

Chapter 1: Introduction

"What" vs "How"

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Declarative vs Procedural Programming

Procedural programming

- The programmer has to specify how to get the output for the range of required inputs.
- The programmer must know the **appropriate** algorithm.

Declarative programming

- Requires a more **descriptive** style.
- The programmer must know **what** relationships hold between various entities.
- Prolog – the most popular logic programming language.
 - Used in Artificial Intelligence and Natural Language Processing.

Example: List Concatenation

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In procedural style:

```
list procedure cat(list a,list b)
{
    list t = list u = copylist(a);
    while (t.tail != nil) t = t.tail;
    t.tail = b;
    return u;
}
```

In declarative style:

```
cat([], L, L).
cat([H | T], L, [H | Z]) :- cat(T, L, Z).
```

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Basics of PROLOG

Facts

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Rules

PROLOG

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- Used to solve problems involving objects, and relationships between objects.
- Program can be thought of as a storehouse of facts and rules. *بناد*
- Conversational Language: The user can ask questions about the set of facts and rules in the PROLOG program.

Relationships

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Example

John owns the book

- The relationship: *ownership*
- The objects: *book, John*

Directional:

- John owns the book
- **Not:** The book owns John

PROLOG

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Sisters Example:

- A rule defining sisters and the facts about the people involved.
- The user would ask:
 - ▣ **Are these two people sisters?**
- The system would answer
 - ▣ **yes** (true) or **no** (false)

Programming in PROLOG

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`own(ahmed,book)`

- Declaring Facts about objects and their relationships.
- Defining Rules about objects and their relationships.
- Asking Questions about objects and their relationships.

`father(x,y):-parent(x,y),male(x)`

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Basics of PROLOG

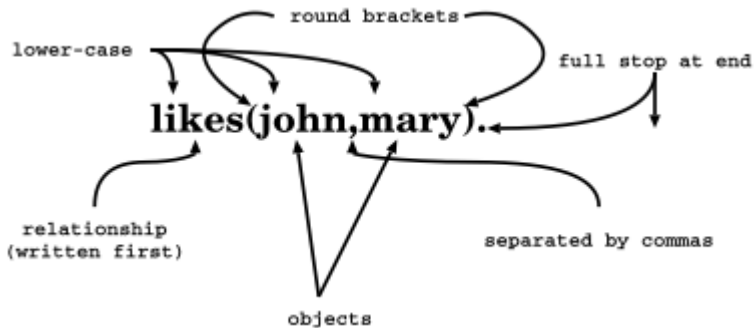
Facts

Questions

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Rules



$$\overset{\downarrow}{\text{mary}} \xrightarrow{\text{likes}} \overset{\downarrow}{\text{john}}$$

john . . . no info . . . ► mary

Examples of Facts

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Example

Gold is valuable.

valuable(gold)

Jane is a female.

female(jane)

John owns some gold.

owns(john,gold)

John is the father of Mary.

father(john,mary)

Are these expressions really facts? Is there anything missing?

Interpretation of Names

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The name refers to an object.

- **Semantic Meaning:** Given by the programmer.
- **Syntactic Meaning:** a set of characters, as PROLOG sees it.

تفسير Interpretation of Names

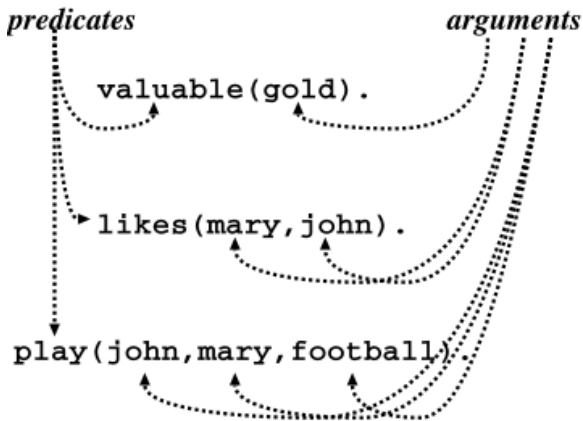


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- Name refers to an object.
- Name gold can refer to:
 - a particular lump of gold, or كاد ندى
 - the chemical element Gold having atomic number .79
- valuable(gold) can mean:
 - that particular lump of gold, named gold, is valuable, or
 - the chemical element Gold, named gold, is valuable.
- The programmer decides (in his/her usage) the meaning.

Fact Terminology

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Database

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Definition

In PROLOG, **database** is a collection of **facts**.

- PROLOG draws its knowledge from these facts.
- The programmer is responsible for their accuracy.

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Questions

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- The database contains the facts from which the questions are answered.
- A Question can look exactly like a fact:
 - `owns(mary,book).`
- The difference is in which mode one is in

Questions

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- In the interactive question mode (indicated by the question mark and dash): ? -

- Question: ? - owns(mary,book).

