Lecture 9

• Exercises
  – Solutions to exercises LPN 8.1 & 8.2
• Theory
Suppose we add the noun ``men'' (which is plural) and the verb ``shoot''. Then we would want a DCG which says that ``The men shoot'' is ok, `The man shoots'' is ok, ``The men shoots'' is not ok, and ``The man shoot'' is not ok. Hint: change the DCG so that it correctly handles these sentences. Use an extra argument to cope with the singular/plural distinction.

s --> np,vp.
np --> det,n.
vp --> v,np.
vp --> v.
det --> [the].
det --> [a].
n --> [woman].
n --> [man].
v --> [shoots].

s(X) --> np(X), vp(X).
np(X) --> det(X), n(X).
vp(X) --> v(X), np(_).
vp(X) --> v(X).
det(_) --> [the].
det(sing) --> [a].
n(sing) --> [woman].
n(sing) --> [man].
n(plur) --> [men].
v(sing) --> [shoots].
v(plur) --> [shoot].
Solution to Exercise 8.2

Translate the following DCG rule into the form Prolog uses:

\[
\text{kanga}(V,R,Q) \rightarrow \text{roo}(V,R),\text{jumps}(Q,Q),\{\text{marsupial}(V,R,Q)\}.
\]

\[
\text{kanga}(V,R,Q,X,T) :\text{--} \text{roo}(V,R,X,A), \text{jumps}(Q,Q,A,T), \text{marsupial}(V,R,Q).
\]

?- expand_term((kanga(V,R,Q) -- roo(V,R), jumps(Q,Q), {marsupial(V,R,Q)}), E).
E = (kanga(V, R, Q, X, T):- roo(V, R, X, A), jumps(Q, Q, A, B), marsupial(V, R, Q), T=B).
Lecture 9: A closer look at terms

• Theory
  – Introduce the == predicate
  – Take a closer look at term structure
  – Introduce strings in Prolog
  – Introduce operators
Comparing terms: ==/2

• Prolog contains an important predicate for comparing terms
• This is the identity predicate ==/2
• The identity predicate ==/2 does not instantiate variables, that is, it behaves differently from =/2
Comparing terms: ==/2

- Prolog contains an important predicate for comparing terms
- This is the identity predicate ==/2
- The identity predicate ==/2 does not instantiate variables, that is, it behaves differently from /=2

```prolog
?- a==a. yes
?- a==b. no
?- a=='a'. yes
?- a==X. X = _443 no
```
Comparing variables

• Two different uninstantiated variables are not identical terms
• Variables instantiated with a term $T$ are identical to $T$
Comparing variables

- Two different **uninstantiated** variables are not identical terms
- Variables **instantiated** with a term $T$ are identical to $T$

```
?- X==X.
X = _443
yes

?- Y==X.
Y = _442
X = _443
no

?- a=U, a==U.
U = a
yes
```
Comparing terms: \=/2

- The predicate \=/2 is defined so that it succeeds in precisely those cases where \=/2 fails.
- In other words, it succeeds whenever two terms are not identical, and fails otherwise.
Comparing terms: \( \neq \neq/2 \)

- The predicate \( \neq \neq/2 \) is defined so that it succeeds in precisely those cases where \( =\neq/2 \) fails.
- In other words, it succeeds whenever two terms are **not identical**, and fails otherwise.

\[
\begin{align*}
\text{?- a \( \neq \neq \) a.} \\
&\text{no} \\
\text{?- a \( \neq \neq \) b.} \\
&\text{yes} \\
\text{?- a \( \neq \neq \) 'a'.} \\
&\text{no} \\
\text{?- a \( \neq \neq \) X.} \\
&\text{X = _443} \\
&\text{yes}
\end{align*}
\]
<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>=</td>
<td>Unification predicate</td>
</tr>
<tr>
<td>=</td>
<td>Negation of unification predicate</td>
</tr>
<tr>
<td>==</td>
<td>Identity predicate</td>
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<tr>
<td>==</td>
<td>Negation of identity predicate</td>
</tr>
<tr>
<td>:=</td>
<td>Arithmetic equality predicate</td>
</tr>
<tr>
<td>==</td>
<td>Negation of arithmetic equality predicate</td>
</tr>
</tbody>
</table>
Terms with a special notation

