CSC 372, Spring 2025

# Prolog Introduction

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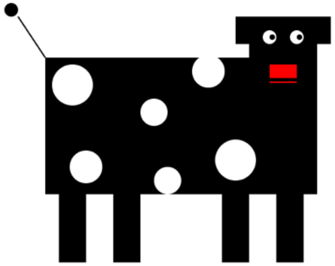
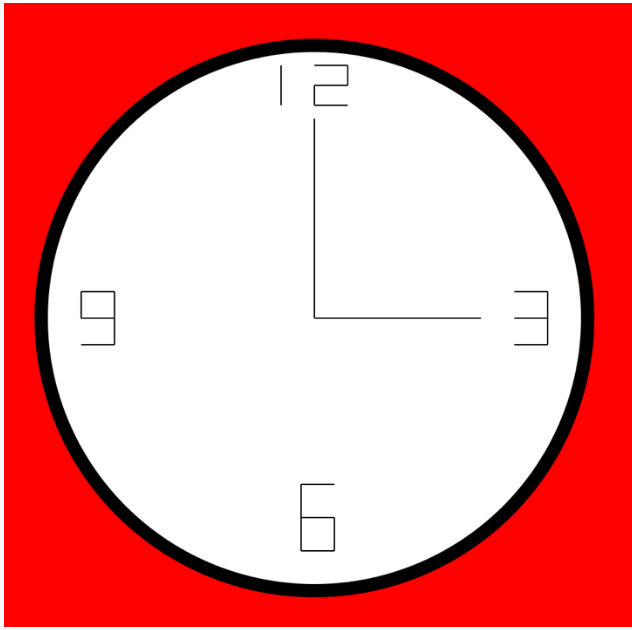
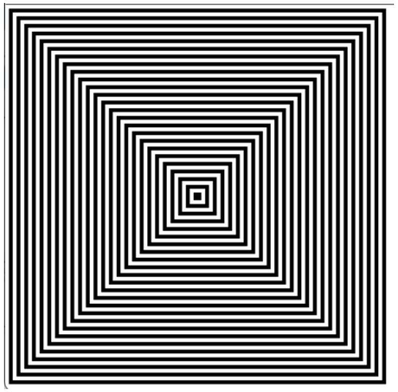
February 20, 2025

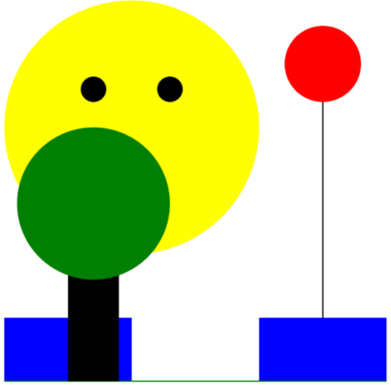
# Plan

- **Announcements**
  - SA4 MT1 Prolog is posted and due Wednesday Feb 26th
  - LA1 grades are out
- **Last time**
  - Midterm 1
- **Today**
  - Introduction to Prolog









# TopHat Questions

- Some questions about Prolog

# Outline for rest of today

- Motivation for Prolog
- Comparison of Prolog with other languages
- Hands on Prolog examples

*Credit for most of the following slides goes to Prof. Melanie Lotz*

# Motivation for Prolog

- **A Prolog program is**
  - a collection of facts and rules that can be used to answer queries.

- **Why developed?**
  - Natural language processing, for parsing sentences and reasoning about meaning.
  - AI in the 1970s and 1980s relied heavily on symbolic reasoning, expert systems, and rule-based decision-making, all of which required some form of logical inference.
  - Traditional procedural languages struggled with problems involving symbolic manipulation, logic inference, and rule-based reasoning.

- **Why did it become popular?**
  - In 1980s, Japan's Fifth Generation Computer Systems (FGCS) was built around logic programming (Prolog).
  - It was widely used in expert systems, NLP applications, and automated reasoning.