 - Meaning: If mary is interpreted as a person called Mary, and book is interpreted as some particular book, then

- ?- owns(mary,book).

 - means: Does Mary own the book?

Database Search

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Example

Facts in the database:

likes(joe,fish).

likes(joe,mary).

likes(mary,book).

likes(john,book).

Questions:

?- likes(joe,money). no

?- likes(joe,mary). yes

?- king(john,france).no

Knowledge

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The questions are always answered with respect to the database.

Example

Facts in the database:

`human(socrates).`

`human(aristotle).`

`athenian(socrates).`

Question:

Is Socrates Greek?

?- `greek(socrates)`

The answer with respect to this database is **No**.

Questions

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Up until now questions just reflect exactly the database.

Does Mary like the book?
?- likes(mary,book).

More Interesting Question: What
objects does Mary like?

Variables.

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Question With Variables

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What does John like?

?- likes(john,X).

or

?- likes(john,SomethingThatJohnLikes).

X and SomethingThatJohnLikes are variables.

Variable begins with a capital letter.

PROLOG Answer

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Database:

likes(john,flowers).

Question:

?- likes(john,X).

PROLOG answers:

X=flowers

Many Answers

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Database:

likes(john,flowers).

likes(john,mary).

likes(paul,mary).

Question:

?-likes(john,X).

PROLOG answers:

X=flowers

and the user acknowledges

X=mary

and the user acknowledges

no

Placemaker

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- The first match is found: $X = \text{flowers}$.
- The user acknowledges.
 - ▣ From that place on the next match is found (the search continues).
 - ▣ From the place of the last instantiation no more match was found.
 - ▣ Thus answer: no.

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More Complicated Relationships:

Does Mary like John and does John like Mary?

Both Conditions must be fulfilled.

Conjunctions

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Database:

likes(mary,food).

likes(mary,cola).

likes(john,cola).

likes(john,mary).

Comma means Conjunction:

?- likes(john,mary), likes(mary,john).

Answer: no

A match for likes(john,mary)

but none for likes(mary,john)

Conjunctions with Variables

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Is there anything that both mary and john like?

Find out what Mary likes and then see if John likes it.

?- likes(mary,X), likes(john,X).

PROLOG answers:

X=cola

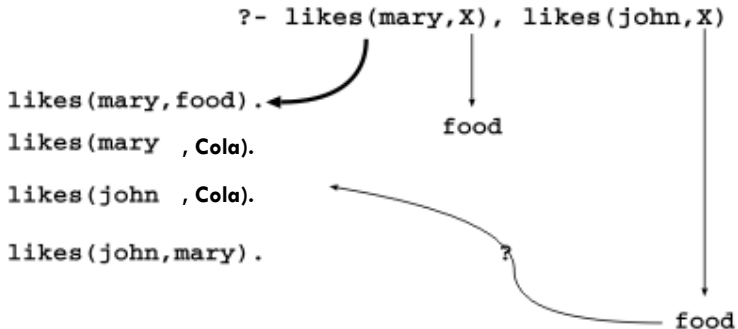
Backtracking

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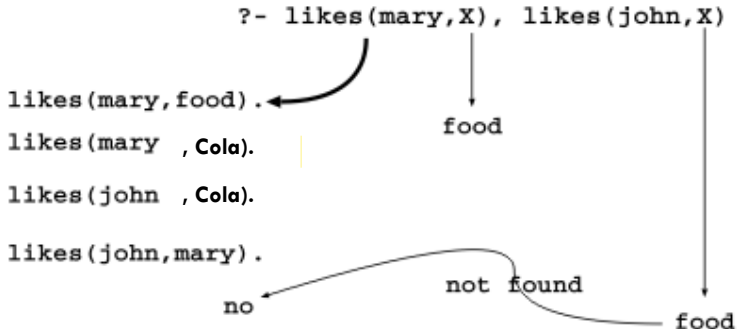
- Find match for the first goal.
- Then see if matches the second.
- If not, find another match for the first.
- See if this matches the second.
- ...etc.

Match First

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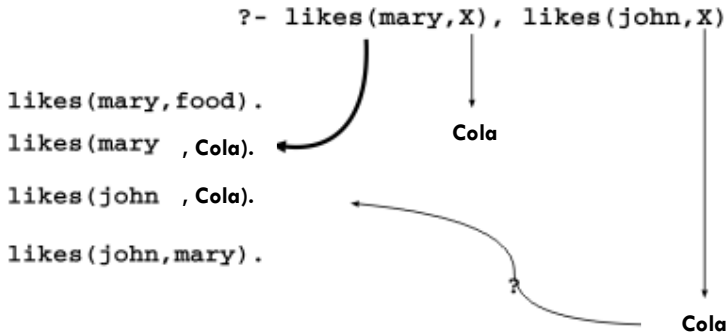


