CS-713 (Artificial Intelligence) : Chapter 7

Introduction to PROLOG, Introduction to LISP

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Introduction to PROLOG

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- PROLOG is a declarative programming language unlike most common programming languages
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  - the programmer specifies a goal to be achieved
  - the PROLOG system works out how to achieve it

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- Procedural programmer must specify in detail how to solve a problem:
  - mix ingredients;
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- In purely declarative languages, the programmer only states what the problem is and leaves the rest to the language system

Applications of PROLOG

- Natural-language processing

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- Compiler construction

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- Database systems

Dialects of PROLOG

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  - C-PROLOG,
  - SWI-PROLOG,
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- You are expected to use SWI-PROLOG: Open-source (GPL) PROLOG environment
  - http://www.swi-prolog.org/
  - Development began in 1987
  - Available for Linux, MacOS X and Windows
  - Fully featured, with many libraries

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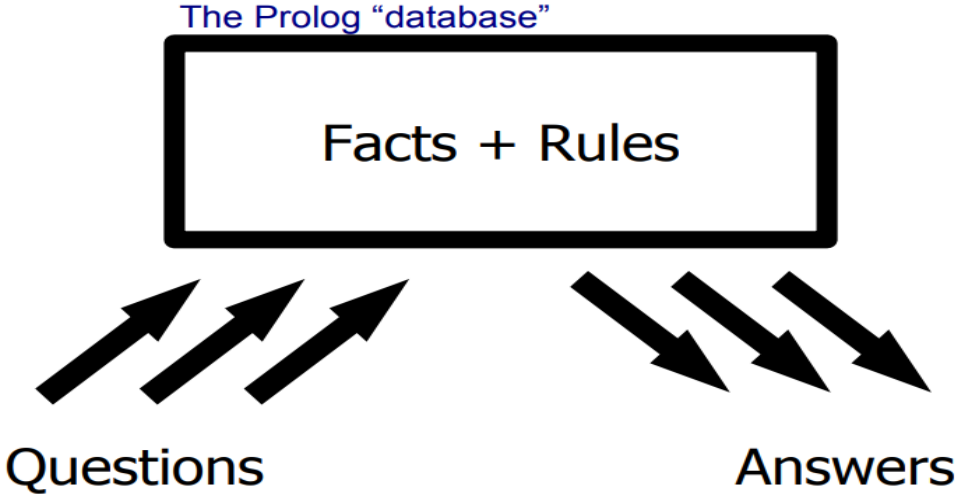
  - Specifying the facts concerning the objects and relations between objects relevant to the problem at hand
  - Specifying the rules concerning the objects and their interrelationships
  - Posing queries concerning the objects and relations.



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- To exit PROLOG, type halt. (Fullstop is to be typed in)

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- Atoms and numbers are sometimes grouped together and called atomic terms.

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- On top of that also any sequence of arbitrary characters enclosed in single quotes denotes an atom.

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- Finally, strings made up solely of special characters like + - * = < > : & (check the manual of your PROLOG system for the exact set of these characters) are also atoms.
  - Examples: +, ::, <------>, ***

Numbers

- All PROLOG implementations have an integer type:
  - a sequence of digits, optionally preceded by a - (minus).
- Some also support floats.

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  - It is called the anonymous variable and is used when the value of a variable is of no particular interest.
  - Multiple occurrences of the anonymous variable in one expression are assumed to be distinct, i.e., their values don't necessarily have to be the same.

Compound Terms

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f(g(X, _), 7)
’My Functor’(dog)
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- It’s important not to put any blank characters between the functor and the opening parentheses, or PROLOG won’t understand what you’re trying to say.
- A term that doesn’t contain any variables is called a ground term.

Clauses, Programs and Queries

- PROLOG programs are made up of facts and rules.
- Facts and rules are also called clauses.
- They are used to define predicates.

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- The intuitive meaning of a fact is that we define a certain instance of a relation as being true.

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is_smaller(X, Y) :- is_bigger(Y, X).
aunt(Aunt, Child) :- sister(Aunt, Parent), parent(Parent, Child).
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  is_smaller(X, Y) :- is_bigger(Y, X).

  aunt(Aunt, Child) :- sister(Aunt, Parent), parent(Parent, Child).
- The intuitive meaning of a rule is that the goal expressed by its head is true, if we (or rather the PROLOG system) can show that all of the expressions (subgoals) in the rule's body are true.

Programs

- A PROLOG program is a sequence of clauses.

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- Examples:

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- Intuitively, when submitting a query like the last example above, we ask PROLOG whether all of its three subgoals are provably true, or in other words whether there exists an X such that small(X), green(X), and slimy(X) are all true.

