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# 1 Building Abstractions with Procedures

**Definition (computational process)**

Abstract beings that inhabit computers.

**Definition (data)**

Computational processes manipulate other abstract things called ***data*** as they evolve.

**Definition (program)**

A pattern of rules by which the evolution of a computational process is directed.

**Definition (programming language)**

That in which programs are carefully composed from symbolic expressions that prescribe the tasks we want our computational processes to perform.

**Definition (bug, glitch)**

Small errors.

**Definition (debug)**

Remove bugs.

## Programming in Lisp

See the [appendix](#).

# Appendix

## A Notes on LISP

### A.1 McCarthy 1960

*Recursive Functions of Symbolic Expressions and Their Computation by Machine*

#### A.1.1 Introduction

LISP:

- "LISP Processor"
- Developed for the IBM 704 computer by the Artificial Intelligence group at M.I.T.
- Designed to facilitate experiments with a proposed system called the *Advice Tracker*:
  - A programming system for manipulating expressions representing formalized declarative and imperative sentences so that the Advice Tracker system could make deductions.
  - Originally proposed in November 1958.
- Came to be based on a scheme for representing the partial recursive functions of a certain class of symbolic expressions, independent of any electronic computer.

In this article:

1. Describe a formalism for defining functions recursively.
2. Describe S-expressions and S-functions, give examples, and describe the universal S-function *apply* which plays the theoretical role of a universal Turing machine and the practical role of an interpreter.
3. Describe the representation of S-expressions in the memory of the IBM 704 by list structures ... and the representation of S-functions by program.
4. Mention the main features of the LISP programming system for the IBM 704.
5. Another way of describing computations with symbolic expressions.
6. Give a recursive function interpretation of flow charts.

#### A.1.2 Functions and Function Definitions

##### Definition (partial function)

A function that is defined only on part of its domain.

##### Definition (propositional expression)

A *propositional expression* is an expression whose possible values are *T* (for truth) and *F* (for falsity)

**Definition (predicate)**

A function whose range consists of the truth values  $T$  and  $F$ .

**Definition (conditional expression)**

A device for expressing the dependence of quantities on propositional quantities, denoted:

$$(p_1 \rightarrow e_1, \dots, p_n \rightarrow e_n)$$

where the  $p$ 's are propositional expressions and the  $e$ 's are expressions of any kind, read “If  $p_1$  then  $e_1$ , otherwise if  $p_2$  then  $e_2$ , ... otherwise if  $p_n$  then  $e_n$ ” or “ $p_1$  yields  $e_1$ , ...,  $p_n$  yields  $e_n$ .”

**How to determine the value of an arbitrary conditional statement** ( $p_1 \rightarrow e_1, \dots, p_n \rightarrow e_n$ ):

- Let  $i = 1$ .
- If the value of  $p_i$  is undefined, then the value of the conditional expression is undefined.
- If the value of  $p_i$  is  $T$ , then the value of the conditional expression is the value of the expression  $e_i$ .
- If the value of  $p_i$  is  $F$ , then increment  $i$  and evaluate  $p_i$ .

*Example.*

- $(1 < 2 \rightarrow 4, 1 > 2 \rightarrow 3) = 4$

Starting from the left with the statement  $1 < 2 \rightarrow 4$ , the propositional expression  $1 < 2$  is true, therefore the value of the conditional expression is 4.

- $(2 < 1 \rightarrow 4, 2 > 1 \rightarrow 3, 2 > 1 \rightarrow 2) = 3$

Starting from the left with the statement  $2 < 1 \rightarrow 4$ , the propositional expression  $2 < 1$  is false. Moving on to the next statement  $2 > 1 \rightarrow 3$ , the propositional expression  $2 > 1$  is true, therefore the value of the conditional expression is 3.

- $(2 < 1 \rightarrow 4, T \rightarrow 3) = 3$

The propositional expression  $2 < 1$  is false, so move on. The propositional expression  $T$  is true, therefore the value of the conditional expression is 3.

- $(2 < 1 \rightarrow \frac{0}{0}, T \rightarrow 3) = 3$

The propositional expression  $2 < 1$  is false, so move on. The propositional expression  $T$  is true, therefore the value of the conditional expression is 3.

- $(2 < 1 \rightarrow 3, T \rightarrow \frac{0}{0})$  is undefined.

The propositional expression  $2 < 1$  is false, so move on. The propositional expression  $T$  is true, therefore the value of the conditional expression is the value of the expression  $\frac{0}{0}$  which is undefined.

- $(2 < 1 \rightarrow 3, 4 < 1 \rightarrow 4)$  is undefined.

The propositional expression  $2 < 1$  is false, so move on. The propositional expression  $4 < 1$  is false, so move on. There's nothing else to move on to, so the value of the conditional expression defaults to being undefined.

*Example.* Applications:

- $|x| = (x < 0 \rightarrow -x, T \rightarrow x)$
- $\delta_{ij} = (i = j \rightarrow 1, T \rightarrow 0)$
- $sgn(x) = (x < 0 \rightarrow -1, x = 0 \rightarrow 0, T \rightarrow 1)$

*Example.* Recursive applications:

- $n! = (n = 0 \rightarrow 1, T \rightarrow n \cdot (n - 1)!)$
- $\text{gcd}(m, n) = (m > n \rightarrow \text{gcd}(n, m), \text{rem}(n, m) = 0 \rightarrow m, T \rightarrow \text{gcd}(\text{rem}(n, m), m))$
- $\text{sqrt}(a, x, \epsilon) = (|x^2 - a| < \epsilon \rightarrow x, T \rightarrow \text{sqrt}(a, \frac{1}{2}(x + \frac{a}{x}), \epsilon))$

*Example.* Propositional connectives defined by conditional expressions:

- $p \wedge q = (p \rightarrow q, T \rightarrow F)$
- $p \vee q = (p \rightarrow T, T \rightarrow q)$
- $\neg p = (p \rightarrow F, T \rightarrow T)$
- $p \supset q = (p \rightarrow q, T \rightarrow T)$

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