CS61A Discussion 9: **Tail Calls and Interpreters**

TA: **Jerry Chen**
Email: **jerry.c@berkeley.edu**
TA Website: **jerryjrchen.com/cs61a**

Attendance

Form: **tinyurl.com/jerrydisc**

For the weekly question,

- please complete the quiz AND

- what would you like to see in disc?

(Of course, please only check in if you showed up!)

Agenda

1. Week in Review
2. Halting Problem (fun diversion)
3. Tail Calls
4. Interpreters

Week In Review

MT2 — how was it?

- Regrades are open, please review the rubric and submit if applicable

Lab 10 (Interpreters) - **Due Friday**

Hw6 - **Due Friday**

Proj2 - Due 4/23

Maps Composition - Resubmit by next Friday

Halting Problem
("fun" diversion)

An **interpreter** is a program that **understands other programs**

Great, we can write **programs that analyze other programs!**

Are there any limitations to what we can calculate?

Halting Problem

The Halting Problem:

```
halts?(P, x):

 return HALTS if P(x) will halt

 return LOOP if P(x) will loop forever
```

Halting Problem

https://xkcd.com/1266/

Halting Problem

The program `halts?` cannot exist!

- First shown by Alan Turing

There are many other such problems that can be proved to be **uncomputable**

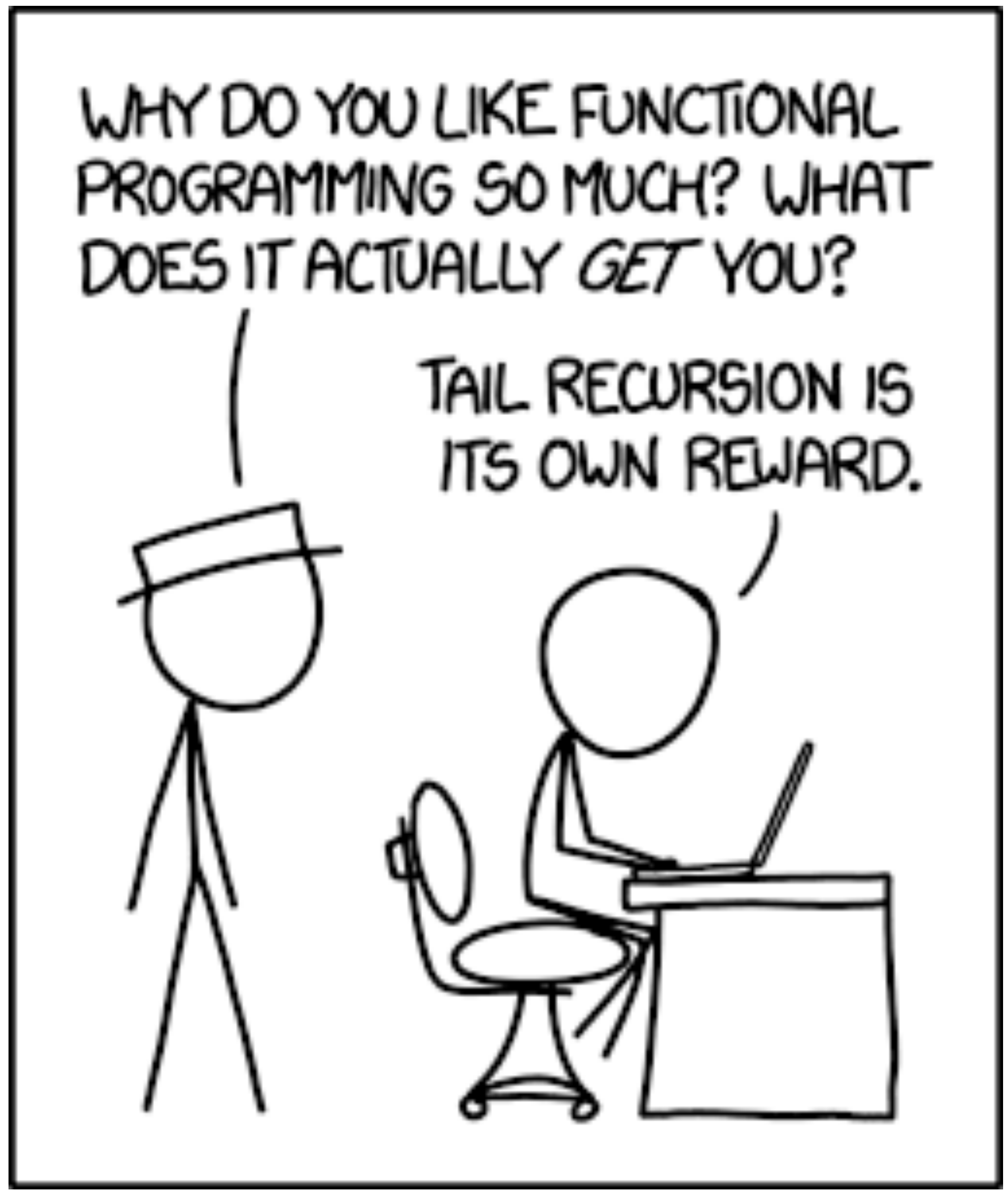
Halting Problem

```
trouble(P):

  LOOP forever if halt?(P, P) == HALTS

  else exit the function
```

What will `halt?(trouble, trouble)` return?
Either way, it's a contradiction!

More of this topic (computability) in CS 70, CS 170, CS 172

Tail Calls



http://xkcd.com/1270/

Tail Calls

Scheme is **recursion only**

- Usually, recursive calls will take up space (think extra frames in the env diagram)

- **Tail calls** allow **recursion using constant space => efficiency of iteration!**

- **Tail recursion** is recursive calls performed at the end ("tail") of a function

Tail Calls

Big idea: with a valid tail call setup, **a recursive call** does not need anything **from the current frame** after it returns

- Put another way, after we do the recursive call, we **do not need to return for any computation**
- This is important because it means we can **reuse the current frame!** (might still need info for lookups)

Tail Calls

```
(define (fact n)
  (if (= n 0)
    1
    (* n (fact (- n 1)))))
```

Tail Calls

```
(define (fact n)
  (define (fact-tail n result)
    (if (= n 0)
      result
      (fact-tail (- n 1) (* n result))))
  (fact-tail n 1))
```

Tail Calls

Usually use a **helper** function to **track state**

Recursive call must be in a **tail context** to be a valid tail call

Tail Context

Tail contexts are essentially places we know a function terminates from ("tail end")

There's a list of them in the discussion handout. Think about why they make sense!

Tail Calls

Summary

- **Tail calls let us use constant space** for recursive calls
- To do a tail call, must perform **recursive calls in a valid tail context**
- Valid tail contexts are at certain "tails" of expressions, and **must not require addl. work** after the recursive call

Tail Recursion

http://i.stack.imgur.com/qRIvz.jpg

Calculator

The humble **Calculator** langage:

- Polish-prefix notation
- Math only
- (Scheme… but less impressive)

Calculator

Supports argument nesting, and the 4 basic arithmetic operations:

```
> (+ (* 4 500) (- 26 (/ 20 2)))

2016
```

Calculator

Expressions are Pairs… seem familiar?

Calculator expressions structured (mostly) the same as Scheme expressions

Pair is the Python data structure equivalent for Scheme cons

Calculator

Recall: evaluating call expressions

- **Evaluate** the operator
- **Evaluate** the operands
- **Apply** the operator to the operands