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- This must be so, because using them in such a position would effectively mean changing their definition.

Equality

- Instead of writing expressions such as =(X, Y), we usually write more conveniently X = Y.
- Such a goal succeeds, if the terms X and Y can be matched.

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- The predicates fail and true serve exactly this purpose.
- Some PROLOG systems also provide the predicate false, with exactly the same functionality as fail.

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- For example, to compile the file big-animals.pl, submit the following query to PROLOG:

  ?- consult('big-animals.pl').

- If the compilation is successful, PROLOG will reply with Yes. Otherwise a list of errors will be displayed.

Output

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- The argument can be any valid PROLOG term.
- In the case of a variable, its value will get printed to the screen.
- Execution of the predicate nl/0 causes the system to skip a line.
- Here are two examples:

```
?- write('Hello World!'), nl.
Hello World!
Yes
```

```
?- X = elephant, write(X), nl.
Elephant
 X = elephant
Yes
```

```
?- X = elephant, write(X), nl.
Elephant
 X = elephant
Yes
```

- In the second example, first the variable X is bound to the atom elephant and then the value of X, i.e., elephant, is written on the screen using the write/1 predicate.

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?- X = elephant, write(X), nl.
Elephant
 X = elephant
Yes
```

- In the second example, first the variable X is bound to the atom elephant and then the value of X, i.e., elephant, is written on the screen using the write/1 predicate.
- After skipping to a new line, PROLOG reports the variable binding(s), i.e., X = elephant.

Checking the Type of a PROLOG Term

```
?- atom(elephant).
Yes
```

Checking the Type of a PROLOG Term

```
?- atom(elephant).
Yes

?- atom(Elephant).
No
```

Checking the Type of a PROLOG Term

```
?- atom(elephant).
Yes

?- atom(Elephant).
No

?- X = f(mouse), compound(X).
X = f(mouse)
Yes
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```
?- atom(elephant).
Yes

?- atom(Elephant).
No

?- X = f(mouse), compound(X).
X = f(mouse)
Yes
```

The last query succeeds, because the variable X is bound to the compound term f(mouse) at the time the subgoal compound(X) is being executed.

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- Applied to a term (like the name of a built-in predicate), the system will display a short description, if available.
- Example:

```
?- help(atom).
atom(+Term)
        Succeeds if Term is bound to an atom.
```

Example Database

```
bigger(elephant, horse).
bigger(horse, donkey).
bigger(donkey, dog).
bigger(donkey, monkey).
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bigger(elephant, horse).
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?- bigger(donkey, dog).
Yes
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bigger(elephant, horse).
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bigger(donkey, dog).
bigger(donkey, monkey).

?- bigger(donkey, dog).
Yes

?- bigger(monkey, elephant).
No

Example Database

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bigger(elephant, horse).
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?- bigger(donkey, dog).
Yes

?- bigger(monkey, elephant).
No

?- bigger(elephant, monkey).
No
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Example Database

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Yes

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No

But why?

?- bigger(elephant, monkey).
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- Still, we know that if elephants are bigger than horses, which in turn are bigger than donkeys, which in turn are bigger than monkeys, then elephants also have to be bigger than monkeys.

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- In mathematical terms: the bigger-relation is transitive.
- But this also has not been defined in our program.
- The correct interpretation of the negative answer PROLOG has given is the following: from the information communicated to the system it cannot be proved that an elephant is bigger than a monkey.

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- For our little example this would mean adding another 5 facts.
- Clearly too much work and probably not too smart anyway.

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- In PROLOG such statements are called rules and are implemented like this:

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- X, Y, and Z are variables, which in PROLOG is indicated by using capital letters.
- If from now on we use is_bigger instead of bigger in our queries, the program will work as intended:

```
?- is_bigger(elephant, monkey).
Yes
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- This process is repeated recursively until the facts that make up the chain between elephant and monkey are found and the query finally succeeds.

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- The PROLOG interpreter replies as follows:

  ?- is_bigger(X, donkey).

  X = horse

  - Horses are bigger than donkeys.

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- In case we want to find out if there are more animals that are bigger than the donkey, we can press the semicolon key, which will cause PROLOG to search for alternative solutions to our query.
- If we do this once, we get the next solution X = elephant: elephants are also bigger than donkeys.
- Pressing semicolon again will return a No, because there are no more solutions:

```
?- is_bigger(X, donkey).
X = horse ;
X = elephant ;
No
```

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- The (correct) answer is No.
- Even though the two single queries is_bigger(donkey, X) and is_bigger(X, monkey) would both succeed when submitted on their own, their conjunction (represented by the comma) does not.

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- Instantiating a variable means assigning it a fixed value.
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  ?- p(X, 2, 2) = p(1, Y, X).

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Yes
```

