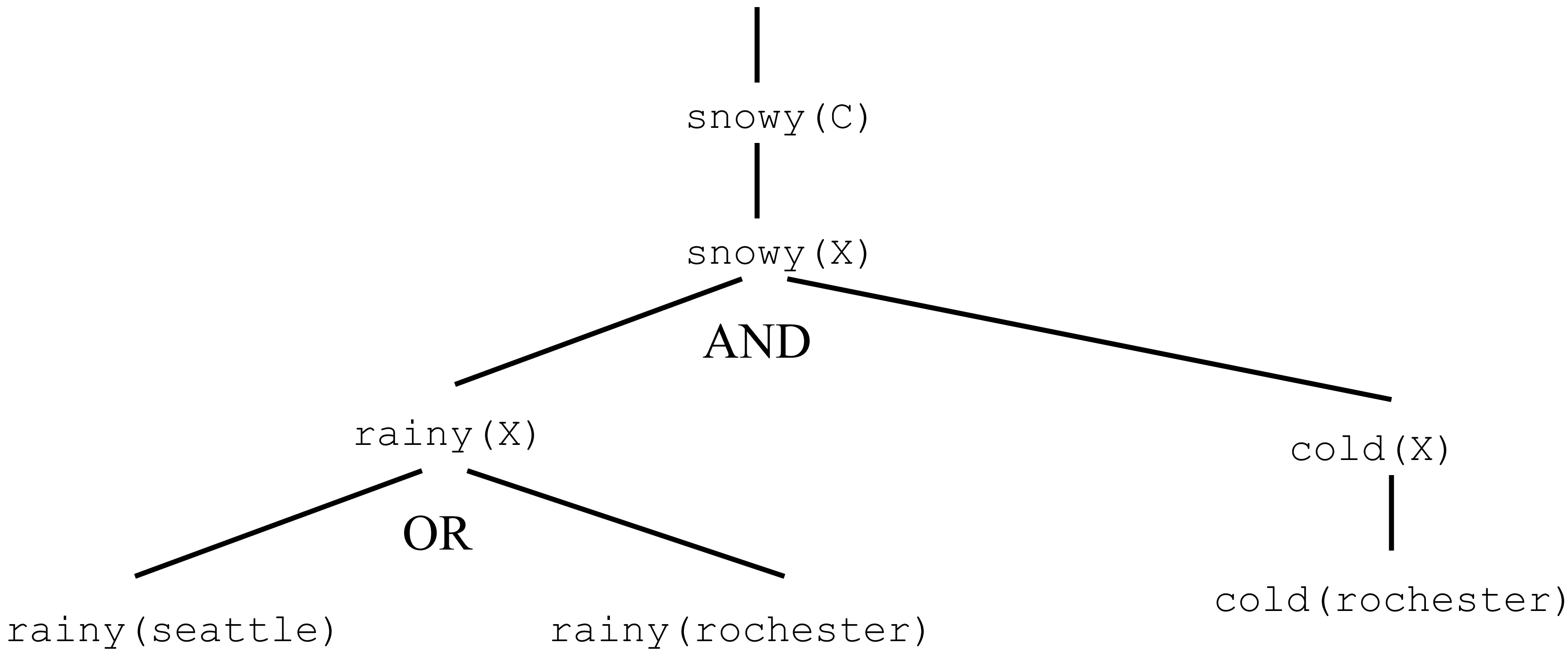
- *Forward chaining* goes from axioms forward into goals.
- *Backward chaining* starts from goals and works backwards to prove them with existing axioms.

