CS 152: *Programming Language Paradigms*

Introduction to Prolog

Prof. Tom Austin
San José State University

Deduction

Propositions:

1. *Socrates is a man.*
2. *All men are mortal.*

Conclusion:

Socrates is mortal

About Prolog

- **Pro**gramming in **Log**ic
  - Logic: "The science of reasoning and proof"
- A *declarative* programming language
  - you specify what you want
  - the computer determines how to do it
- A *logical* programming language
  - Relies on deductive reasoning
  - Reach conclusion from premises

References for Prolog

- "Learn Prolog Now", http://www.learnprolognow.org
- SWI-Prolog website (contains manual and tutorials), http://www.swi-prolog.org
- "NLP with Prolog in the IBM Watson System", http://www.cs.nmsu.edu/ALP/2011/03/natural-language-processing-with-prolog-in-the-ibm-watson-system/

Facts

Socrates is a man. Helen is a woman.

In Prolog:

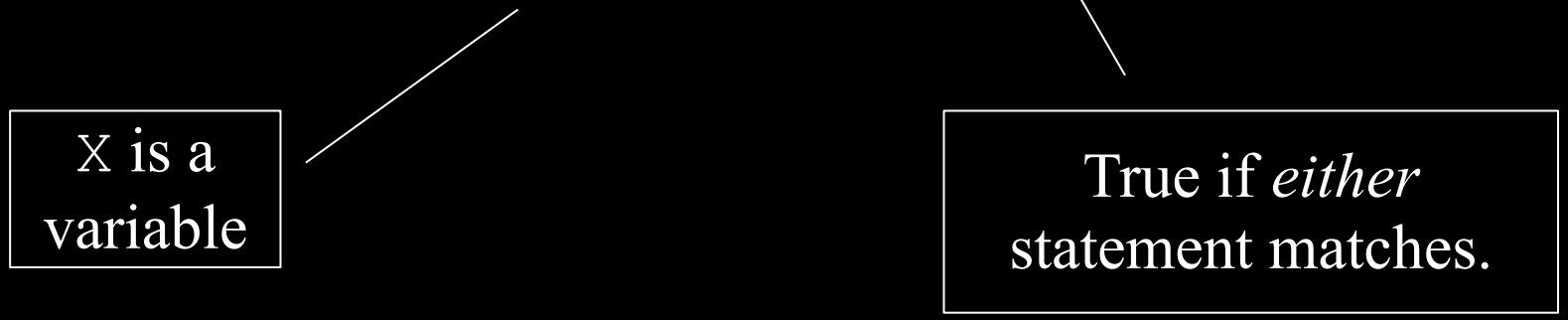
```
man(socrates).
woman(helen).
```

Rules

Man is mortal. Woman is mortal.

In Prolog:

```
mortal(X) :- man(X).
mortal(X) :- woman(X).
```



More facts and rules.

```
married(socrates).
married(helen).
husband(Person) :-
     married(Person),
     man(Person).
```

comma is "and"

Using `not`

```
immortal(zeus).
man(zeus).

mortal(X) :- man(X),
             not(immortal(X)).
```

Alternate syntax for `not`

```
immortal(zeus).
man(zeus).

mortal(X) :- man(X),
             \+immortal(X).
```

Socrates.prolog

Our *knowledge base*.

```
man(socrates).
man(zeus).
woman(helen).

immortal(zeus).

mortal(X) :- man(X), not(immortal(X)).
mortal(X) :- woman(X).

married(socrates).
married(helen).
husband(Person) :- married(Person),
                   man(Person).
```

Loading Prolog file

```
$ swipl
Welcome to SWI-Prolog
…
?-
```

Loading Prolog file

```
$ swipl
Welcome to SWI-Prolog
…
?- [socrates].
true.
?-
```

Query: Is Socrates Mortal?

```
$ swipl
Welcome to SWI-Prolog
…
?- [socrates].
true.
?- mortal(socrates).
true.
```

Query: Who is mortal?

```
?- mortal(Person).
Person = socrates ;
Person = helen.
```

Hit semicolon for more results, period to quit.

In class:

Game of Thrones in Prolog

```
king(robert).

wife(cersei,robert).

brother(jamie,cersei).
brother(jamie,tyrion).
brother(tyrion,jamie).

friend(robert,ned).
friend(robert,jon_arryn).
friend(tyrion,bronn).
friend(tyrion,jamie).

enemy(cersei, X) :- friend(robert,X).
enemy(cersei, X) :- friend(tyrion,X), X \= jamie.
enemy(jamie, X) :- enemy(cersei,X),
                   not(brother(jamie,X)).

queen(X) :- wife(X,Y), king(Y).
```

Valid rule

```
enemy(jamie, X) :-
   enemy(cersei,X),
   not(brother(jamie,X)).
```

Broken rule

```
enemy(jamie, X) :-
   not(brother(jamie,X)),
   enemy(cersei,X).
```

Broken rule

```
enemy(jamie, X) :-
   not(brother(jamie,X)),
   enemy(cersei,X).
```

`not` narrows results.
It cannot be used as the first subgoal.