- Another example for matching:

```
?- f(a, g(X, Y)) = f(X, Z), Z = g(W, h(X)).
X = a
Y = h(a)
Z = g(a, h(a))
W = a
Yes
```

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- Consider the following query:

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?- X = my_functor(Y).
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Y = _G177
Yes
```

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- In fact, what the output for the above example will look like exactly will depend on the PROLOG system you use.
- For instance, some systems will avoid introducing a new variable (here _G177) and instead simply report the variable binding as X = my_functor(Y).

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- For instance:

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  Yes

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- Syntactically, a query looks just like a fact. But it's interpreted as a question.

How PROLOG Responds to a Query

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  Yes

  ?-

- If no match is found, PROLOG replies with No:

  ?- female(queen_victoria).

  No

  ?-

PROLOG's Search Strategy

- Let's extend the database a bit:

```
child_of(liz, charlie).
child_of(liz, anne).
child_of(liz, andrew).
child_of(charlie, harry).
child_of(charlie, will).
child_of(anne, zara).
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```

- PROLOG searches the database of clauses in order (first-to-last), so the first clause it matches will be the first one entered in the database.

```
?- child_of(charlie, X).
X = harry
```

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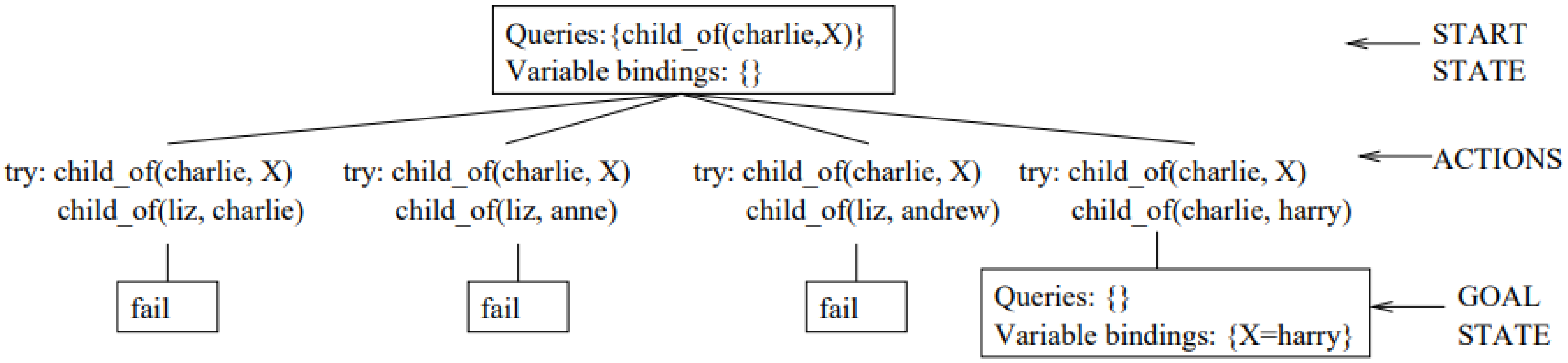
  - An unsuccessful match results in a special state called fail.
- The goal state is one where the set of unresolved queries is empty.


Queries: {child_of(charlie,X)}
Variable bindings: {}
START STATE
ACTIONS
try: child_of(charlie, X)
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child_of(charlie, harry)
fail
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Variable bindings: {X=harry}
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- Rules thus introduce searches of depth greater than 1.
- Note: New queries are added to the front of the list of queries. So PROLOG implements a depth-first search.

An Example

- Consider this simple database:

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  - We test this query against each clause in the database, left-to-right. And this succeeds.

