Declarative Languages

Databases

A table is a collection of records, which are tuples of values organized in columns. Databases store tables and have methods for adding, editing, and retrieving records. The Structured Query Language (SQL) is perhaps the most widely used programming language. SQL is an example of a declarative programming language.

Declarative Programming

Characteristics of declarative languages:

- A "program" is a description of the desired solution.
- The interpreter figures out how to generate such a solution.

In imperative languages such as Python & Scheme:

- A "program" is a description of computational processes.
- The interpreter carries out execution and evaluation rules.

Building a universal problem solver is hard. Declarative languages often handle only some subset of problems.

The Logic Language
The Logic Language

The logic language is invented for this course.
- Based on the Scheme project with ideas from Prolog (1972).
- Expressions are facts or queries, which contain relations.
- Expressions and relations are Scheme lists.
- For example, (likes john dogs) is a relation.
- Implementation fits on a single sheet of paper (next lecture).

Today's theme: Simple Facts

A simple fact expression in the Logic language declares a relation to be true.

Let's say I want to track the heredity of a pack of dogs.

Language Syntax:
- A relation is a Scheme list.
- A fact expression is a Scheme list of relations.

```
logic> (fact (parent delano herbert))
logic> (fact (parent abraham barack))
logic> (fact (parent abraham clinton))
logic> (fact (parent fillmore abraham))
logic> (fact (parent fillmore delano))
logic> (fact (parent fillmore grover))
logic> (fact (parent eisenhower fillmore))
```

Queries

A query contains one or more relations that may contain variables.

```
Queries

A variable can have any name

Eisenhower  Fillmore
  Abraham  Delano  Grover
  Barack  Clinton  Herbert

Each line is an assignment of variables to values
```

Compound Facts and Queries

Relations are Not Procedure Calls

In logic, a relation is not a call expression.
- Scheme: the expression (abs -3) calls abs on -3. It returns 3.
- Logic: (abs -3) asserts that abs of -3 is 3.

To assert that 1 + 2 = 3, we use a relation: (add 1 2 3)

We can ask the Logic interpreter to complete relations based on known facts.

```
(add ? 2 3)  1
(add 1 ? 3)  2
(add 1 2 ?)  3
( ? 1 2 3)  add
```

(Demo)
Compound Facts

A fact can include multiple relations and variables as well.

\[ \text{fact} \langle \text{conclusion} \rangle \langle \text{hypothesis} \rangle \langle \text{hypothesis} \rangle \ldots \langle \text{hypothesis} \rangle \]

Means \langle \text{conclusion} \rangle \text{ is true if all the } \langle \text{hypothesis} \rangle \text{'s are true.}

\[ \text{logic} \langle \text{fact} \rangle \langle \text{child} \rangle \langle \text{parent} \rangle \]

\[ \text{logic} \langle \text{query} \rangle \langle \text{child} \rangle \langle \text{parent} \rangle \]

\[ \text{Success!} \]

\[ \text{logic} \langle \text{query} \rangle \langle \text{child} \rangle \langle \text{parent} \rangle \]

\[ \text{Failure.} \]
Hierarchical Facts

Relations can contain relations in addition to symbols.

logic> (fact (dog (name abraham) (color white)))
logic> (fact (dog (name barack) (color tan)))
logic> (fact (dog (name clinton) (color white)))
logic> (fact (dog (name delano) (color white)))
logic> (fact (dog (name eisenhower) (color tan)))
logic> (fact (dog (name fillmore) (color gray)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color gray)))

Variables can refer to symbols or whole relations.

logic> (query (dog (name clinton) (color ?color)))
Success!
?color: white

logic> (query (dog (name clinton) ?stats))
Success!
?stats: (color white)

Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

logic> (query (dog (name ?x) (color ?fur))
          (ancestor ?y ?x)
          (dog (name ?y) (color ?fur)))
Success!

 x: barack  fur: tan  y: eisenhower
 x: clinton  fur: white  y: abraham
 x: grover  fur: tan  y: eisenhower
 x: herbert  fur: gray  y: fillmore