# Functional Data Structures

Mattox Beckman

Illinois Institute of Technology
Computer Science

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# Who is Mattox?

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|---|---|
| Name | Mattox Beckman |
| History | PhD, Fall 2003, University of Illinois at Urbana-Champaign |
| Area | Programming Languages |
| Specialty | Partial Evaluation, Functional Programming |
| Professional Interests | Teaching; Partial Evaluation; Interpreters; Functional Programming; Semantics and Types; Continuations |
| Personal Interests | Home-brewing; Theology; Investing; Plants; Tarantulas; Evolution; Travel; Korean Culture... and many many more ... |

# Models of Computation

- Why do programming languages look the way they do?
  - Imperative Languages: von Neuman model

    ```
    a := a + 1
    ```
  - OO Languages: message passing model

    ```
    a.increment()
    ```
  - Functional Languages: lambda calculus

    $$a + 1$$
  - Logic Language: unification / first order logic

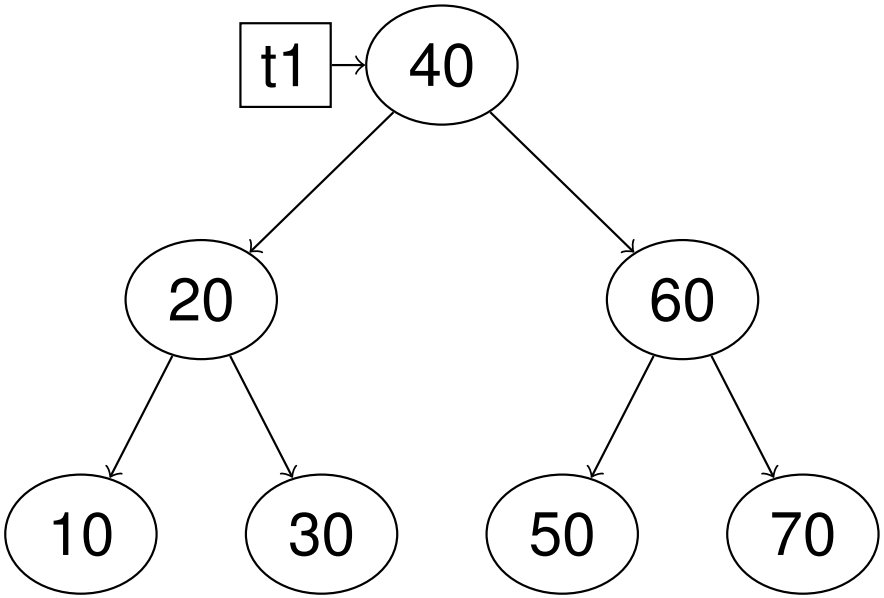
    ```
    inc(a,b) :- b is a+1
    ```