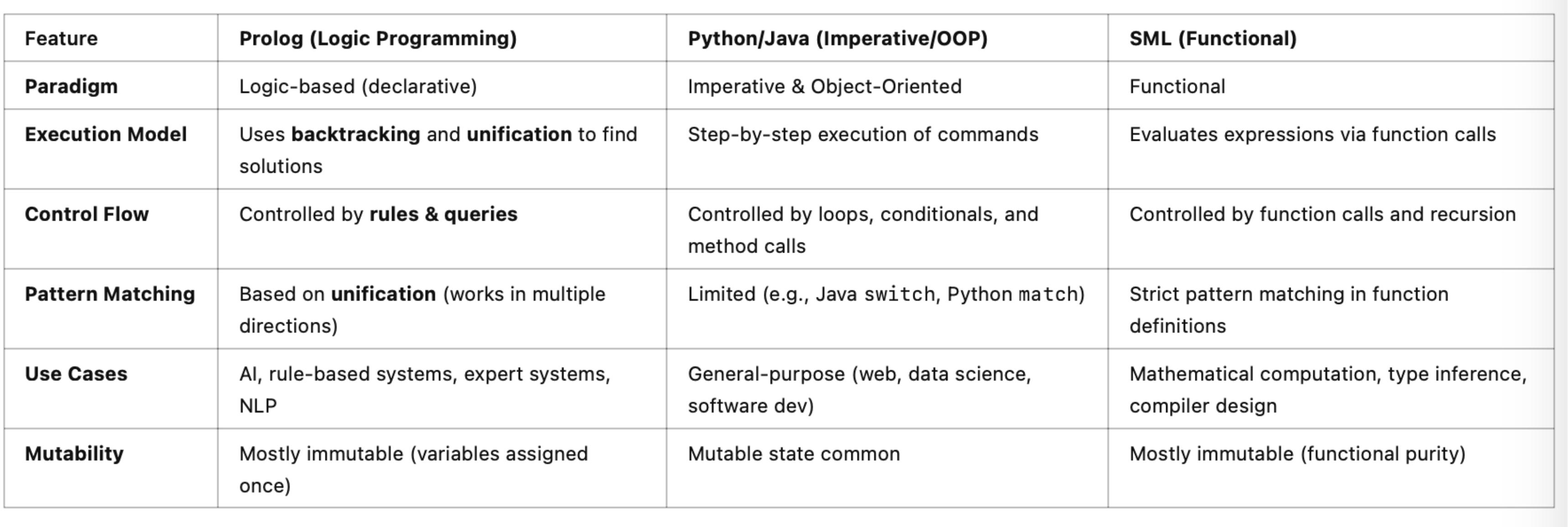
# Kinds of Applications Written in Prolog

- **Automated Reasoning**
  - Theorem Proving: Derives logical conclusions from axioms.
  - Type Inference: Infers types in functional programming.
  - Expert Systems: Supports decision-making (e.g., medical diagnosis).

- **Natural Language & Knowledge Representation**
  - Chatbots: Uses rule-based logic for conversations.
  - Parsing & Grammar Checking: Analyzes sentence structure.
  - Deductive Databases: Uses logic rules for query processing.

- **AI, Robotics, & Planning**
  - SAT Solver: Solves constraint satisfaction and optimization problems.
  - Sudoku Solver: Fills in grids using constraint logic.
  - Automated Planning: AI-driven task execution.
  - Constraint Solving: Optimizes pathfinding and scheduling.

# Comparison of Prolog with other PLs



| Feature | **Prolog (Logic Programming)** | **Python/Java (Imperative/OOP)** | **SML (Functional)** |
|---|---|---|---|
| **Paradigm** | Logic-based (declarative) | Imperative & Object-Oriented | Functional |
| **Execution Model** | Uses **backtracking** and **unification** to find solutions | Step-by-step execution of commands | Evaluates expressions via function calls |
| **Control Flow** | Controlled by **rules & queries** | Controlled by loops, conditionals, and method calls | Controlled by function calls and recursion |
| **Pattern Matching** | Based on **unification** (works in multiple directions) | Limited (e.g., Java `switch`, Python `match`) | Strict pattern matching in function definitions |
| **Use Cases** | AI, rule-based systems, expert systems, NLP | General-purpose (web, data science, software dev) | Mathematical computation, type inference, compiler design |
| **Mutability** | Mostly immutable (variables assigned once) | Mutable state common | Mostly immutable (functional purity) |

From ChatGPT 2/20/25

# Using Prolog

- Use the docker container from SA1

```
// start docker desktop

// start the container
docker run -it -v $(pwd):/workspace chapel_sml_prolog

devuser@d918ee370200:~$ cd /workspace

devuser@d918ee370200:/workspace$ swipl
…
For online help and background, visit https://www.swi-
prolog.org
For built-in help, use ?- help(Topic). or ?-
apropos(Word).


?-
```

# Prolog Basics

- Everything in Prolog is a term

- A term is
  - a constant,
  - a variable,
  - or a compound term.

