

Recursive Functions of Symbolic Expressions and Their Computation by Machine, Part I

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Introduction

WARNING

- I make mistakes.
 - Sorry if I did!
- Feedback welcome.

Who's John McCarthy

- TODO
- The part II of this paper has never been written.
 - What

A bit of context

- LISP and Fortran were written for the IBM 704 (available at MIT).
 - “Only computer which can handle complex math” - Wikipedia
- Only Fortran older than LISP.
 - One of the oldest high level programming language (non-assembly language).
- Today, LISP is a family of languages
 - Many "dialects"
 - This paper is the foundation of all of these languages... and more (JINGLE!).

IBM 704



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Good Old Languages

- IPL2 (1956) - List processing in Assembly.
- Fortran (1957) - No list processing
- LISP (for LISt Processing) (1962?)

Goals of LISP

- AI (term coined by McCarthy)
 - They thought they were almost there in the 50s / 60s.
 - McCarthy wrote a “funny paper” later “HUMAN-LEVEL AI IS HARDER THAN IT SEEMED IN 1955” (
- Chess player (beginning of CS game theory).
- Programming the Advice Taker (proposed in 1958).
- ... what about for people to understand? (*MORE ON THAT LATER*)

The Paper

Advice Taker

“representing information about the world by sentences in a suitable formal language and a reasoning program that would decide what to do by making logical inferences. Representing sentences by list structure seemed appropriate - it still is - and a list processing language also seemed appropriate for programming the operations involved in deduction - and still is.” - McCarthy, 1979

- From the paper: LISP handle declarative and imperative sentences.

S-Expression and M-expressions

S-Expression (paper)

Characters: (.)
(CAR(CONS,x,y))
(CDR(CONS,x,y))

M-Expression (paper, never implemented)

car [cons [x; y]] = x
cdr [cons [x; y]] = y

Actual code (Scheme)

(car (cons x y))
(cdr (cons x y))

Recursion

- Describe formalism for defining function recursively.
- First programming language with recursion.

$$\begin{aligned} 2! &= (2 = 0 \rightarrow 1, T \rightarrow 2 \cdot (2 - 1)!) \\ &= 2 \cdot 1! \\ &= 2 \cdot (1 = 0 \rightarrow 1, T \rightarrow \cdot (1 - 1)!) \\ &= 2 \cdot 1 \cdot 0! \\ &= 2 \cdot 1 \cdot (0 = 0 \rightarrow 1, T \rightarrow 0 \cdot (0 - 1)!) \\ &= 2 \cdot 1 \cdot 1 \\ &= 2 \end{aligned}$$

Conditionals

- Invented conditional expression from propositional logic
 - Predicate: function returning #T or #F
- Idea of conditional in programming introduced here (not present in Assembly)

Functions

- Precise that it's **not** the usual mathematics term “function”.
 - Same input potentially lead to different output.
- Inspired by Church's lambda-notation (1936).
 - Turing Machine (1936) “too complicated”.

Linked List (basic data structure)

Modern LISP (Scheme)

```
(car (cons x y))  
(cdr (cons x y))
```

Pointer diagram

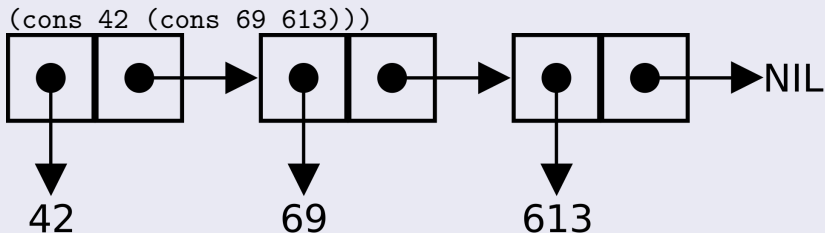


Figure 3: Pointer diagram

???

- Relics from IBM 704 memory access.

`caddr[x]` for `car[cdr[cdr[x]]]`

`(caddr x)` equivalent to `(car (cdr (cdr x)))`

“Second, it is convenient to allow English words and phrases to stand for atomic entities for mnemonic reasons”
- John McCarthy (paper)

- ... what about other programmers?

Going Through a List

- Need to go from cdr to cdr to go through the list:

Garbage collection

"... formerly pointed cannot be reached by a car — cdr chain from any base register. Such a register may be considered abandoned by the program because its contents can no longer be found by any possible program; hence its contents are no longer of interest, and so we would like to have it back on the free-storage list. This comes about in the following way. Nothing happens until the program runs out of free storage. When a free register is wanted, and there is none left on the free-storage list, a reclamation cycle starts.

Lists

- List data structure
- car / cdr from IBM 704
 - Curse following us till NOW

Legacy

The most important

- First functional programming language
- Smalltalk (70s) was very influenced by LISP (today: Pharo)
 - One rule
 - Garbage collection
 - ... but don't like special forms

LISP today

- Common LISP
- Emacs LISP
- Clojure
- Scheme

References

- Slides TODO
- HUMAN-LEVEL AI IS HARDER THAN IT SEEMED IN 1955
- kk