# Why Functional Programming?

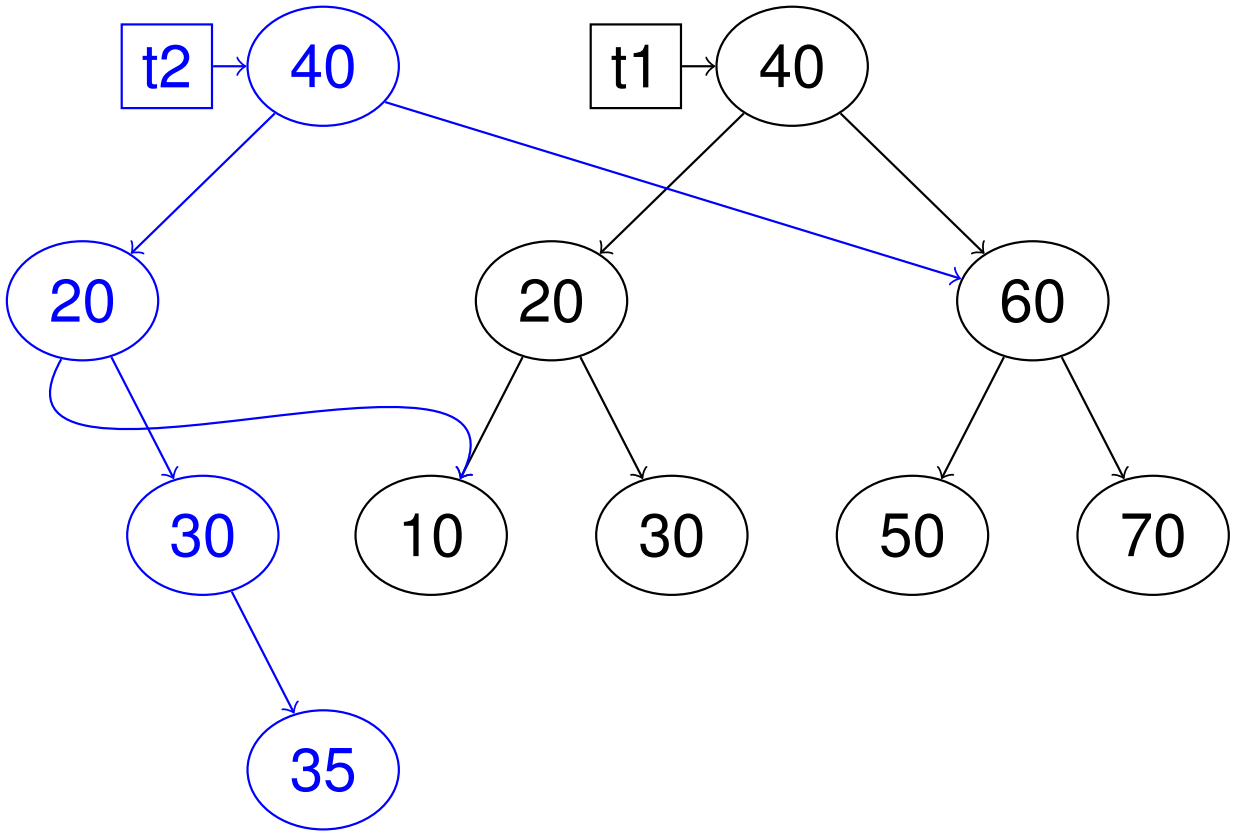
- Economy of Expression

```
guess [] = []
guess (x:xs) = guess [y | y <- xs, y < x]
               ++ [x] ++
                guess [y | y <- xs, y >= x]
```

