LING 364: Introduction to Formal Semantics

Lecture 3

January 19th

Administrivia

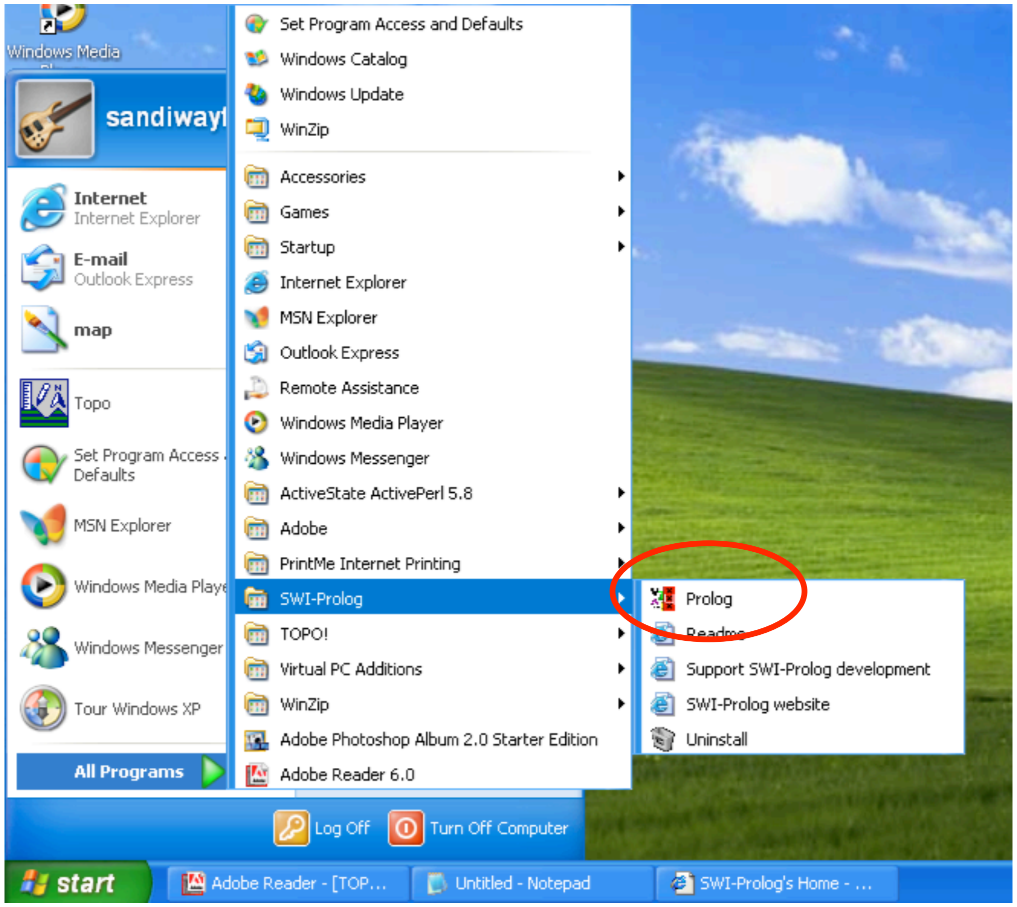
- **mailing list**
  - *ling364@listserv.arizona.edu*
  - *you should have received a welcome email*

Today’s Topic

- Getting familiar with SWI-Prolog
- Do exercises in class and as part of Homework 1

How to start

- Windows Start Menu



Introduction

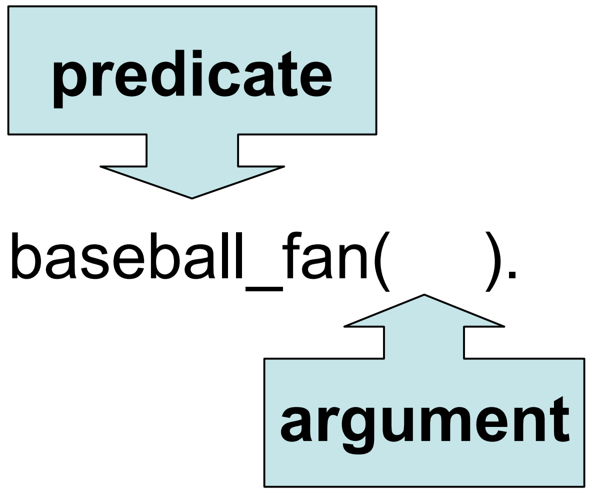
- Prolog is a logic programming language
  - allows you to express
    - facts
    - inference rules
  - can hold a database of these two things
    - the database represents a scenario or (possible) world
    - initially, the world is empty
    - you can add facts or inference rules to this database
  - finally, you can ask questions about this world
    - questions involving facts or facts inferred by inference rules