• Sometimes terms look different, but Prolog regards them as identical
• For example: a and 'a', but there are many other cases
• Why does Prolog do this?
  – Because it makes programming more pleasant
  – More natural way of coding Prolog programs
Arithmetic terms

• Recall lecture 5 where we introduced arithmetic
• +, -, <, >, etc are functors and expressions such as 2+3 are actually ordinary complex terms
• The term 2+3 is identical to the term +(2,3)
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• +, -, <, >, etc are functors and expressions such as 2+3 are actually ordinary complex terms
• The term 2+3 is identical to the term +(2,3)

?- 2+3 == +(2,3).
yes
?- -(2,3) == 2-3.
yes
?- (4<2) == <(4,2).
yes
Lists as terms

• Another example of Prolog working with one internal representation, while showing another to the user

• Using the \( | \) constructor, there are many ways of writing the same list

?- [a,b,c,d] == [a|[b,c,d]].
yes
?- [a,b,c,d] == [a,b,c|[d]].
yes
?- [a,b,c,d] == [a,b,c,d|[|]].
yes
?- [a,b,c,d] == [a,b|[c,d]].
yes
Prolog lists internally

- Internally, lists are built out of two special terms:
  - `[]` (which represents the empty list)
  - `'.'` (a functor of arity 2 used to build non-empty lists)
- These two terms are also called list constructors
- A recursive definition shows how they construct lists
Definition of prolog list

- The empty list is the term []. It has length 0.
- A non-empty list is any term of the form \((term, list)\), where \(term\) is any Prolog term, and \(list\) is any Prolog list. If \(list\) has length \(n\), then \((term, list)\) has length \(n+1\).
A few examples...

?- .(a,[]) == [a].
yes

?- .(f(d,e),[]) == [f(d,e)].
yes

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

?- .(a,.(b,.(f(d,e),[]))) == [a,b,f(d,e)].
yes
Internal list representation

- Works similarly to the | notation:
  - It represents a list in two parts
    - Its first element, the *head*
    - the rest of the list, the *tail*
- The trick is to read these terms as trees
  - Internal nodes are labeled with`
  - All nodes have two daughter nodes
    - Subtree under left daughter is the head
    - Subtree under right daughter is the tail
Example of a list as tree

- Example: \([a,[b,c],d]\)
Examining terms

• We will now look at built-in predicates that let us examine Prolog terms more closely
  – Predicates that determine the type of terms
  – Predicates that tell us something about the internal structure of terms
Type of terms

Terms

Simple Terms

Constants

Atoms

Variables

Numbers

Complex Terms
## Checking the type of a term

<table>
<thead>
<tr>
<th>Term</th>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>atom/1</td>
<td>Is the argument an atom?</td>
</tr>
<tr>
<td>integer/1</td>
<td>... an integer?</td>
</tr>
<tr>
<td>float/1</td>
<td>... a floating point number?</td>
</tr>
<tr>
<td>number/1</td>
<td>... an integer or float?</td>
</tr>
<tr>
<td>atomic/1</td>
<td>... a constant?</td>
</tr>
<tr>
<td>var/1</td>
<td>... an uninstantiated variable?</td>
</tr>
<tr>
<td>nonvar/1</td>
<td>... an instantiated variable or another term that is not an uninstantiated variable</td>
</tr>
</tbody>
</table>
Type checking: atom/1

?- atom(a).
yes

?- atom(7).
no

?- atom(X).
no
Type checking: atom/1

?- X=a, atom(X).
X = a
yes

?- atom(X), X=a.
no
Type checking: atomic/1

?- atomic(mia).
yes

?- atomic(5).
yes

?- atomic(lovess(vincent, mia)).
no
Type checking: var/1

?- var(mia).
no

?- var(X).
yes

?- X=5, var(X).
no
Type checking: nonvar/1

?- nonvar(X).
no

?- nonvar(mia).
yes

?- nonvar(23).
yes
The structure of terms

• Given a complex term of unknown structure, what kind of information might we want to extract from it?