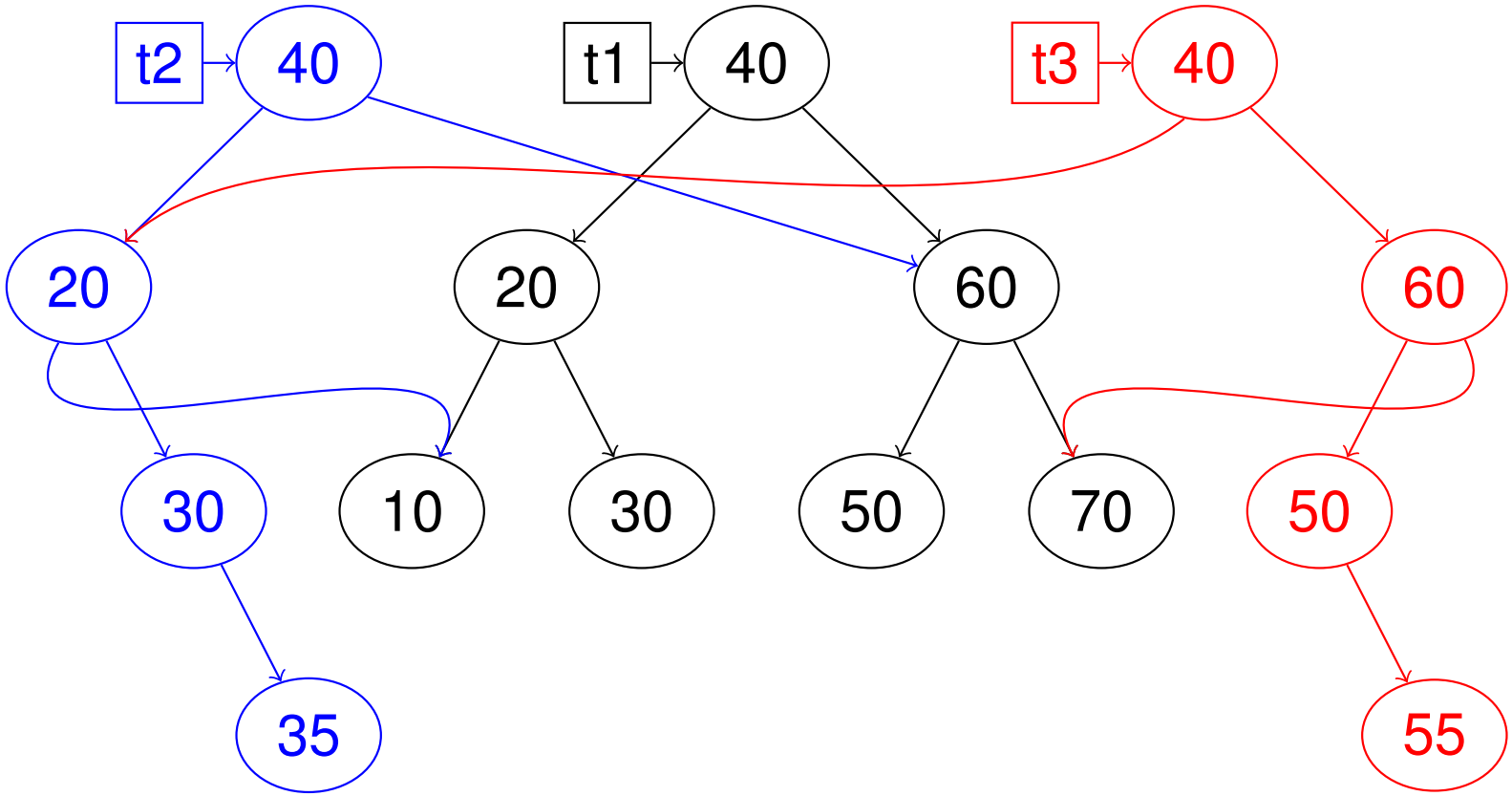
- Lazy Evaluation
- No Assignment!!
  - - May use more memory
  - + Easier to verify
  - + Easy to parallelize




What if we run `t2 = add(t1,35)` on this?




What if we run `t3 = add(t2,55)` on this?


