Lecture 4: Lists

- Theory
  - Introduce lists, an important recursive data structure often used in Prolog programming
  - Define the **member/2** predicate, a fundamental Prolog tool for manipulating lists
  - Illustrate the idea of recursing down lists

Lecture 4: Lists

- Exercises
  - Exercises of LPN chapter 4
  - Practical work

Lists

- A list is a finite sequence of elements
- Examples of lists in Prolog:

```
[mia, vincent, jules, yolanda]
[mia, robber(honeybunny), X, 2, mia]
[ ]
[mia, [vincent, jules], [butch, friend(butch)]]
[[ ], dead(z), [2, [b,c]], [ ], Z, [2, [b,c]]]
```

Important things about lists

- List elements are enclosed in square brackets
- The length of a list is the number of elements it has
- All sorts of Prolog terms can be elements of a list
- There is a special list:
  the empty list   [ ]

Head and Tail

- A non-empty list can be thought of as consisting of two parts
  - The head
  - The tail
- The head is the first item in the list
- The tail is everything else
  - The tail is the list that remains when we take the first element away
  - <u>The tail of a list is always a list</u>

Head and Tail example 1

- [mia, vincent, jules, yolanda]

  Head:
  Tail:

Head and Tail example 1

- [mia, vincent, jules, yolanda]

  Head: mia
  Tail:

Head and Tail example 1

- [mia, vincent, jules, yolanda]

  Head: mia
  Tail: [vincent, jules, yolanda]

Head and Tail example 2

- [[ ], dead(z), [2, [b,c]], [ ], Z, [2, [b,c]]]

  Head:
  Tail:

Head and Tail example 2

- [[ ], dead(z), [2, [b,c]], [ ], Z, [2, [b,c]]]

  Head: [ ]
  Tail:

Head and Tail example 2

- [[ ], dead(z), [2, [b,c]], [ ], Z, [2, [b,c]]]

  Head: [ ]
  Tail: [dead(z), [2, [b,c]], [ ], Z, [2, [b,c]]]

Head and Tail example 3

- [dead(z)]

  Head:
  Tail:

Head and Tail example 3

- [dead(z)]

  Head: dead(z)
  Tail:

Head and Tail example 3

- [dead(z)]

  Head: dead(z)
  Tail: [ ]

Head and tail of empty list

- The empty list has neither a head nor a tail
- For Prolog, [ ] is a special simple list without any internal structure
- The empty list plays an important role in recursive predicates for list processing in Prolog

The built-in operator |

- Prolog has a special built-in operator | which can be used to decompose a list into its head and tail
- The | operator is a key tool for writing Prolog list manipulation predicates

The built-in operator |

```
?- [Head|Tail] = [mia, vincent, jules, yolanda].

Head = mia
Tail = [vincent,jules,yolanda]
yes


?-
```

The built-in operator |

```
?- [X|Y] = [mia, vincent, jules, yolanda].

X = mia
Y = [vincent,jules,yolanda]
yes

?-
```

The built-in operator |

```
?- [X|Y] = [ ].

no

?-
```

The built-in operator |

```
?- [X,Y|Tail] = [[ ], dead(z), [2, [b,c]], [], Z, [2, [b,c]]] .

X = [ ]
Y = dead(z)
Z = _4543
Tail = [[2, [b,c]], [ ], Z, [2, [b,c]]]
yes

?-
```

Anonymous variable

- Suppose we are interested in the second and fourth element of a list

```
?- [X1,X2,X3,X4|Tail] = [mia, vincent, marsellus, jody, yolanda].
X1 = mia
X2 = vincent
X3 = marsellus
X4 = jody
Tail = [yolanda]
yes

?-
```

Anonymous variables

- There is a simpler way of obtaining only the information we want:

```
?- [ _,X2, _,X4|_ ] = [mia, vincent, marsellus, jody, yolanda].
X2 = vincent
X4 = jody
yes

?-
```

- The underscore is the anonymous variable

The anonymous variable

- Is used when you need to use a variable, but you are not interested in what Prolog instantiates it to
- Each occurrence of the anonymous variable is independent, i.e. can be bound to something different

Exercises

- Exercise 4.1 of LPN
- Exercise 4.2 of LPN

Text

Exercise 4.1 *How does Prolog respond to the following queries?*

1. `[a,b,c,d] = [a,[b,c,d]].`
2. `[a,b,c,d] = [a|[b,c,d]].`
3. `[a,b,c,d] = [a,b,[c,d]].`
4. `[a,b,c,d] = [a,b|[c,d]].`
5. `[a,b,c,d] = [a,b,c,[d]].`
6. `[a,b,c,d] = [a,b,c|[d]].`
7. `[a,b,c,d] = [a,b,c,d,[]].`
8. `[a,b,c,d] = [a,b,c,d|[]].`
9. `[] = _.`
10. `[] = [_].`
11. `[] = [_|[]].`