• Obviously:
  – The functor
  – The arity
  – The arguments

• Prolog provides built-in predicates to produce this information
The functor/3 predicate

- The functor/3 predicate gives the functor and arity of a complex predicate
The functor/3 predicate

- The functor/3 predicate gives the functor and arity of a complex predicate
  \[ ?- \text{functor(friends(lou,andy),F,A)}. \]
  \[ F = \text{friends} \]
  \[ A = 2 \]
  \[ \text{yes} \]
The functor/3 predicate

• The functor/3 predicate gives the functor and arity of a complex predicate

  \( \text{?- functor(friends(lou,andy),F,A).} \)
  
  \( F = \text{friends} \)
  
  \( A = 2 \)
  
  yes

  \( \text{?- functor([lou,andy,vicky],F,A).} \)
  
  \( F = . \)
  
  \( A = 2 \)
  
  yes
functor/3 and constants

• What happens when we use functor/3 with constants?
functor/3 and constants

• What happens when we use functor/3 with constants?
  ?- functor(mia,F,A).
    F = mia
    A = 0
  yes
functor/3 and constants

- What happens when we use functor/3 with constants?

  ?- functor(mia,F,A).
    F = mia
    A = 0
    yes
  yes

  ?- functor(14,F,A).
    F = 14
    A = 0
    yes
functor/3 for constructing terms

- You can also use functor/3 to construct terms:
  – ?- functor(Term,friends,2).
    Term = friends(_,_)
    yes
Checking for complex terms

complexTerm(X):- nonvar(X), functor(X,_,A), A > 0.
• Prolog also provides us with the predicate `arg/3`
• This predicate tells us about the arguments of complex terms
• It takes three arguments:
  – A number \( N \)
  – A complex term \( T \)
  – The \( N \)th argument of \( T \)
Arguments: arg/3

- Prolog also provides us with the predicate arg/3
- This predicate tells us about the arguments of complex terms
- It takes three arguments:
  - A number $N$
  - A complex term $T$
  - The $N$th argument of $T$

?- arg(2,likes(lou,andy),A).
A = andy
yes
Strings

- Strings are represented in Prolog by a list of character codes.
- Prolog offers double quotes for an easy notation for strings.

?- S = "Vicky".
S = [86,105,99,107,121]
yes
Working with strings

• There are several standard predicates for working with strings

• A particular useful one is `atom_codes/2`
  – returns a string representation of an atom

```prolog
?- atom_codes(vicky,S).
S = [118,105,99,107,121]
yes
```
Operators

• As we have seen, in certain cases, Prolog allows us to use operator notations that are more user friendly
• Recall, for instance, the arithmetic expressions such as 2+2 which internally means +(2,2)
• Prolog also has a mechanism to add your own operators
Properties of operators

• Infix operators
  – Functors written between their arguments
  – Examples: + - = == , ; . -->

• Prefix operators
  – Functors written before their argument
  – Example: - (to represent negative numbers)

• Postfix operators
  – Functors written after their argument
  – Example: ++ in the C programming language
Precedence

• Every operator has a certain precedence to work out ambiguous expressions

• For instance, does 2+3*3 mean 2+(3*3), or (2+3)*3?

• Because the precedence of + is greater than that of *, Prolog chooses + to be the main functor of 2+3*3

• Prolog thus interpret 2+3*3 as 2+(3*3)
Associativity

• Prolog uses associativity to disambiguate operators with the same precedence value

• Example: 2+3+4

  Does this mean?
  – Left associative: (2+3)+4
  – Right associative: 2+(3+4)

• Operators can also be defined as non-associative, in which case you are forced to use bracketing in ambiguous cases
  – Examples in Prolog: :- -->
Defining operators

- Prolog lets you define your own operators
- Operator definitions look like this:

  :- op(Precedence, Type, Name).

  - Precedence: number between 0 and 1200
  - Type: the type of operator
Types of operators in Prolog

- yfx  left-associative, infix
- xfy  right-associative, infix
- xfx  non-associative, infix
- fx   non-associative, prefix
- fy   right-associative, prefix
- xf   non-associative, postfix
- yf   left-associative, postfix
Operators in SWI Prolog

<p>| | |</p>
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<td><code>xfy</code></td>
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Exercises LPN Chapter 9

• 9.3, 9.5
Next lecture

• Cuts and negation
  – How to control Prolog's backtracking behaviour with the help of the cut predicate
  – Explain how the cut can be packaged into a more structured form, namely negation as failure