

Logic Programming
Using Data Structures
Part 1

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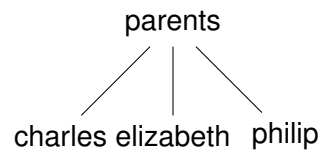
Representing Structures as Trees

Structures can be represented as trees:

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

Example

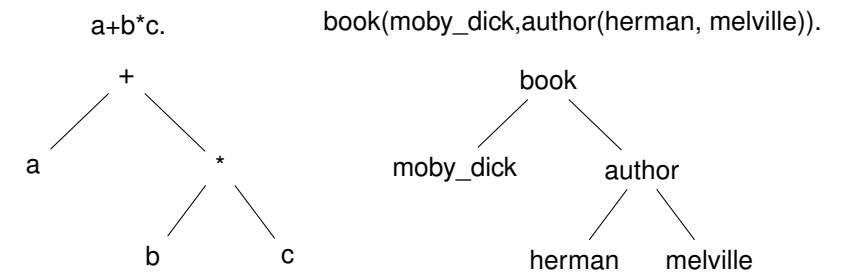
parents(charles,elizabeth,philip).



Representing Structures as Trees

Branch may point to another structure: nested structures.

Example



Parsing

Represent a syntax of an English sentence as a structure.

Simplified view:

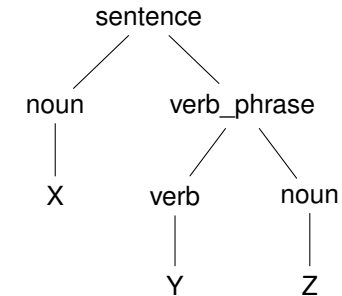
- ▶ Sentence: noun, verb phrase.
- ▶ Verb phrase: verb, noun.

Parsing

Structure:

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

Tree representation:

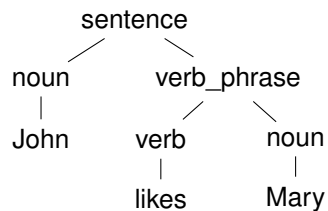


Parsing

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

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

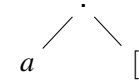
NB. $.(a, b)$ is a PROLOG term, but not a list!

Lists as Trees

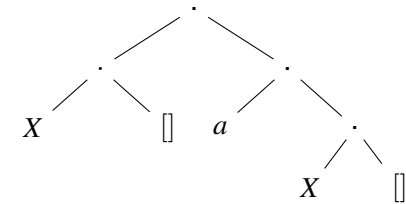
Lists can be represented as a special kind of tree.

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

Example

$[X, Y, Z]$	$=$	$[john, likes, fish]$	$X = john, Y = likes,$ $Z = fish$
$[cat]$	$=$	$[X Y]$	$X = cat, Y = []$
$[X, Y Z]$	$=$	$[mary, likes, wine]$	$X = mary, Y = likes,$ $Z = [wine]$
$[[the, Y], Z]$	$=$	$[[X, hare], [is, here]]$	$X = the, Y = hare,$ $Z = [is, here]$
$[[the, Y] Z]$	$=$	$[[X, hare], [is, here]]$	$X = the, Y = hare,$ $Z = [[is, here]]$
$[golden T]$	$=$	$[golden, norfolk]$	$T = [norfolk]$
$[vale, horse]$	$=$	$[horse, X]$	(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

$\text{member}(X, [X|_])$.

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

$\text{member}(X, [_|Y]) :- \text{member}(X, Y)$.

Recursion

- ▶ First Condition is the *boundary condition*.
(A hidden boundary condition is when the list is the empty list, which fails.)
- ▶ 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

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

Member Failure

```
?- 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]) ?  
No
```

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) .`