Functional Programming in Education

George Wilson

Data61/CSIRO

george.wilson@data61.csiro.au

22nd May 2018

University

First year, first semester

Which language?

```java
class Hello {

  public static void main(String[] args) {
    System.out.println("Hello, world!");
  }

}
```

	Content
Week 1	Basic expressions
Week 2	procedure declarations
Week 3	if-statement
Week 4	while-statement
Week 5	for-statement
...	

Structure and Interpretation of Computer Programs

Second Edition

Harold Abelson and
Gerald Jay Sussman
with Julie Sussman

```scheme
(define (factorial n)
  (if (<= n 1)
      1
      (* n (factorial (- n 1)))))
```

Evaluation by substitution

```
(define (sum-of-squares x y)
  (+ (sqr x) (sqr y)))
```

Evaluation by substitution

```
(define (sum-of-squares x y)
  (+ (sqr x) (sqr y)))
```

```
     (sum-of-squares 3 4)
```

Evaluation by substitution

```
(define (sum-of-squares x y)
  (+ (sqr x) (sqr y)))
```

```
     (sum-of-squares 3 4)
=>   (+ (sqr 3) (sqr 4))
```

Evaluation by substitution

```
(define (sum-of-squares x y)
  (+ (sqr x) (sqr y)))
```

```
     (sum-of-squares 3 4)
=>   (+ (sqr 3) (sqr 4))
=>   (+ (* 3 3) (sqr 4))
```

Evaluation by substitution

```
(define (sum-of-squares x y)
  (+ (sqr x) (sqr y)))
```

```
     (sum-of-squares 3 4)
=>   (+ (sqr 3) (sqr 4))
=>   (+ (* 3 3) (sqr 4))
=>   (+ 9 (sqr 4))
```

Evaluation by substitution

```
(define (sum-of-squares x y)
  (+ (sqr x) (sqr y)))
```

```
     (sum-of-squares 3 4)
=>   (+ (sqr 3) (sqr 4))
=>   (+ (* 3 3) (sqr 4))
=>   (+ 9 (sqr 4))
=>   (+ 9 (* 4 4))
```

Evaluation by substitution

```
(define (sum-of-squares x y)
  (+ (sqr x) (sqr y)))
```

```
     (sum-of-squares 3 4)
=>   (+ (sqr 3) (sqr 4))
=>   (+ (* 3 3) (sqr 4))
=>   (+ 9 (sqr 4))
=>   (+ 9 (* 4 4))
=>   (+ 9 16)
```

Evaluation by substitution

```
(define (sum-of-squares x y)
  (+ (sqr x) (sqr y)))
```

```
     (sum-of-squares 3 4)
=>   (+ (sqr 3) (sqr 4))
=>   (+ (* 3 3) (sqr 4))
=>   (+ 9 (sqr 4))
=>   (+ 9 (* 4 4))
=>   (+ 9 16)
=>   25
```

```
(factorial 6)
(* 6 (factorial 5))
(* 6 (* 5 (factorial 4)))
(* 6 (* 5 (* 4 (factorial 3))))
(* 6 (* 5 (* 4 (* 3 (factorial 2)))))
(* 6 (* 5 (* 4 (* 3 (* 2 (factorial 1))))))
(* 6 (* 5 (* 4 (* 3 (* 2 1)))))
(* 6 (* 5 (* 4 (* 3 2))))
(* 6 (* 5 (* 4 6)))
(* 6 (* 5 24))
(* 6 120)
720
```

