CSCI 334:
Principles of Programming Languages

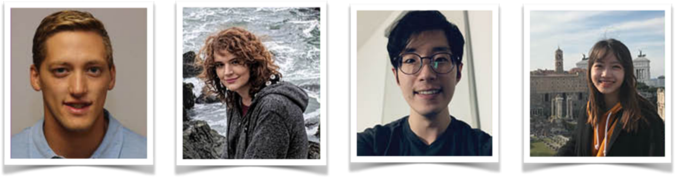
Lecture 5: PL Fundamentals III

Instructor: Dan Barowy

Williams

Announcements

Colloquium today:
thesis presentations in Wege, 2:30pm



(they've all worked really hard—
show support for your fellow CS Ephs!)

Announcements

- Reminder: no laptops during class
- Recording lectures?
- Lab 3 handout
- `qtree` LaTeX package
- Lab 1 solutions

Outline

- Quiz
- Life tip
- Moar lambda calculus

Quiz

Life Tip

Confusion is not necessarily a bad thing.

Life Tip

Sometimes Confusion is a Good Thing
Tania Lombrozo
NPR, December 14, 2015

"Students who were confused … as reflected in inconsistent responses on subsequent questions … ultimately did better on a final test assessing whether they learned the key points from the lessons."

`https://www.npr.org/sections/13.7/2015/12/14/459651340/sometimes-confusion-is-a-good-thing`

Life Tip

Sometimes Confusion is a Good Thing
Tania Lombrozo
NPR, December 14, 2015

"One possibility is that confusion is … a marker that an important cognitive process has taken place: The learner has appreciated some inconsistency or deficit in her prior beliefs. … [A]nother possibility is that confusion is itself a step toward learning — an experience that motivates the learner to reconcile an inconsistency or remedy some deficit. In this view, confusion isn't just a side effect of beneficial cognitive processes, but a beneficial process itself. Supporting this stronger view, there's evidence that experiencing difficulties in learning can sometimes be desirable, leading to deeper processing and better long-term memory."

`https://www.npr.org/sections/13.7/2015/12/14/459651340/sometimes-confusion-is-a-good-thing`

Life Tip

The importance of stupidity in scientific research
Martin A. Schwartz
Journal of Cell Science 2008 121: 1771 doi: 10.1242/jcs.033340

“Focusing on important questions puts us in the awkward position of being ignorant. One of the beautiful things about science is that it allows us to bumble along, getting it wrong time after time, and feel perfectly fine as long as we learn something each time. No doubt, this can be difficult for students who are accustomed to getting the answers right.”

Life Tip

Confusion is not necessarily a bad thing.

It is a signal that you are not confident in your knowledge.

Use this signal to guide your study.

Life Tip

Happy/sad cards

Example

```
(λa.λb.(- a b)) 2 1
```

What am I doing?

Where do I start?

Another way to find redexes

```
(λa.(λz.(+ x z))((λz.(+ x z)) a )) 2
```

Leftmost order: `(λa.(λz.(+ x z))((λz.(+ x z)) a )) 2`

Rightmost order: `(λa.(λz.(+ x z))((λz.(+ x z)) a )) 2`

Neither: `(λa.(λz.(+ x z))((λz.(+ x z)) a )) 2`

Another way to find redexes

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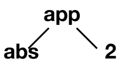

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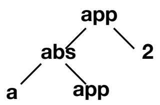

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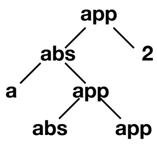

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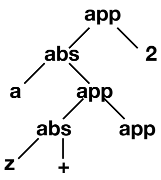

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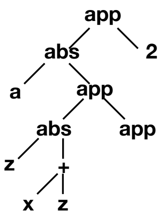

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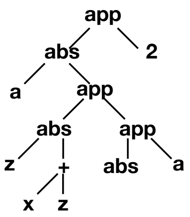

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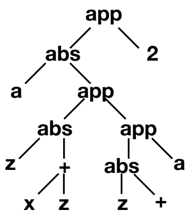

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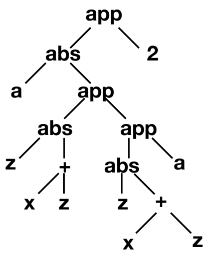

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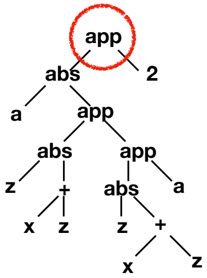

When I say *leftmost*, I mean: "leftmost outermost" application

Another way to find redexes

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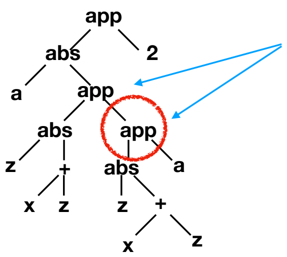

Q: Wait! Isn't there a "more left" app?

A: Yes, but it is not the *innermost*. "Leftmost" is used to break ties among multiple innermost apps.

When I say *rightmost* I mean: "leftmost innermost" application

MMM

$\underline{\texttt{(MM)M}}$ or $\texttt{M(MM)}$?

(remember this rule!!!)

Example

`(λa.λb.(- a b)) 2 1`

Reduction strategies

$$\underbrace{\texttt{(}\lambda\texttt{x.y)}}_{\text{function}}\underbrace{\texttt{((}\lambda\texttt{x.x x)(}\lambda\texttt{x.x x))}}_{\text{argument}}$$

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$$\underbrace{\texttt{(}\lambda\texttt{x.y)}}_{\text{function}}\underbrace{\texttt{((}\lambda\texttt{x.x x)(}\lambda\texttt{x.x x))}}_{\text{argument}}$$

Leftmost reduction:
Choose the leftmost redex first.

1. `([(λx.x x)(λx.x x)/x]y)`
2. `y`

Reduction strategies

$$\texttt{(}\lambda\texttt{x.y)(}\underbrace{\texttt{(}\lambda\texttt{x.x x)}}_{\text{function}}\underbrace{\texttt{(}\lambda\texttt{x.x x)}}_{\text{argument}}\texttt{)}$$

Rightmost reduction:
Choose the rightmost redex first.

1. `(λx.y)(([(λx.x x)/x]x x))`
2. $\texttt{(}\lambda\texttt{x.y)(}\underline{\texttt{(}\lambda\texttt{x.x x)}}\,\underline{\texttt{(}\lambda\texttt{x.x x)}}\texttt{)}$
3. `(λx.y)(([(λx.x x)/x]x x))`
4. uh oh…

Activity

Leftmost reduction:

`(λf.λx.f(f x))(λz.(+ x z))2`

α-Reduction:

`λx.<expr> =`$_\alpha$` λy.[y/x]<expr>`

β-Reduction:

`(λx.<expr>)y =`$_\beta$` [y/x]<expr>`

`[y/x]` means “substitute `y` for `x` in `<expr>`”

Activity

Rightmost reduction:

`(λf.λx.f(f x))(λz.(+ x z))2`

α-Reduction:

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β-Reduction:

`(λx.<expr>)y =`$_\beta$` [y/x]<expr>`

`[y/x]` means “substitute `y` for `x` in `<expr>`”

Recap & Next Class

Today we covered:

Lambda calculus

Next class:

Computability