Facts

- Example:
  - Mary is a baseball fan.
  - Pete is a baseball fan.
  - John is a baseball fan.

Facts

- Example:
  - baseball_fan(mary).
  - baseball_fan(pete).
  - baseball_fan(john).



underscore: _
can be part of a word, use it to make predicates easier to read, cf. baseballfan

words begin with a lower case letter
e.g. mary not Mary
(variables begin with an initial upper case letter)

no space between predicate and (, and there is always a period at the end of a fact or rule

Facts

- How to add facts to the database (world):
  - ?- assert(<Fact>).
- Means:
  - assert <Fact> is true in this world
- Example:
  - ?- assert(baseball_fan(mary)).
  - *asserts* baseball_fan(mary) *is true in this world*

Don’t type in part of line shown in blue

Facts

- How to get a list of what’s in the world:
  - ?- listing.
- How to “*unadd*” or retract a fact from the database:

  <Fact>

  - ?- retract(   ).

Facts

- Asking questions:
  - ?- baseball_fan(mary).
  - **Yes**
  - ?- baseball_fan(jill).
  - **No**

- Assuming our world contains:
  - baseball_fan(mary).
  - baseball_fan(pete).
  - baseball_fan(john).

Prolog uses the **Closed World Assumption**
the world is defined by ?- listing.
i.e. if a fact isn’t in or inferable from the database,
it isn’t true in our world

Facts

- Questions with logical variables
  - Logic variables are words that begin with an upper case letter
    - e.g. X, Mary, MARY, M33 are all (distinct) variables
    - x, mARY, m33 are all individuals (non-variables)
  - Example:
    - ?- baseball_fan(X).
    - asks what is the value of X such that the proposition baseball_fan(X). is true in this world
    - X = mary ;
    - X = pete ;
    - X = john ;
    - No

semicolon ;
indicates disjunction (or)
used to ask Prolog for more answers

Facts

- Questions with logical variables
  - Example:
    - ?- baseball_fan(x).
    - No
    - asks if individual x is a baseball fan in this world
  - Example:
    - ?- baseball_fan(X), baseball_fan(Y).
    - X = mary, Y = mary ;
    - X = mary, Y = pete ;
    - .... a total of *9 possible answers*
  - Example:
    - ?- baseball_fan(X), baseball_fan(X).
    - *has only 3 possible answers*

comma ,
indicates conjunction (and)

variable scope
the scope of a variable is the entire query (or rule)
e.g. two X's must be the same X