Incredible breadth of content

complexity analysis

symbolic computation with quotation

interpreters

object-oriented programming

logic programming

many other concepts

PR

received April 198

A critique of Abelson and Sussman
- or -
Why calculating is better than scheming

Philip Wadler
Programming Research Group
11 Keble Road
Oxford, OX1 3QD

Abelson and Sussman have written an excellent textbook which may start a revolution in the way programming is taught [Abelson and Sussman 1985a, b]. Instead of emphasizing a particular programming language, they emphasize standard engineering techniques as they apply to programming. Still, their textbook is intimately tied to the Scheme dialect of Lisp. I believe that the same approach used in their text, if applied to a language such as KRC or Miranda, would result in an even better introduction to programming as an engineering discipline. My belief has strengthened as my experience in teaching with Scheme and with KRC has increased.

```
perimeter shape =
  case shape of
    Square s        -> s * 4
    Rectangle w h -> 2*w + 2*h
    Circle r        -> 2 * pi * r
```

```
(define (sum items)
  (cond ((null? items) 0)
        (else (+ (car items) (sum (cdr items))))))
```

```scheme
(define (sum items)
  (cond ((null? items) 0)
        (else (+ (car items) (sum (cdr items))))))
```

```haskell
sum items = case items of
  []   -> 0
  x:xs -> x + sum xs
```

```haskell
[] ++ ys       =  ys
(x:xs) ++ ys   =  x:(xs ++ ys)

(xs ++ ys) ++ zs = xs ++ (ys ++ zs)
```

Criticisms

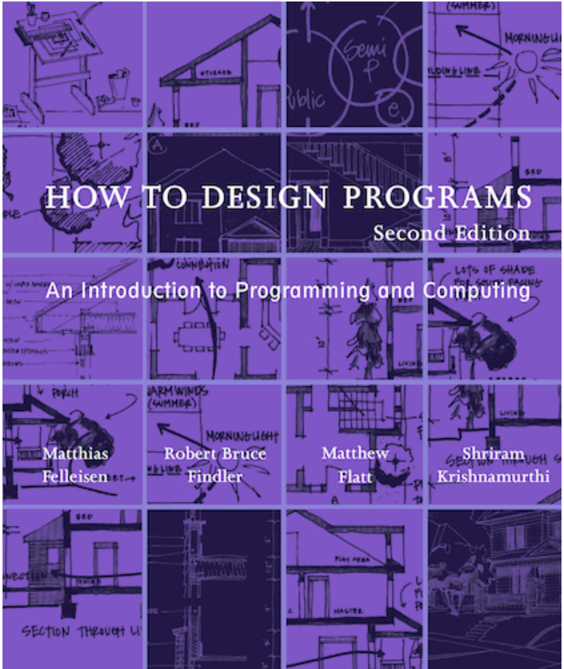
Examples are drawn from overly-technical domains

```
(define (deriv exp var)
  (cond ((number? exp) 0)
        ((variable? exp)
         (if (same-variable? exp var) 1 0))
        ((sum? exp)
         (make-sum (deriv (addend exp) var)
                   (deriv (augend exp) var)))
        ((product? exp)
         (make-sum
           (make-product (multiplier exp)
                         (deriv (multiplicand exp) var))
           (make-product (deriv (multiplier exp) var)
                         (multiplicand exp))))
        (else
         (error "unknown expression type -- DERIV" exp))))
```

Criticisms

Lacking coverage of foundational problem-solving techniques

> From an educational point of view, our experience suggests that undergraduate computer science courses should emphasize basic notions of modularity, specification, and data abstraction, and should not let these be displaced by more advanced topics, such as design patterns, object-oriented methods, concurrency, functional languages, and so on.
>
> — Jackson and Chapin, 2000 (emphasis mine)



HOW TO DESIGN PROGRAMS

Second Edition

An Introduction to Programming and Computing

Matthias Felleisen
Robert Bruce Findler
Matthew Flatt
Shriram Krishnamurthi

prologue.rkt - DrRacket

File Edit View Language Racket Insert Scripts Tabs Help

prologue.rkt ▾ (define ...) ▾

```
(require 2htdp/image)
(require 2htdp/universe)
```

(define rocket )

