CSE 341
Section 7

Fall 2018

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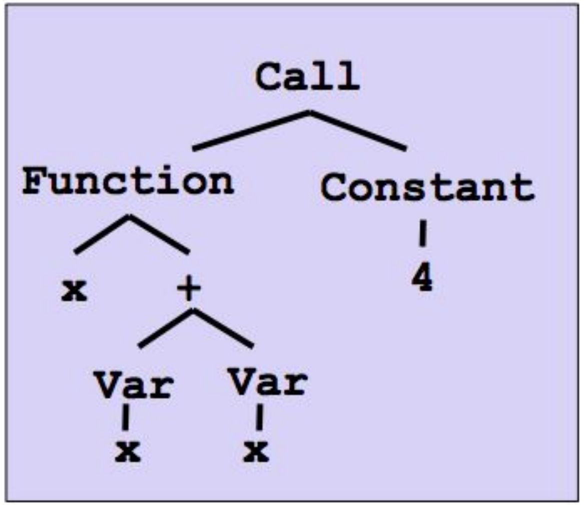
Outline

- Interpreting LBI (Language Being Implemented)
  - Assume Correct Syntax
  - Check for Correct Semantics
  - Evaluating the AST
- LBI “Macros”
- Eval, Quote, and Quasiquote
- Variable Number of Arguments
- Apply

Building an LBI Interpreter

- We are skipping the parsing phase ← **Do Not Implement**
  - Can be skipped because AST ("Abstract Syntax Tree") nodes represented as Racket structs.
- LBI vs. Metalanguage:
  - MUPL is the LBI.
  - Racket is the "metalanguage".



A larger language example...

```
(struct const (int) #:transparent)
(struct negate (e1)#:transparent)
(struct add (e1 e2) #:transparent)
(struct bool (b)#:transparent)
(struct multiply (e1 e2)#:transparent)
(struct eq-num (e1 e2)#:transparent)
(struct if-then-else (e1 e2 e3)#:transparent)
```

LBI → ***`(add (const 1) (const 1))`***
Metalanguage → Racket structs/operations on structs/the above code.

Correct Syntax Examples

Using these Racket structs…

```
(struct const (int) #:transparent)
(struct add (e1 e2) #:transparent)
(struct if-then-else (e1 e2 e3)#:transparent)
```

…we can interpret these LBI programs:

```
(const 34)
(add (const 34) (const 30))
(if-then-else (bool #t) (const 10) (const 20))
```

Incorrect Syntax Examples

While using these Racket structs…

```
(struct const (int) #:transparent)
(struct add (e1 e2) #:transparent)
(struct if-then-else (e1 e2 e3)#:transparent)
```

…we can assume we won't see LBI programs like:

```
(const "dan then dog")
(add 5 4)
(if-then-else (bool '(1 2)) (const 5) (bool #f))
```

Illegal input ASTs may crash the interpreter - this is OK

Racket vs. LBI

Structs in Racket, when defined to take an argument, can take any Racket value:

```
(struct const (int) #:transparent)
(struct add (e1 e2) #:transparent)
(struct if-then-else (e1 e2 e3)#:transparent)
```

But in LBI, we restrict `const` to take only an integer value, `add` to take two LBI expressions, and so on…

```
(const “dan then dog”)
(add 5 4)
(if-then-else (bool ‘(1 2)) (const 5) (bool #f))
```

Illegal input ASTs may crash the interpreter - this is OK

Check for Correct Semantics

What if the program is a legal AST, but evaluation of it tries to use the *wrong* kind of value?

```
(struct const (int) #:transparent)
(struct add (e1 e2) #:transparent)
(struct if-then-else (e1 e2 e3)#:transparent)
```

This is invalid LBI syntax that we need to check for...

```
(add (const 1) (bool #t))
(if-then-else (const 5) (const 5) (bool #f))
```

- You should detect this and give an error message that is not in terms of the interpreter implementation

Evaluating the AST

- **`eval-exp`** should return a LBI value
- LBI values all evaluate to themselves
- Otherwise, we haven't interpreted far enough

```
(const 7)  ; evaluates to (const 7)
(add (const 3) (const 4)) ; evaluates to (const 7)
```

Evaluating the AST

- What’s wrong with this implementation of eval? (other than it being called “eval-exp-wrong”...)

Evaluating the AST

- It doesn’t recursively check for semantic correctness!
    - Let’s see a better version of this...

Macros Review

- Extend language syntax (allow new constructs)
- Written in terms of existing syntax
- Expanded before language is actually interpreted or compiled

LBI "Macros"

- Interpreting LBI using Racket as the metalanguage
- LBI is made up of Racket structs
- In Racket, these are just data types
- Why not write a Racket function that returns LBI ASTs?

LBI “Macros”

If our LBI Macro is a Racket function

```
(define (++ exp) (add (const 1) exp))
```

Then the LBI code

```
(++ (++ (const 7)))
```

Expands to

```
(add (const 1) (add (const 1) (const 7)))
```

LBI “Macros”

If our LBI Macro is a Racket function

```
(define (andalso e1 e2) (if-then-else e1 e2 (bool #f)))
```

Then the LBI code

```
(andalso (bool #t) (bool #t))
```

Expands to

```
(if-then-else (bool #t) (bool #t) (bool #f))
```

`quote`

- Syntactically, Racket statements can be thought of as lists of tokens
- **`(+ 3 4)`** is a “plus sign”, a “3”, and a “4”
- **`quote`**-ing a parenthesized expression produces a list of tokens

`quote` Examples

```
(+ 3 4) ; 7

; '(+ 3 4)
(quote (+ 3 4))
`(+ 3 4)

; '(+ 3 #t)
(quote (+ 3 #t))
`(+ 3 #t)
```

`quasiquote`

- Inserts evaluated tokens into a quote
- Convenient for generating dynamic token lists
- Use `unquote` to escape a `quasiquote` back to evaluated Racket code
- A `quasiquote` and `quote` are equivalent unless we use an `unquote` operation

Self Interpretation

- Many languages provide an **`eval`** function or something similar
- Performs interpretation or compilation at runtime
  - Needs full language implementation during runtime
- It's useful, but there's usually a better way
- Makes analysis, debugging difficult

`eval`

- Racket's **`eval`** operates on lists of tokens
- Like those generated from **`quote`** and **`quasiquote`**
- Treat the input data as a program and evaluate it

Variable Number of Arguments

- Some functions (like **+**) can take a variable number of arguments
- There is syntax that lets you define your own

```
(define fn-any
  (lambda xs                ; any number of args
    (print xs)))
(define fn-1-or-more
  (lambda (a . xs)          ; at least 1 arg
    (begin (print a) (print xs))))
(define fn-2-or-more
  (lambda (a  b . xs)  ; at least 2 args
```

`apply`

- Applies a list of values as the arguments to a function in order by position

```
(define fn-any
  (lambda xs ; any number of args
    (print xs)))
(apply fn-any (list 1 2 3 4))

(apply + (list 1 2 3 4))    ; 10
(apply max (list 1 2 3 4))  ; 4
```