Lecture 37: Declarative Programming

Announcements:
- Autograder should start running this weekend.
- Remember: you still have to provide your own tests!
- We have updated files other than scheme.py a few times. I generally announce if the modification is important. You can use Unix `diff` to check for differences between what you have and the version in `~cs61a/lib/projects/scheme`.
- Submit your Project 4 contest entries as "proj4-contest" by next Wednesday. Assuming we get entries, we'll ask the class to judge these entries.

Imperative vs. Declarative

- So far, our programs are explicit directions for solving a problem; the problem itself is implicit in the program.
- **Declarative** programming turns this around:
  - A "program" is a description of the desired characteristics of a solution.
  - It is up to the system to figure out how to achieve these characteristics.
- Taken to the extreme, this is a very difficult problem in AI.
- However, people have come up with interesting compromises for small problems.
- For example, **constraint solvers** allow you to specify relationships between objects (like minimum or maximum distances) and then try to find configurations of those objects that meet the constraints.

Prolog and Predecessors

- Way back in 1959, researchers at CMU created GPS (General Problem Solver [A. Newell, J. C. Shaw, H. A. Simon])
  - Input defined objects and allowable operations on them, plus a description of the desired outcome.
  - Output consisted of a sequence of operations to bring the outcome about.
  - Only worked for small problems, unsurprisingly.
- **Planner** at MIT [C. Hewitt, 1969] was another programming language for theorem proving: one specified desired goal assertion, and system would find rules to apply to demonstrate the assertion. Again, this didn't scale all that well.
- Planner was one inspiration for the development of the logic-programming language Prolog.

Prolog (Lisp Style)

- Let's interpret Scheme expressions as **logical assertions**.
- For example, `(likes brian potstickers)` might be such an assertion: `likes` is a predicate that relates `brian` and `potstickers`.
- We don't interpret the arguments of the predicate: they are just uninterpreted data structures.
- We also allow one other type of expression: a symbol that starts with an underscore will indicate a logical variable.
- An assertion such as `(likes brian _X)` asserts that there is some replacement for `_X` that makes the assertion true.

Facts and Rules

- We will make **queries** in the form of assertions, possibly with logical variables.
- The system will look to see if the queries are true based on a database of facts (axioms or postulates) about the predicates.
- It will inform us of what replacements for logical variables make the assertion true.
- Each fact will have the form
  ```(fact Conclusion Hypothesis1 Hypothesis2 ...)`
  Meaning "For any substitution of logical variables in the Conclusion and Hypotheses, we may derive the conclusion if we can derive each of the hypotheses."

Example: Family Relations

First, some facts with no hypotheses:

```
(fact (parent george paul))
(fact (parent martin george))
(fact (parent martin martin_jr))
(fact (parent martin donald))
(fact (parent george ann))
```

Now some general rules about relations:

```
(fact (ancestor _X _Y))
(fact (ancestor _X _Y) (parent _X _Z) (ancestor _Z _Y))
```

From these, we ought to be able to conclude that Martin is an ancestor of Ann, for example.
Relations, Not Functions

• In this style of programming, we don't define functions, but rather relations.
• Instead of saying $\text{abs}(-3) \Rightarrow 3$, we say $\text{abs}(-3, 3)$ (that is, "3 stands in the abs relation to -3.”)
• Instead of $\text{add}(x, y) \Rightarrow z$, we say $\text{add}(x, y, z)$.
• This will allow us to run programs "both ways": from inputs to outputs, or from outputs to inputs.