61A Lecture 33

Friday, November 16

Databases

A database is a collection of records (tuples) and an interface for adding, editing, and retrieving records.

The Structured Query Language (SQL) is perhaps the most widely used programming language on Earth.

```
SELECT * FROM toy_info WHERE color='yellow';
```

toy_id	toy	color	cost	weight
2	whiffleball	yellow	2.20	0.40
5	frisbee	yellow	1.50	0.20
10	yoyo	yellow	1.50	0.20

SQL is an example of a declarative programming language.

It separates *what* to compute from *how* it is computed.

The language interpreter is free to compute the result in any way it deems appropriate.

http://www.headfirstlabs.com/sql_hands_on/

Logical/Declarative Programming

The principal characteristics of declarative languages:

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

By contrast, in imperative languages such as Python & Scheme:

- A "program" is a description of procedures.
- The interpreter carries out execution/evaluation rules.

Building a universal problem solver is a difficult task.

Declarative programming languages compromise by solving only a subset of problems.

They typically trade off data scale for problem complexity.

The *Logic* Language

The *Logic* language is invented for this course.

- Based on the Scheme project + ideas from Prolog
- 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:

http://awhimsicalbohemian.typepad.com/.a/6a00e5538b84f3883301538dfa8f19970b-800wi

Simple Facts

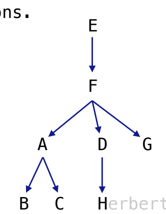
A simple fact expression in the *Logic* language declares a relation to be true.

Let's say I want to track my many dogs' ancestry.

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))
```



Relations are Not Procedure Calls

In *Logic*, a relation is not a call expression.

- In Scheme, we write (abs -3) to call abs on -3. It returns 3.
- In *Logic*, (abs -3 3) asserts that the abs of -3 is 3.

For example, if we wanted to assert that 1 + 2 = 3,

(add 1 2 3)

Why declare knowledge in this way? It will allow us to solve problems in two directions:

(add 1 2 _)

(add _ 2 3)

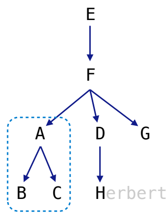
(add 1 _ 3)

Queries

A query contains one or more relations. The *Logic* interpreter returns whether (& how) they are all simultaneously satisfied.

Queries may contain variables: symbols starting with **?**

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

logic> (query (parent abraham ?child))
Success!
child: barack
child: clinton
```



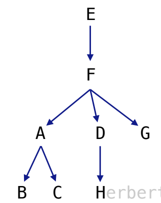
Compound Facts

A fact can include multiple relations and variables as well.

(fact <conclusion> <hypothesis$_0$> <hypothesis$_1$> ... <hypothesis$_N$>)

Means <conclusion> is true if all <hypothesis$_K$> are true.

```
logic> (fact (child ?c ?p) (parent ?p ?c))

logic> (query (child herbert delano))
Success!

logic> (query (child eisenhower clinton))
Failure.

logic> (query (child ?child fillmore))
Success!
child: abraham
child: delano
child: grover
```

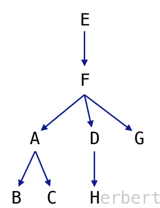


Recursive Facts

A fact is recursive if the same relation is mentioned in a hypothesis and the conclusion.

```
logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))
logic> (query (ancestor ?a herbert))
Success!
a: delano
a: fillmore
a: eisenhower

logic> (query (ancestor ?a barack)
              (ancestor ?a herbert))
Success!
a: fillmore
a: eisenhower
```

Demo



Searching to Satisfy Queries

The *Logic* interpreter performs a search in the space of relations for each query to find a satisfying assignment.

```
logic> (query (ancestor ?a herbert))
Success!
a: delano
a: fillmore
a: eisenhower

logic> (fact (parent delano herbert))
logic> (fact (parent fillmore delano))

logic> (fact (ancestor ?a ?y) (parent ?a ?y))
logic> (fact (ancestor ?a ?y) (parent ?a ?z) (ancestor ?z ?y))

(parent delano herbert)       ; (1), a simple fact
(ancestor delano herbert)     ; (2), from (1) and the 1st ancestor fact
(parent fillmore delano)      ; (3), a simple fact
(ancestor fillmore herbert)   ; (4), from (2), (3), & the 2nd ancestor fact
```

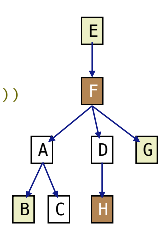

Hierarchical Facts

Relations can contain relations in addition to atoms.

```
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 brown)))
logic> (fact (dog (name grover) (color tan)))
logic> (fact (dog (name herbert) (color brown)))
```

Variables can refer to atoms or relations.

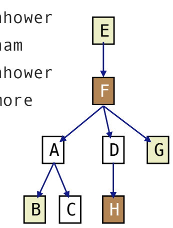
```
logic> (query (dog (name clinton) (color ?color)))
Success!
color: white

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



Example: Combining Multiple Data Sources

Which dogs have an ancestor of the same color?

```
logic> (query (dog (name ?name) (color ?color))
              (ancestor ?ancestor ?name)
              (dog (name ?ancestor) (color ?color)))
Success!
name: barack     color: tan      ancestor: eisenhower
name: clinton    color: white    ancestor: abraham
name: grover     color: tan      ancestor: eisenhower
name: herbert    color: brown    ancestor: fillmore
```



Example: Appending Lists

Two lists append to form a third list if:

- The first list is empty and the second and third are the same
- The rest of 1 and 2 append to form the rest of 3

```
logic> (fact (append-to-form () ?x ?x))

logic> (fact (append-to-form (?a . ?r) ?y (?a . ?z))
             (append-to-form ?r ?y ?z))
```

Demo