# *Logic Programming*

## *Using Data Structures*

## *Part 1*

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# Contents

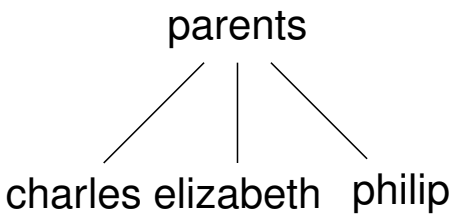
# Representing Structures as Trees

Structures can be represented as trees:

- Each functor — a node.
- Each component — a branch.

## Example

parents(charles, elizabeth, philip).



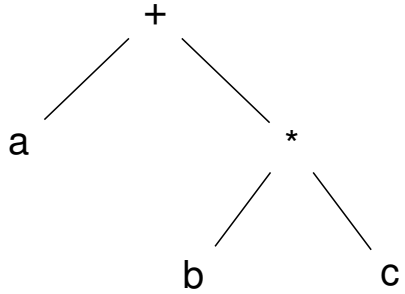



# Representing Structures as Trees

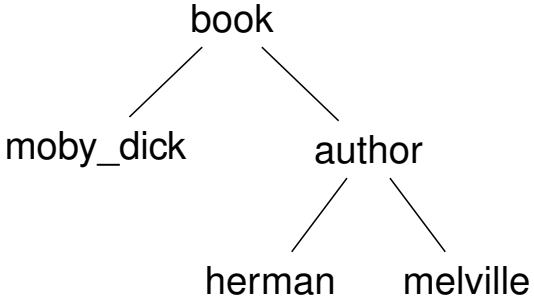
Branch may point to another structure: nested structures.

## Example

a+b*c.




book(moby_dick, author(herman, melville)).



# Parsing

Represent a syntax of an English sentence as a structure.

Simplified view:

- Sentence: noun, verb phrase.
- Verb phrase: verb, noun.

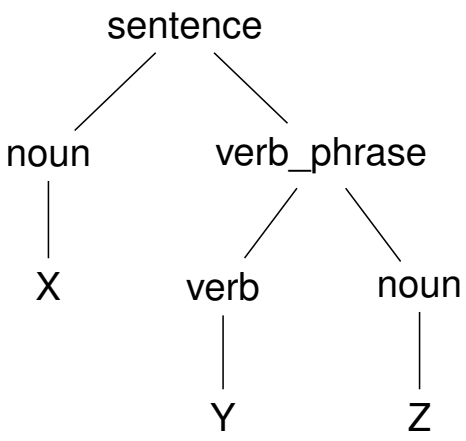


# Parsing

Structure:

sentence(noun(X), verb_phrase(verb(Y), noun(Z))).

Tree representation:

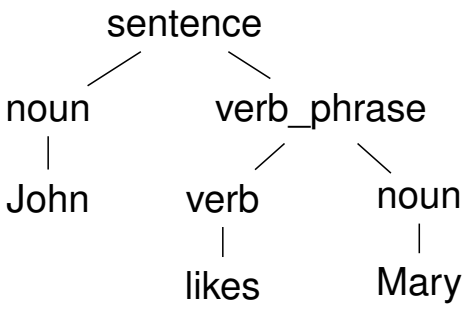


# Parsing

## Example

John likes Mary.

sentence(noun(John), verb_phrase(verb(likes), noun(Mary))).






# Lists

Very common data structure in nonnumeric programming.

Ordered sequence of elements that can have any length.

- Ordered: the order of elements in the sequence matters.
- Elements: any terms — constants, variables, structures — including other lists.

Can represent practically any kind of structure used in symbolic computation.

The only data structures in LISP — lists and constants. In

PROLOG — just one particular data structure.

# Lists

A list in PROLOG is either

- the empty list $[\,]$, or
- a structure $.(h, t)$ where $h$ is any term and $t$ is a list.
  $h$ is called the head and $t$ is called the tail of the list $.(h, t)$.

## Example

- $[]$.
- $.(a, [])$.
- $.(a, .(b, []))$.
- $.(a, .(a, .(1, [])))$.
- $.(.(f(a, X), []), .(X, []))$.
- $.([], [])$.

NB. $.(a, b)$ is a PROLOG term, but not a list!

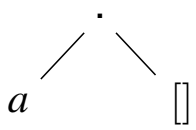


# Lists as Trees

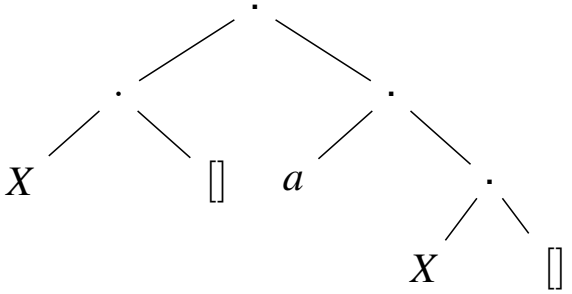
Lists can be represented as a special kind of tree.

## Example

$.(a, [])$




$.(.(X, []), .(a, .(X, [])))$



# List Notation

Syntactic sugar:

- Elements separated by comma.
- Whole list enclosed in square brackets.

## Example

| | |
|---|---|
| $.(a, [])$ | $[a]$ |
| $.(.(X, []), .(a, .(X, [])))$ | $[[X], a, X]$ |
| $.([], [])$ | $[[]]$ |



# List Manipulation

Splitting a list $L$ into head and tail:

- Head of $L$ — the first element of $L$.
- Tail of $L$ — the list that consists of all elements of $L$ except the first.