t2
40
t1
40
t3
40
20
20
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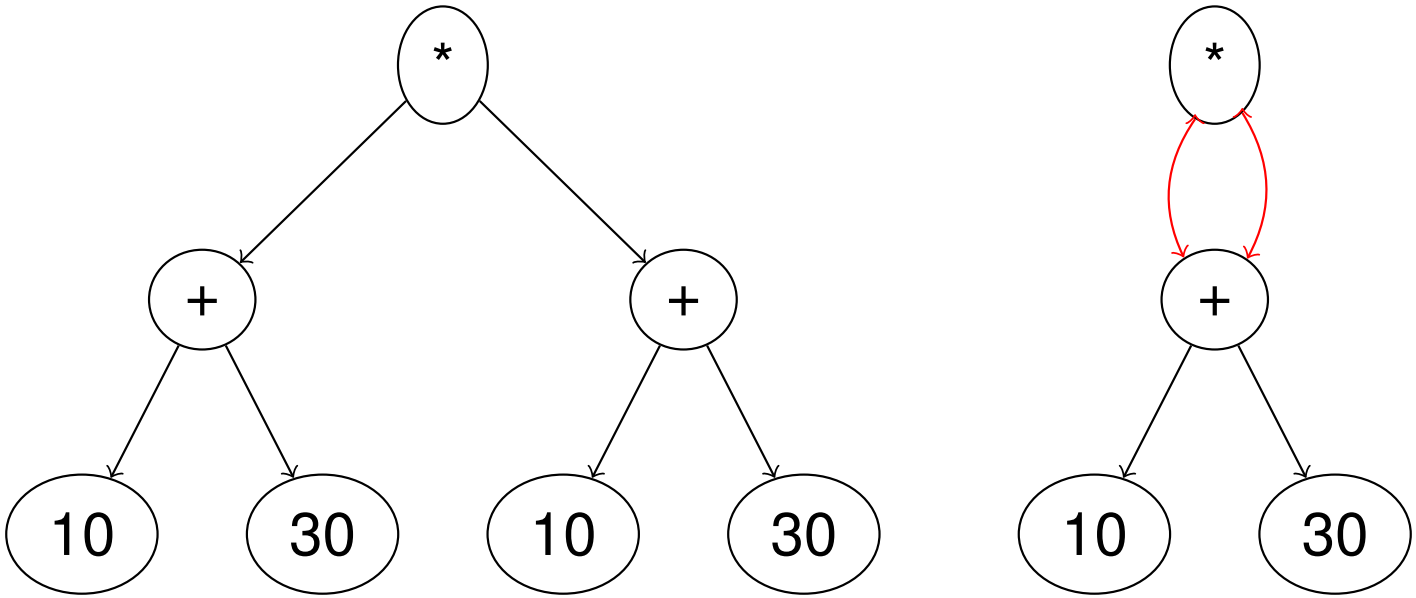
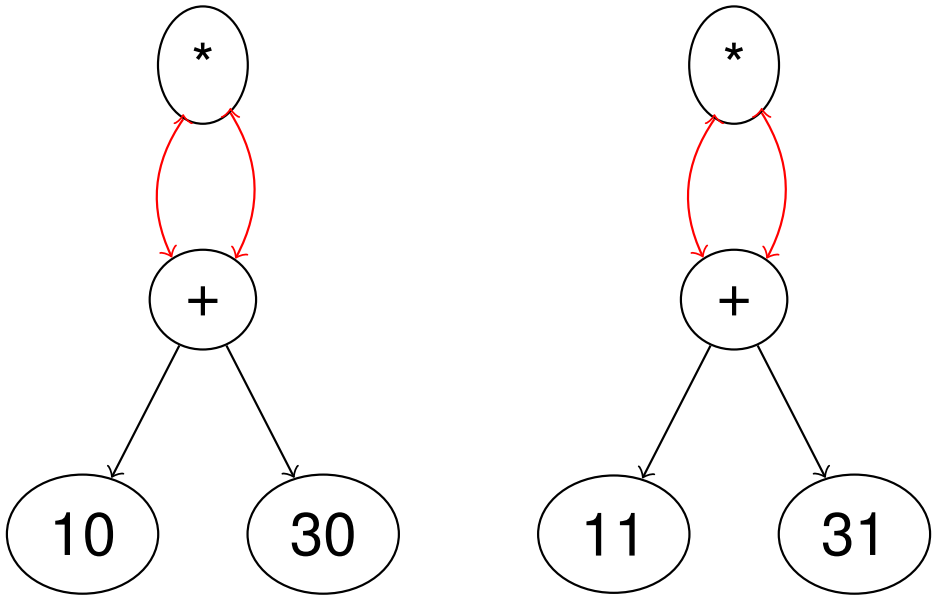
10
30
50
70
50
35
55