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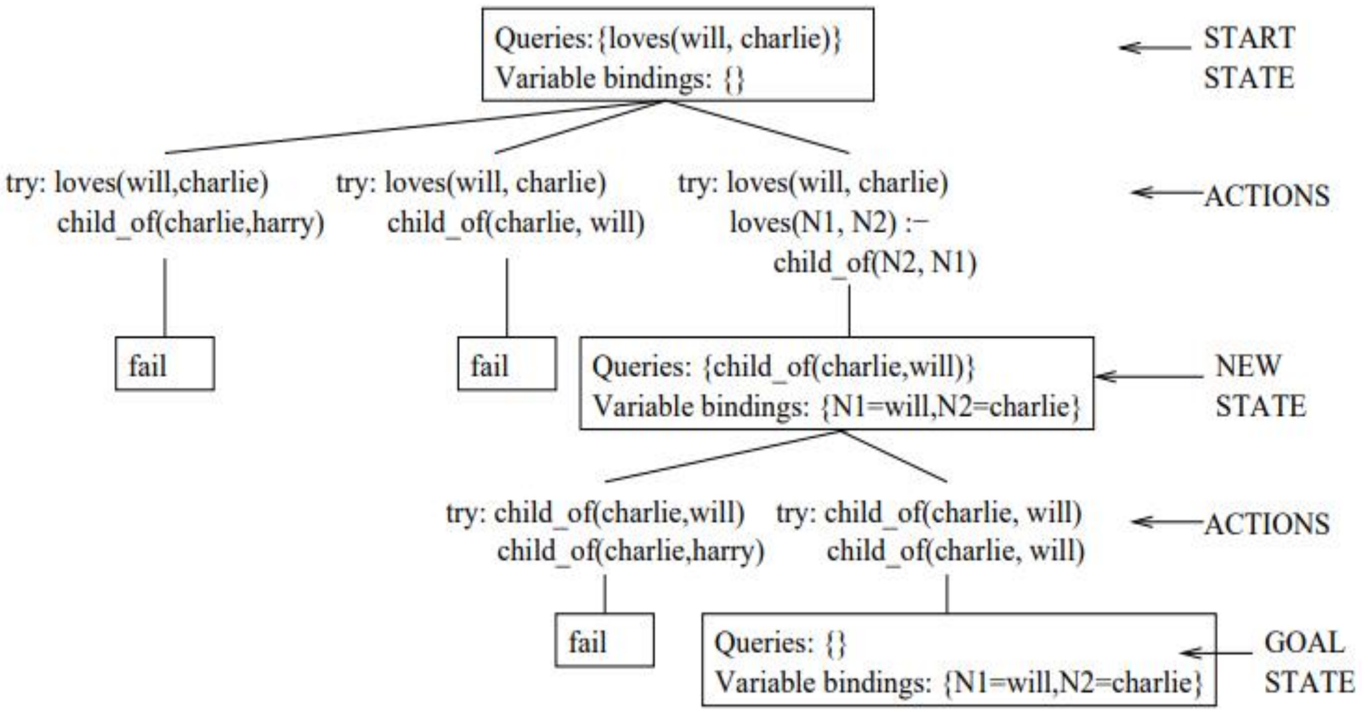

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- Note: The base case always has to appear first!

Introduction to LISP

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  - Source files for LISP programs are typically named with the extension ".lisp".
- LISP Executor: CLISP is the GNU Common LISP multi-architectural compiler used for setting up LISP in Windows.
  - Windows version emulates a unix environment using MingW under windows.
  - Installer takes care of this and automatically adds CLISP to Windows PATH variable.

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- Any s-expression is a valid program.
- LISP programs run either on an interpreter or as compiled code.
- The interpreter checks the source code in a repeated loop, which is also called the read-evaluate-print loop (REPL).
  - It reads the program code, evaluates it, and prints the values returned by the program.

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- If you would like to run the same program as a compiled code, then create a LISP source code file named myprog.lisp and type the following code in it:

  ```
  (write (+ 7 9 11))
  ```

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- If you would like to run the same program as a compiled code, then create a LISP source code file named myprog.lisp and type the following code in it:

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  (write (+ 7 9 11))
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- When you click the Execute button, or type Ctrl+E, LISP executes it immediately and the result returned is:

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LISP Uses Prefix Notation

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- In the above program the + symbol works as the function name for the process of summation of the numbers.
- In prefix notation, operators are written before their operands. For example, the expression,

  a * (b + c) / d

- will be written as:

  (/ (* a (+ b c)) d)

Hello World

```
(write-line "Hello World")
```

Basic Building Blocks in LISP

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Atom

- An atom is a number or string of contiguous characters. It includes numbers and special characters.

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- Following are examples of some valid atoms:

  hello-world

  name

  123008907

  hello

  Block#221

  abc123

List

- A list is a sequence of atoms and/or other lists enclosed in parentheses.

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- Following are examples of some valid lists:

  (i am a list)

  (a (a b c) d e fgh)

  (father tom (susan bill joe))

  (sun mon tue wed thur fri sat)

  ( )

String

- A string is a group of characters enclosed in double quotation marks.

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- Following are examples of some valid strings:

  " I am a string"

  "a ba c d efg #$%^&!"

  "Please enter the following details :"

  "Hello from ‘Mr. Beans' "

Adding Comments

- The semicolon symbol (;) is used for indicating a comment line.