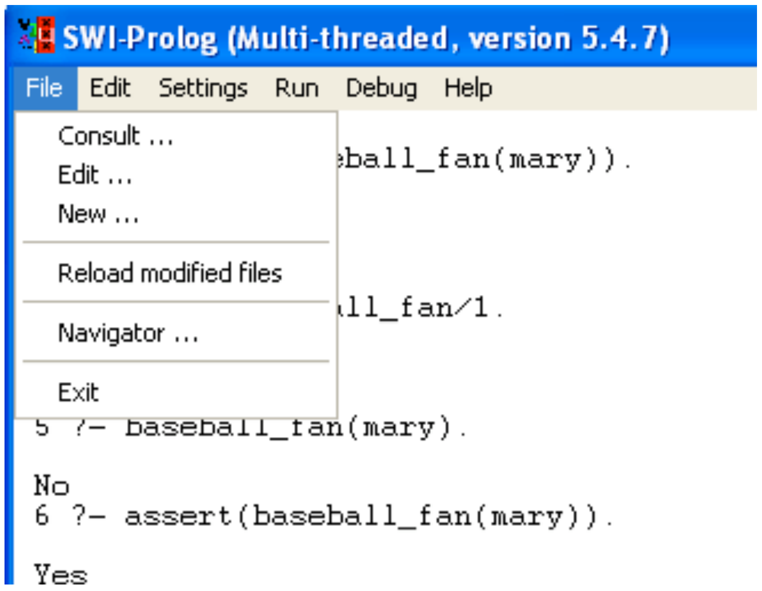
Facts

- Questions with logical variables
  - Example:
    - ?- baseball_fan(X), baseball_fan(Y), \+ X = Y.
    - asks for what value of X and for what value of Y such that baseball_fan(X). is true and baseball_fan(Y). is true in this world
    - and it is not (\+) the case that X = Y (equals)
    - How many answers should I get?

Prolog negation \+
a limited form of logical negation

Useful things to know...

- Data entry:
  - you can either enter facts at the Prolog prompt ?-
  - or edit your facts in a text file, give it a name, and load in or "consult" that file ?- [<filename>].



```
ball_fan(mary)).

ll_fan/1.

5 ?- baseball_fan(mary).

No
6 ?- assert(baseball_fan(mary)).

Yes
```

Useful things to know...

- The up arrow and down arrow keys can be used at the Prolog prompt to retrieve previous queries
  - you can edit them and resubmit
  - saves typing...

Useful things to know...

- **Getting stuck**?
  - Type <control>-C
  - Then type **a** (for abort)
  - gets you back to the Prolog interpreter prompt (`?-`)
- **how to see what the current working directory is?**
  - (the working directory is where your files are stored)
  - ***important****: every machine in the lab is different*
  - `?- working_directory(X,Y).`
    - `X`: current working directory, `Y`: new working directory
- **How to change to a new working directory?**
  - `?- working_directory(X,`***`NEW`***`).`

Homework 1

- Do the following exercises during this lab session and after class as your homework
  - Submit your answers by email
  - Submit all relevant output and databases
    - *you can copy and paste from the Prolog window*

- Homework Policy (Revisited):
  - due one week from today
  - in my inbox by midnight

Exercise 1a

(4pts)

- Enter Prolog facts corresponding to:
  - Mary is a student
  - Pete is a student
  - Mary is a baseball fan
  - Pete is a baseball fan
  - John is a baseball fan
- Construct the Prolog query corresponding to:
  - who is both a student and a baseball fan?
- Run the query

Exercise 1b

- (2pts)
- Construct the Prolog query corresponding to:
  - who is a baseball fan and not a student?
- Run the query

Relations as Facts

  - So far we have just been using predicates with a single argument
  - It is useful to have predicates with multiple arguments (separated by a comma) to express relations

- Example:
  - the square is bigger than the circle
  - bigger_than(square,circle).
- Queries:
  - ?- bigger_than(square,X).
  - ?- bigger_than(X,circle).

bigger_than/2 means predicate bigger_than takes two arguments

Rules

- We can write inference rules in Prolog and put them in the database
- Prolog will use them to make inferences when referenced
- Example (adapted from quiz 1):
  - Mary is sleeping
  - John is snoring
  - snoring presupposes sleeping

Rules

- English:
  - Mary is sleeping
  - John is snoring
  - (R1) snoring presupposes sleeping
- Prolog:
  - sleeping(mary).
  - snoring(john).
  - sleeping(X) :- snoring(X).
  - means X is sleeping if X is snoring

Prolog limitations:
head must contain only a single fact
body may contain facts connected by ; and , or negated \+

$$\overbrace{\mathbf{<Fact_1>}}^{\textbf{head}}\ \mathbf{:-}\ \overbrace{\mathbf{<Fact_2>}}^{\textbf{body}}\mathbf{.}$$

:- means “if”

Rules

- Prolog:
  - sleeping(mary).
  - snoring(john).
  - sleeping(X) :- snoring(X).
- Query:
  - ?- sleeping(john).