Backtracking example

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

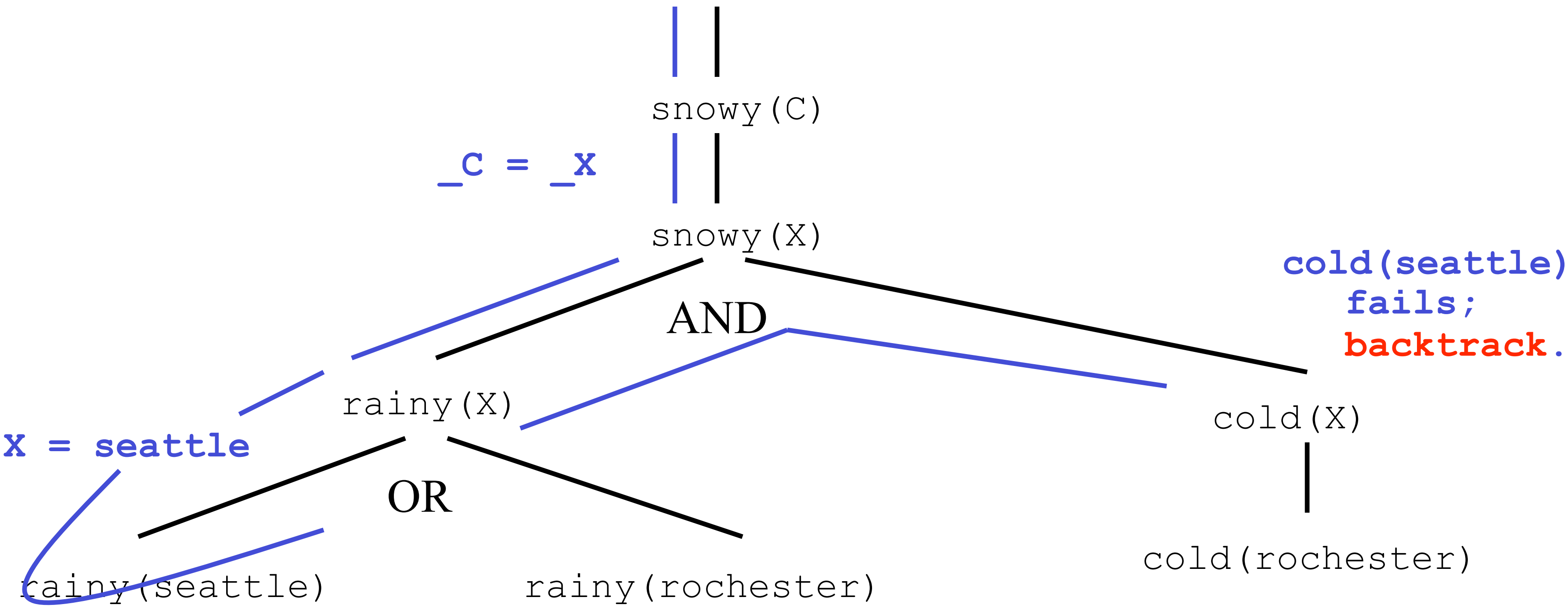
Backtracking example

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



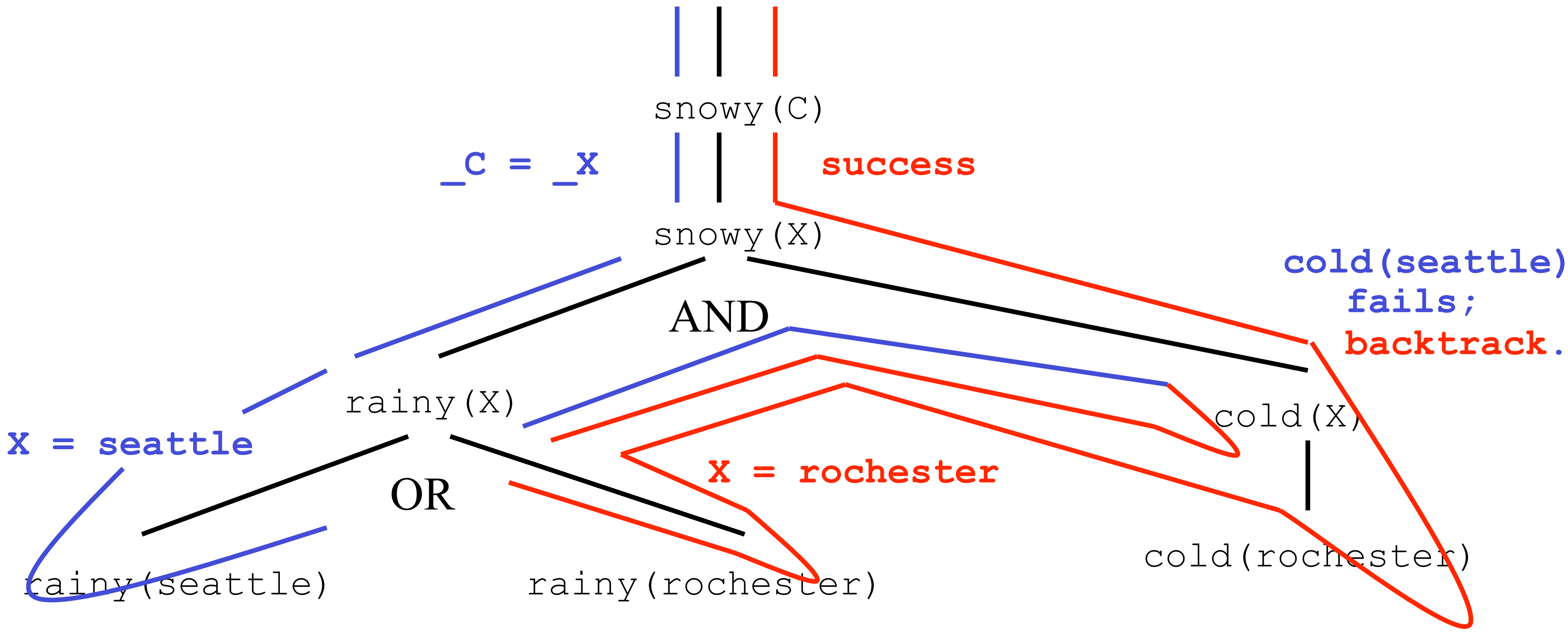
Backtracking example

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



Backtracking example

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



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.