Sample queries

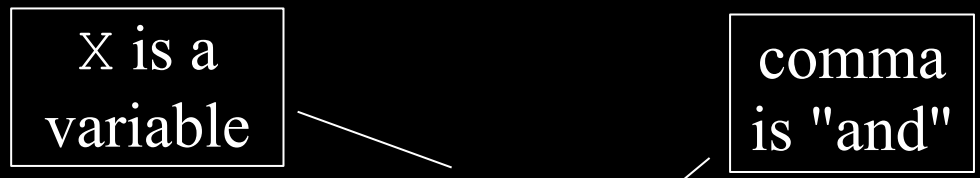
- `queen(X).`
- `enemy(cersei,X).`
- `friend(tyrion,ned).`
- `enemy(tyrion,ned).`
- `enemy(jamie,Y).`

Review: Facts

```
likes(batman, gotham).
likes(batman, justice).
likes(ras_al_ghul, justice).
likes(ras_al_ghul, revenge).
```

Review: Queries & Variables

What do Batman and Ra's al Ghul both like?




```
?- likes(batman,X),
 likes(ras_al_ghul,X).
```

How does Prolog resolve queries?

Through 2 processes:

- *Resolution*
- *Unification*

Resolution & Unification

- **Resolution**: The process of matching facts & rules to perform *inferencing*
  - infer: derive logical conclusions from the rules.
  - If a subgoal matches the head of another rule, we can replace it with the body of the matching rule.
- **Unification**: Instantiation of variables via pattern matching

Query:
```
likes(batman, X),
likes(ras_al_ghul, X).
```

Knowledge Base:

```
likes(batman, gotham).
likes(batman, justice).
likes(ras_al_ghul, justice).
likes(ras_al_ghul, revenge).
```

Query: **`likes(batman, X),`**
`likes(ras_al_ghul, X).`

Knowledge Base:

`likes(batman, gotham).`
`likes(batman, justice).`
`likes(ras_al_ghul, justice).`
`likes(ras_al_ghul, revenge).`

Finds match for first sub-query; sets a *marker*

Query: `likes(batman, gotham),`
`likes(ras_al_ghul, gotham).`

Knowledge Base:

`likes(batman, gotham).`
`likes(batman, justice).`
`likes(ras_al_ghul, justice).`
`likes(ras_al_ghul, revenge).`

X is bound to gotham

Query: `likes(batman, gotham),`
`likes(ras_al_ghul, gotham).`

No match found: fails and backtracks to marker

ase:

```
likes(batman, gotham).
likes(batman, justice).
likes(ras_al_ghul, justice).
likes(ras_al_ghul, revenge).
```

Query: `likes(batman, X),`
`likes(ras_al_ghul, X).`

Knowledge Base:

`likes(batman, gotham).`
`likes(batman, justice).`
`likes(ras_al_ghul, justice).`
`likes(ras_al_ghul, revenge).`

Finds another match for first sub-query

Query: `likes(batman, justice),`
`likes(ras_al_ghul, justice).`

Knowledge Base:

```
likes(batman, gotham).
likes(batman, justice).
likes(ras_al_ghul, justice).
likes(ras_al_ghul, revenge).
```

X is bound to justice

Query: likes(batman, justice),
likes(ras_al_ghul,
justice).

Knowledge Base:

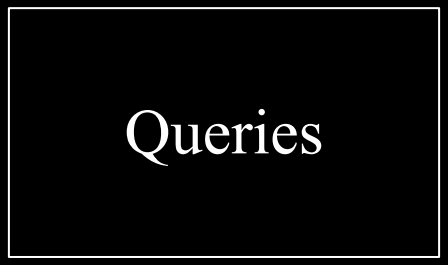
likes(batman, gotham).
likes(batman, justice).
likes(ras_al_ghul, justice).
likes(ras_al_ghul, revenge).

Match found, and the result is returned

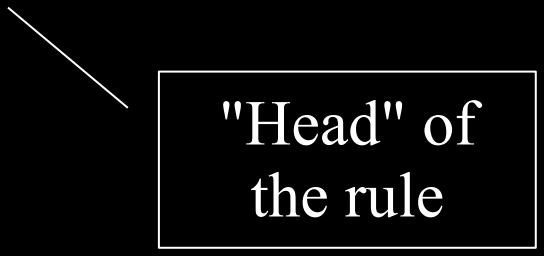
More facts:

```
villain(joker).
villain(penguin).
villain(catwoman).
villain(scarecrow).

kills_people(joker).
kills_people(penguin).
power(scarecrow, fear).

romantic_interest(catwoman).
romantic_interest(talia).
```

Rules




```
scary(V) :- villain(V),
            kills_people(V).
```




```
scary(V) :- villain(V),
            power(V,_).
```

Who is scary?
(in-class)

Murder Mystery Lab

See Canvas for details.