  - notice that there is no fact sleeping(john). in the database, so we cannot immediately conclude it is true.

- but we can use the inference rule for (R1) since the query matches the head of the rule
  - i.e. from:
    - ?- sleeping(john).
    - sleeping(X) :- snoring(X).
  - we can reduce the query to:
    - ?- snoring(john).
  - which matches
    - snoring(john).
  - in the database
- we can conclude then that sleeping(john). is true in this world

Exercise 2

- (4pts)
  - Two sentences are **synonymous** if they have the same meaning, i.e. they have the same truth conditions:
  - (5) The square is bigger than the circle
  - (6) The circle is smaller than the square
    - (chapter 1: page 18)
  - we know
  - (R2) If X is bigger than Y, then Y is smaller than X
- Write the Prolog fact and rule corresponding to (5) and (R2)
- Demonstrate you can conclude (6)

Exercise 3a

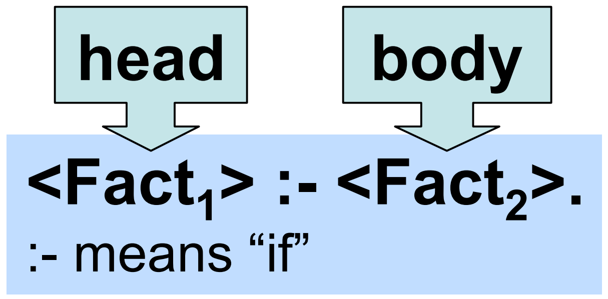
- (2pts)
  - Two sentences are **contrary** if both can’t be true:
  - (7) The square is bigger than the circle
  - (8) The square is smaller than the circle
    - (chapter 1: page 19)
- Enter the Prolog fact corresponding to (7) and use (R2) from exercise 2
- Construct the Prolog query corresponding to the conjunction of (7) and (8).
- Show the result of the query.

Exercise 3b

- (3pts)
  - Two sentences are **contrary** if both can't be true:
  - (7) The square is bigger than the circle
  - (8) The square is smaller than the circle
    - (chapter 1: page 19)
- Enter the Prolog fact corresponding to (8) and (R3)
  - (R3) If X is smaller than Y, then Y is bigger than X
- Construct the Prolog query corresponding to the conjunction of (7) and (8).
- Show the result of the query.

Negation and Prolog

- Prolog has some limitations with respect to \+ (negation). We have already mentioned this before:



<Fact$_1$> :- <Fact$_2$>.
:- means “if”

Prolog limitations:
head must contain only a single fact
body may contain facts connected by ; and , or negated \+

- Doesn’t allow:
  - \+ baseball_fan(lester).
  - \+ baseball_fan(X) :- never_heard_of_baseball(X).

Negation and Prolog

- Can’t have:
  - baseball_fan(mary).
  - \+ baseball_fan(john).
- 2nd fact is *by default* true given the Closed World Assumption with database:
  - baseball_fan(mary).

- Also can’t have:
  - baseball_fan(john).
  - \+ baseball_fan(john).

Negation and Prolog

- Also, technically:
  - football_fan(mary).

  is false given the same Closed World Assumption.
- Prolog assumes unknown predicate/arguments are errors
  - Well, actually, Prolog calls them "errors"
  - Example:
    - ?- a(X).
    - ERROR: Undefined procedure: a/1
- To change Prolog's behavior to the pure Closed World Assumption behavior for predicate a/1:
  - ?- dynamic a/1.

Exercise 4

(4pts) **Extra Credit**

- From Quiz 1:
  - 3. Given the statement “All crows are black”, give an example of a sentence expressing a tautology involving this statement?
- Possible answer:
  - All crows are black or not all crows are black
- Let Prolog predicate p/0 denote the proposition “All crows are black”
  - ?- assert(p). “*All crows are black is true in this world*”
- Construct the Prolog version of the tautology
- Show that it is true no matter what the scenario
- Construct a contradictory statement involving p
- Show that it is false not matter what the scenario

Homework Summary

- Homework 1
  - 15 points on offer
  - 4 points extra credit
  - (cf. Quiz 1: 3 pts)