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- For Example,

```
(write-line "Hello World") ; greet the world
; tell them your whereabouts
(write-line "I am at learning LISP")
```

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- For Example,

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- When you click the Execute button, or type Ctrl+E, LISP executes it immediately and the result returned is”

  Hello World

  I am at learning LISP

Some Notable Points

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- LISP represents a function call f(x) as (f x), for example cos(45) is written as cos 45
- LISP expressions are case-insensitive, cos 45 or COS 45 are same.
- LISP tries to evaluate everything, including the arguments of a function. Only three types of elements are constants and always return their own value:
  - Numbers
  - The letter t, that stands for logical true
  - The value nil, that stands for logical false, as well as an empty list

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- At times, we need to take atoms or lists literally and don't want them evaluated or treated as function calls.
- To do this, we need to precede the atom or the list with a single quotation mark.

- The following example demonstrates this.

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  Create a file named main.lisp and type the following code into it:

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(write-line “single quote used, it inhibits evaluation”)
(write ‘(* 2 3))
(write-line “ ”)
(write-line “single quote not used, so expression evaluated”)
(write (* 2 3))
```

- The following example demonstrates this.

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- When you click the Execute button, or type Ctrl+E, LISP executes it immediately and the result returned is:

  single quote used, it inhibits evaluation

  (* 2 3)

  single quote not used, so expression evaluated

  6

Data Types

- LISP data types can be categorized as.
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- The typep predicate is used for finding whether an object belongs to a specific type.
- The type-of function returns the data type of a given object.

Example

Source Code

```
(defvar x 10)
(defvar y 34.567)
(defvar ch nil)
(defvar bg 11.0e+4)

(print (type-of x))
(print (type-of y))
(print (type-of ch))
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(print (type-of ch))
(print (type-of bg))
```

Output

```
(INTEGER 0 281474976710655)
SINGLE-FLOAT
NULL
SINGLE-FLOAT
```

Macros

Syntax for defining a macro is:

```
(defmacro macro-name (parameter-list))
"Optional documentation string."
body-form
```

Example

- Let us write a simple macro named setTo10, which will take a number and set its value to 10.

```
(defmacro setTo10(num)
(setq num 10)(print num))
(setq x 25)
(print x)
(setTo10 x)
```

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(print x)
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- Output:

```
25
10
```

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- Since there is no type declaration for variables in LISP, you directly specify a value for a symbol with the setq construct.
- For Example:

```
(setq x 10)
```

- The above expression assigns the value 10 to the variable x. You can refer to the variable using the symbol itself as an expression.

- The symbol-value function allows you to extract the value stored at the symbol storage place.

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- For Example:

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(setq x 10)
(setq y 20)
(format t “x = ~2d y = ~2d ~%” x y)
(setq x 100)
(setq y 200)
(format t “x = ~2d y = ~2d” x y)
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- Output:

  x = 10 y = 20

  x = 100 y = 200

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- When let is executed, each variable is assigned the respective value and lastly the s-expression is evaluated. The value of the last expression evaluated is returned.
- If you don't include an initial value for a variable, it is assigned to nil.

Example

```
(let ((x 'a) (y 'b)(z 'c))
(format t “x = ~a y = ~a z = ~a” x y z))
```

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- Output:

```
x = A y = B z = C
```

Example

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- Output:

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- The prog construct also has the list of local variables as its first argument, which is followed by the body of the prog, and any number of s-expressions.

Example

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(let ((x 'a) (y 'b)(z 'c))
(format t “x = ~a y = ~a z = ~a” x y z))
```

- Output:

  x = A y = B z = C

- The prog construct also has the list of local variables as its first argument, which is followed by the body of the prog, and any number of s-expressions.
- The prog function executes the list of s-expressions in sequence and returns nil unless it encounters a function call named return. Then the argument of the return function is evaluated and returned.

Example

```
(prog ((x '(a b c))(y '(1 2 3))(z '(p q 10)))
(format t “x = ~a y = ~a z = ~a” x y z))
```

Example

```
(prog ((x '(a b c))(y '(1 2 3))(z '(p q 10)))
(format t “x = ~a y = ~a z = ~a” x y z))
```

- Output:

  x = (A B C) y = (1 2 3) z = (P Q 10)

Constants

- Constants are declared using the defconstant construct.

```
(defconstant PI 3.141592)
(defun area-circle(rad)
  (terpri)
  (format t "Radius: ~5f" rad)
  (format t "~%Area: ~10f" (* PI rad rad)))
(area-circle 10)
```

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(area-circle 10)
```

- Output:

```
Radius:  10.0
Area:   314.1592
```