Member

- One of the most basic things we would like to know is whether something is an element of a list or not
- So let's write a predicate that when given a term X and a list L, tells us whether or not X belongs to L
- This predicate is usually called

member/2

member/2

```
member(X,[X|T]).
member(X,[H|T]):- member(X,T).
```

```
?-
```

member/2

```
member(X,[X|T]).
member(X,[H|T]):- member(X,T).
```

```
?- member(yolanda,[yolanda,trudy,vincent,jules]).
```

member/2

```
member(X,[X|T]).
member(X,[H|T]):- member(X,T).
```

```
?- member(yolanda,[yolanda,trudy,vincent,jules]).
yes
?-
```

member/2

```
member(X,[X|T]).
member(X,[H|T]):- member(X,T).
```

```
?- member(vincent,[yolanda,trudy,vincent,jules]).
```

member/2

```
member(X,[X|T]).
member(X,[H|T]):- member(X,T).
```

```
?- member(vincent,[yolanda,trudy,vincent,jules]).
yes
?-
```

member/2

```
member(X,[X|T]).
member(X,[H|T]):- member(X,T).
```

```
?- member(zed,[yolanda,trudy,vincent,jules]).
```

member/2

```
member(X,[X|T]).
member(X,[H|T]):- member(X,T).
```

```
?- member(zed,[yolanda,trudy,vincent,jules]).
no
?-
```

member/2

```
member(X,[X|T]).
member(X,[H|T]):- member(X,T).
```

```
?- member(X,[yolanda,trudy,vincent,jules]).
```

member/2

```
member(X,[X|T]).
member(X,[H|T]):- member(X,T).
```

```
?- member(X,[yolanda,trudy,vincent,jules]).
X = yolanda
```

member/2

```
member(X,[X|T]).
member(X,[H|T]):- member(X,T).
```

```
?- member(X,[yolanda,trudy,vincent,jules]).
X = yolanda;
X = trudy;
X = vincent;
X = jules;
no
```

Rewriting member/2

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

Recursing down lists

- The member/2 predicate works by recursively working its way down a list
  - doing something to the head, and then
  - recursively doing the same thing to the tail
- This technique is very common in Prolog. Therefore:
  - It's very important that you master it
  - So let's look at another example!

Example: a2b/2

The predicate a2b/2 takes two lists as arguments and succeeds

- if the first argument is a list of a's, and
- the second argument is a list of b's of exactly the same length

Example: a2b/2

The predicate a2b/2 takes two lists as arguments and succeeds

- if the first argument is a list of a's, and
- the second argument is a list of b's of exactly the same length

```
?- a2b([a,a,a,a],[b,b,b,b]).
yes
?- a2b([a,a,a,a],[b,b,b]).
no
?- a2b([a,c,a,a],[b,b,b,t]).
no
```

Defining a2b/2: step 1

```
a2b([],[]).
```

- Often the best away to solve such problems is to think about the simplest possible case
- Here it means: the empty list

Defining a2b/2: step 2

```
a2b([],[]).
a2b([a|L1],[b|L2]):- a2b(L1,L2).
```

- Now think recursively!
- When should a2b/2 decide that two non-empty lists are a list of as and a list of bs of exactly the same length?

Testing a2b/2

```
a2b([],[]).
a2b([a|L1],[b|L2]):- a2b(L1,L2).
```

```
?- a2b([a,a,a],[b,b,b]).
```

Testing a2b/2

```
a2b([],[]).
a2b([a|L1],[b|L2]):- a2b(L1,L2).
```

```
?- a2b([a,a,a],[b,b,b]).
yes
?-
```

Testing a2b/2

```
a2b([],[]).
a2b([a|L1],[b|L2]):- a2b(L1,L2).
```

```
?- a2b([a,a,a,a],[b,b,b]).
```

Testing a2b/2

```
a2b([],[]).
a2b([a|L1],[b|L2]):- a2b(L1,L2).
```

```
?- a2b([a,a,a,a],[b,b,b]).
no
?-
```

Testing a2b/2

```
a2b([],[]).
a2b([a|L1],[b|L2]):- a2b(L1,L2).
```

```
?- a2b([a,t,a,a],[b,b,b,c]).
```

Testing a2b/2

```
a2b([],[]).
a2b([a|L1],[b|L2]):- a2b(L1,L2).
```

```
?- a2b([a,t,a,a],[b,b,b,c]).
no
?-
```

Further investigating a2b/2

```
a2b([],[]).
a2b([a|L1],[b|L2]):- a2b(L1,L2).
```

```
?- a2b([a,a,a,a,a], X).
```

Further investigating a2b/2

```
a2b([],[]).
a2b([a|L1],[b|L2]):- a2b(L1,L2).
```

```
?- a2b([a,a,a,a,a], X).
X = [b,b,b,b,b]
yes
?-
```

Further investigating a2b/2

```
a2b([],[]).
a2b([a|L1],[b|L2]):- a2b(L1,L2).
```

```
?- a2b(X,[b,b,b,b,b,b,b]).
```

Further investigating a2b/2

```
a2b([],[]).
a2b([a|L1],[b|L2]):- a2b(L1,L2).
```

```
?- a2b(X,[b,b,b,b,b,b,b]).
X = [a,a,a,a,a,a,a]
yes
?-
```

Summary of this lecture

- In this lecture we introduced list and recursive predicates that work on lists
- The kind of programming that these predicates illustrated is fundamental to Prolog
- You will see that most Predicates you will write in your Prolog career will be variants of these predicates