Special notation for splitting lists into head and tail:

- $[X|Y]$, where $X$ is head and $Y$ is the tail.

NB. $[a|b]$ is a PROLOG term that corresponds to $.(a, b)$.

It is not a list!

# Head and Tail

## Example

| List | Head | Tail |
|---|---|---|
| $[a, b, c, d]$ | $a$ | $[b, c, d]$ |
| $[a]$ | $a$ | $[]$ |
| $[]$ | (none) | (none) |
| $[[the, cat], sat]$ | $[the, cat]$ | $[sat]$ |
| $[X + Y, x + y]$ | $X + Y$ | $[x + y]$ |



# Unifying Lists

| | | | |
|---|---|---|---|
| $[X, Y, Z]$ | $=$ | $[john, likes, fish]$ | $X = john$, $Y = likes$, $Z = fish$ |
| $[cat]$ | $=$ | $[X\|Y]$ | $X = cat$, $Y = []$ |
| $[X, Y\|Z]$ | $=$ | $[mary, likes, wine]$ | $X = mary$, $Y = likes$, $Z = [wine]$ |
| $[[the, Y], Z]$ | $=$ | $[[X, hare], [is, here]]$ | $X = the$, $Y = hare$, $Z = [is, here]$ |
| $[[the, Y]\|Z]$ | $=$ | $[[X, hare], [is, here]]$ | $X = the$, $Y = hare$, $Z = [[is, here]]$ |
| $[golden\|T]$ | $=$ | $[golden, norfolk]$ | $T = [norfolk]$ |
| $[vale, horse]$ | $=$ | $[horse, X]$ | (none) |
| $[white\|Q]$ | $=$ | $[P\|horse]$ | $P = white$, $Q = horse$ |

## Strings are Lists

PROLOG strings — character string enclosed in double quotes.

Examples: “This is a string”, “abc”, “123”, etc.

Represented as lists of integers that represent the characters (ASCII codes).

For instance, the string “system” is represented as $[115, 121, 115, 116, 101, 109]$.



## Membership in a List

`member(X,Y)` is true when X is a member of the list Y.

One of two conditions:

1. X is a member of the list if X is the same as the head of the list

```
member(X,[X|_]).
```

2. X is a member of the list if X is a member of the tail of the list

```
member(X,[_|Y]) :- member(X,Y).
```

# Recursion

The first condition is the *boundary condition*.

(A hidden boundary condition is when the list is the empty list, which fails.)

The second condition is the *recursive case*.

In each recursion the list that is being checked is getting smaller until the predicate is satisfied or the empty list is reached.



# Member Success

Step-by-step, using `trace`.

```
?- member(a, [a,b,c]).
Call: (8) member(a,[a,b,c]) ?
Exit: (8) member(a,[a,b,c]) ?
true

?- member(b, [a,b,c]).
Call: (8) member(b,[a,b,c]) ?
Call: (9) member(b,[b,c]) ?
Exit: (9) member(b,[b,c]) ?
Exit: (8) member(b,[a,b,c]) ?
true
```

# Member Failure

Step-by-step, using `trace`.

```
?- member(d,[a,b,c]).
Call: (8) member(d,[a,b,c]) ?
Call: (9) member(d,[b,c]) ?
Call: (10) member(d,[c]) ?
Call: (11) member(d,[]) ?
Fail: (11) member(d,[]) ?
Fail: (10) member(d,[c]) ?
Fail: (9) member(b,[b,c]) ?
Fail: (8) member(b,[a,b,c]) ?
false
```



# Member. Questions

What happens if you ask PROLOG the following questions:

```
?- member(X, [a,b,c]).
?- member(a, X).
?- member(X, Y).
?- member(X, _).
?- member(_, Y).
?- member(_, _).
```

# Recursion. Termination Problems

Avoid circular definitions. The following program will loop on any goal involving `parent` or `child`:

```
parent(X, Y) :- child(Y, X).
child(X, Y) :- parent(Y, X).
```

Use left recursion carefully. The following program will loop on `?- person(X)`:

```
person(X) :- person(Y), mother(X, Y).
person(adam).
```



# Recursion. Termination Problems

Rule order matters.

General heuristics: Put facts before rules whenever possible.

Sometimes putting rules in a certain order works fine for goals of one form but not if goals of another form are generated:

```
islist([_|B]) :- islist(B).
islist([]).
```

works for goals like `islist([1,2,3])`, `islist([])`, `islist(f(1,2))` but loops for `islist(X)`.

What will happen if you change the order of `islist` clauses?

# Weaker Version of `islist`

Weak version of `islist`.

```
weak_islist([]).
weak_islist([_|_]).
```

Can it loop?

Does it always give the correct answer?



# Mapping?

Map a given structure to another structure given a set of rules:

1. Traverse the old structure component by component
2. Construct the new structure with transformed components.

# Mapping a Sentence to Another

## Example

you are a computer maps to a reply i am not a computer.
do you speak french maps to a reply no i speak german.

Procedure:

1. Accept a sentence.
2. Change you to i.
3. Change are to am not.
4. Change french to german.
5. Change do to no.
6. Leave the other words unchanged.



# Mapping a Sentence. PROLOG Program

## Example

```
change(you, i).
change(are, [am,not]).
change(french, german).
change(do, no).
change(X, X).

alter([], []).
alter([H|T], [X|Y]) :-
change(H, X),
alter(T, Y).
```

# Boundary Conditions

Termination:

```
alter([],[]).
```

Catch all (If none of the other conditions were satisfied, then just return the same):

```
change(X,X).
```