- A compound term consists of
  - Functor – The name of the term, which must be an atom (a lowercase identifier or quoted string).
  - Arity – The number of arguments the term takes.
  - Arguments – The values or subterms inside the parentheses, which can be atoms, numbers, variables, or other compound terms.

# Prolog Basics

- A constant is
  - an integer (e.g., 123, -123),
  - a real number (e.g., 3.14, -3.14e-4),
  - or an atom
    - starts with a lowercase letter and has 0 or more letters, digits, or underscores after it
    - treated like a constant
    - examples: fred, ml, parent, *, =,

# Prolog Basics

- A variable starts with an uppercase letter or an underscore (the ones starting with _ get special treatment).
  - X
  - Child
  - _123

- A compound term has an atom followed by a list of terms.
  - x(y, z)
  - parent(adam, Child)

# Question on Prolog Basics

- In the compound terms below, identify each piece as one of the following
  - a constant integer
  - a constant atom
  - a variable
  - a functor/predicate name, which is an atom
  - arity

- Compound Terms
  - x(y, z)
  - parent(adam, Child)
  - likes(alice, hobby(reading))

- Prolog identifies terms by Functor/Arity, e.g., parent/2 or hobby/1.

# Prolog Unification

- Unification is pattern matching.

- Two terms unify if there is some way of binding their variables that makes them identical.
  - parent(adam, Child) and parent(adam, seth) unify by binding Child (a variable) to seth (an atom)
  - friend(alice, X) and friend(Y, bob) unify by binding X to bob and Y to alice.

# How Prolog Works

- The language system maintains a collection of facts and rules of inference, a kind of internal database that can change as the system runs.
- A Prolog program is a set of data for this database.
- The simplest item in the database is a fact, which is just a term followed by a period. (e.g. parent(adam, seth).)
- A rule tells the system how to prove something.
- A goal is a term to be proved.

# Example: Building a family tree

- Baggins family tree
  - https://tolkiengateway.net/wiki/Baggins_family

# Exercise

- Try the following queries:
  - 3 = 3.
  - 3 = 4.
  - X = 3.
  - 3 = 1 + 2.
  - X = 1 + 2.
  - 1 + 2 = 1 + 2.
  - 1 + 2 = 3 + 0.
  - X + 2 = 1 + 2.
  - X + 1 = 1 + 2.
  - 1 + 2 = X.
  - 1 + 2 = 3.

- What does = mean/do in Prolog?

# Exercise

- Try the following queries:
  - 3 is 3.
  - 3 is 4.
  - X is 3.
  - 3 is 1 + 2.
  - X is 1 + 2.
  - 1 + 2 is 1 + 2.
  - 1 + 2 is 3 + 0.
  - X + 2 is 1 + 2.
  - X + 1 is 1 + 2.
  - 1 + 2 is X.
  - 1 + 2 is 3.

- What does is mean/do in Prolog?

# Exercise

- Try the following queries:
  - 3 =:= 3.
  - 3 =:= 4.
  - X =:= 3.
  - 3 =:= 1 + 2.
  - X =:= 1 + 2.
  - 1 + 2 =:= 1 + 2.
  - 1 + 2 =:= 3 + 0.
  - X + 2 =:= 1 + 2.
  - X + 1 =:= 1 + 2.
  - 1 + 2 =:= X.
  - 1 + 2 =:= 3.

- What does =:= mean/do in Prolog?

# Terms that have infix notation

+

-

*

/

>

<

>=

=<

- Let’s use these in some examples

# Exercise

- Try out the following queries. Write down the results.
  - X = [1,2,3,4].
  - [X|Y] = [1,2,3,4].
  - [X,Y|Z] = [1,2,3,4].
  - [_,_,_|X] = [1,2,3,4].
  - [A,B,C,D|E] = [1,2,3,4].

- Explain what each of the following mean: [], |, _

# Exercise

- Predict the results of the following queries.
  - [A,B] = [1,2].
  - [A,B,C] = [1,2].
  - [A,B|C] = [1,2].
  - [_|A] = [1,2].