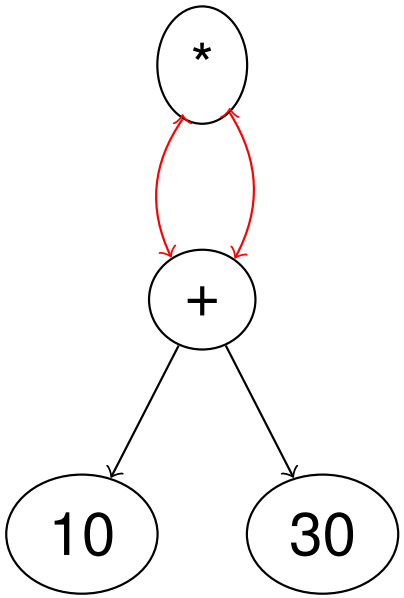
# Shared References and Mathematical Purity

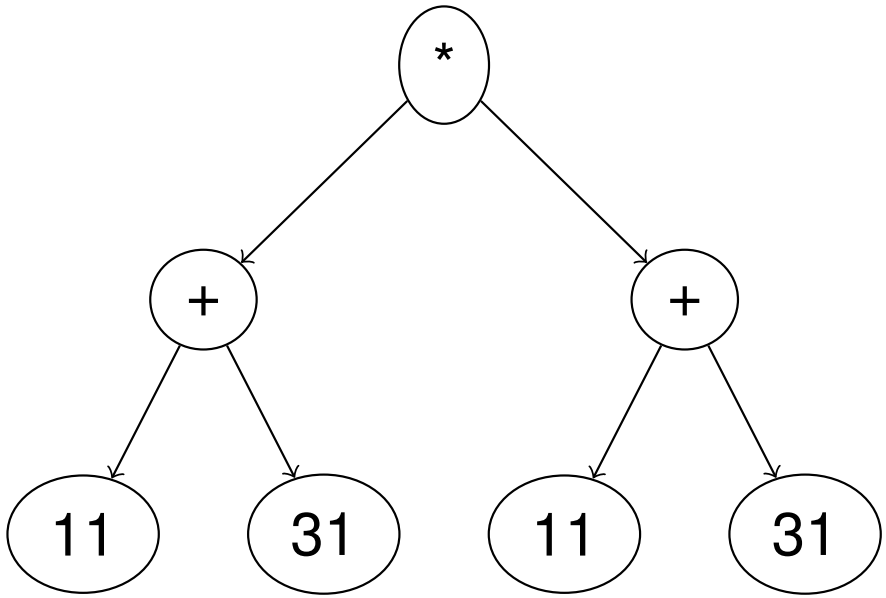


# How to do this?



# And not this?



# Some Solutions

- Hard code the functions. (Yuck)
- Use a “trace”. (Works, but cumbersome.)
- Build a new language construct!

# Smart Data Structures

- We can't check where sharing occurs.
- Maybe the data structure can keep track of sharing for us.

```
(defn app [f x] ((first x) f))

(defn mk-const [x]
  [(fn [f] (mk-const (f x))) x])

(defn mk-pair [a b]
  [(fn [f] (mk-pair (app f a) (app f b))) [a b]])

(defn mk-spair [a]
  [(fn [f] (mk-spair (app f a))) [a a]])

(defn loud-inc [x] (println "Inc called!") (+ x 1))
```

# Sample Run

- For a proof of concept, we try this with a pair that does not keep track of sharing.

```
user> (def c1 (mk-const 10))
user> (def p1 (mk-pair c1 c1))
user> p1
[<@28b6e768> [[<@1271ba> 10] [<@1271ba> 10]]]
user> (app loud-inc p1)
Inc called!
Inc called!
[<@239d5fe6> [[<@3103074e> 11] [<@3dd4ab05> 11]]]
```

# Sample Run, ctd.

- This time, the pair is smart about things.

```
user> (def p2 (mk-spair c1))
user> p2
[<@67ce08c7> [[<@1271ba> 10] [<@1271ba> 10]]]
user> (app loud-inc p2)
Inc called!
[<@38f0b51d> [[<@4302a01f> 11] [<@4302a01f> 11]]]
```

# Future Work

- We'd like this to be less cumbersome.
- In fact, we'd like this to be done completely behind the scenes.