Match Second



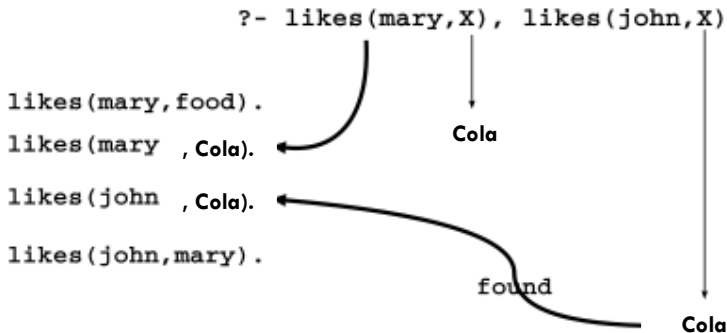
Backtrack

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Success

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Rules

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- How to express that John likes all people?
- Listing all people?
 - likes(john, alfred).
 - likes(john, bertrand).
 - likes(john, charles).
 - likes(john, david).
 - etc.
- Not feasible. More compact way: Using **rules**.
John likes any object provided(if) it is a person.

Rule Examples

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- Rules state Dependence:

I use an umbrella **if** there is rain.

- Rules Define:

X is a bird **if** X is an animal and X has feathers.

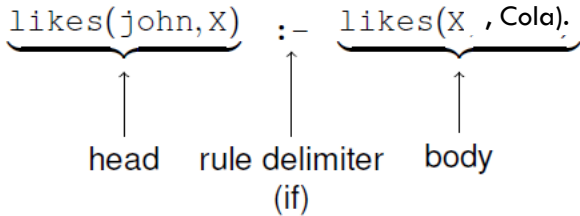
Formulating Rules

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- John likes anyone who likes cola.
- John likes any Something if it likes cola
- John likes X if X likes cola

Rule Syntax

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Variable Scope

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The occurrences of X within a rule refer to the same object:

```
likes(john,X):- likes(X ,cola),likes(X,food).
```

```
likes(john,mary):-
```

```
likes(mary,cola),likes(mary,food).
```

```
likes(john,adam):- likes(adam, cola),likes(adam,  
food).
```

Royal Parents

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Example

The parents of X are Y and Z.

Y is the mother.

Z is the father.

Database:

`male(albert).`

`male(edward).`

`female(alice).`

`female(victoria).`

`parents(edward,victoria,albert).`

`parents(alice,victoria,albert).`

Sisters

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Example

X is a sister of Y if:

- X is female,

- X has parents M and F,

- Y has parents M and F.

Rule:

```
sister(X,Y):-female(X),  
               parents(X,M,F),  
               parents(Y,M,F).
```

Sisters Question

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```
sister(X,Y):-female(X),  
              parents(X,M,F),  
              parents(Y,M,F)
```

Question:

?- sister(alice,edward).

The question (goal) matches the head of the rule, if one replaces *X* with *alice* and *Y* with *edward*.

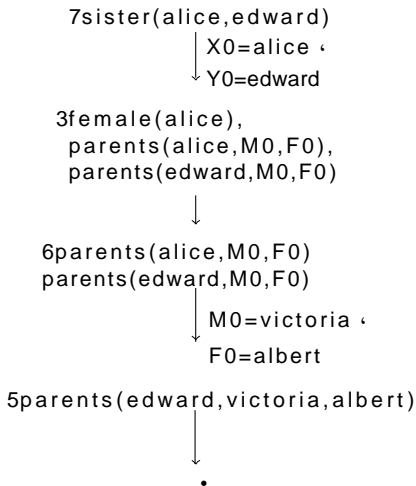
The instance of the body becomes new goal:

```
female(alice), parents(alice,M,F),  
parents(edward,M,F).
```

Is Alice Edward's Sister?

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- (1) male(albert).
- (2) male(edward).
- (3) female(alice).
- (4) female(victoria).
- (5) parents(edward,
victoria, albert).
- (6) parents(alice,
victoria,albert).
- (7) sister(X,Y):-
female(X),
parents(X,M,F),
parents(Y,M,F).



Who's Sister Is Alice?

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- (1) male(albert).
- (2) male(edward).
- (3) female(alice).
- (4) female(victoria).
- (5) parents(edward,
victoria, albert).
- (6) parents(alice,
victoria, albert).
- (7) sister(X,Y):-
female(X),
parents(X,M,F),
parents(Y,M,F).

```
7sister(alice,X)
  | X0=alice,
  | Y0=X
  |
3female(alice),
  parents(alice,M0,F0),
  parents(X,M0,F0).
  |
6parents(alice,M0,F0),
  parents(X,M0,F0).
  |
  M0=victoria
  F0=albert
5parents(X,victoria,albert)
  |
  X=edward
  .
```

Answer: X = edward.