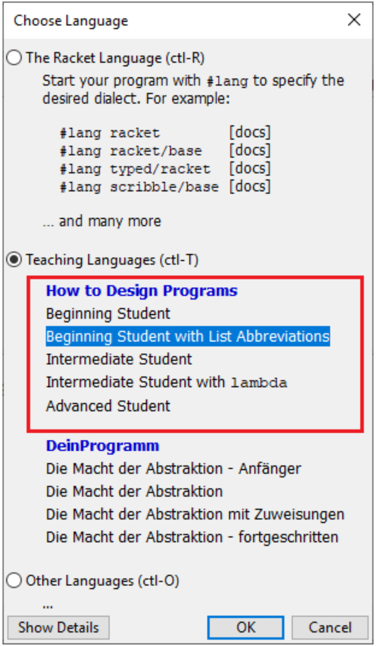
```
(define (picture-of-rocket height)
  (place-image rocket 50 height (empty-scene 100 60)))

(define (sign x)
  (cond ((> x 0) 1)
        ((= x 0) 0)
        ((< x 0) -1)))

(define (picture-of-rocket.v2 height)
  (cond
    [(<= height 60)
     (place-image  50 height
                   (empty-scene 100 60))]
    [(> height 60)
     (place-image  50 60
                   (empty-scene 100 60))]))
```

Welcome to DrRacket, version 7.2 [3m].
Language: Beginning Student; memory limit: 128 MB.

```
> (picture-of-rocket.v2 5555)
place-image: expects 4 arguments, but found only 3
> 
```


Choose Language
The Racket Language (ctl-R)
Start your program with #lang to specify the desired dialect. For example:
#lang racket [docs]
#lang racket/base [docs]
#lang typed/racket [docs]
#lang scribble/base [docs]
... and many more
Teaching Languages (ctl-T)
How to Design Programs
Beginning Student
Beginning Student with List Abbreviations
Intermediate Student
Intermediate Student with lambda
Advanced Student
DeinProgramm
Die Macht der Abstraktion - Anfänger
Die Macht der Abstraktion
Die Macht der Abstraktion mit Zuweisungen
Die Macht der Abstraktion - fortgeschritten
Other Languages (ctl-O)
...
Show Details
OK
Cancel

Robert Harper on type theory, and Daniel Jackson on software design.

1. **From Problem Analysis to Data Definitions**

   Identify the information that must be represented and how it is represented in the chosen programming language. Formulate data definitions and illustrate them with examples.

2. **Signature, Purpose Statement, Header**

   State what kind of data the desired function consumes and produces. Formulate a concise answer to the question *what* the function computes. Define a stub that lives up to the signature.

3. **Functional Examples**

   Work through examples that illustrate the function's purpose.

4. **Function Template**

   Translate the data definitions into an outline of the function.

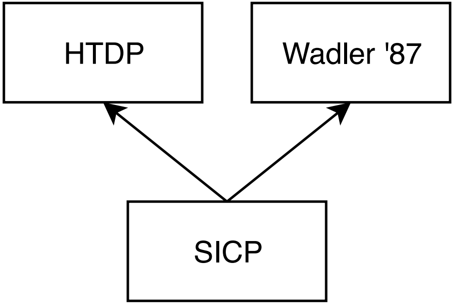
5. **Function Definition**

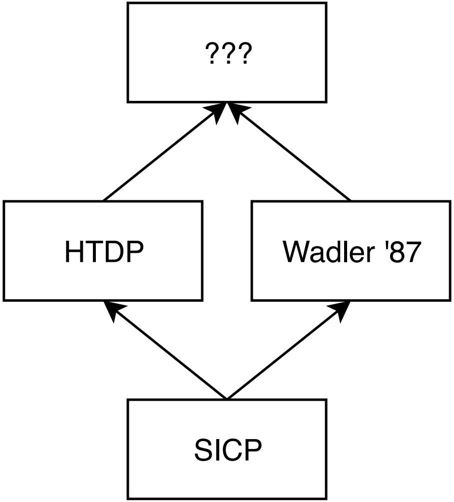
   Fill in the gaps in the function template. Exploit the purpose statement and the examples.

6. **Testing**

   Articulate the examples as tests and ensure that the function passes all. Doing so discovers mistakes. Tests also supplement examples in that they help others read and understand the definition when the need arises—and it will arise for any serious program.

Figure 1: The basic steps of a function design recipe


HTDP
Wadler '87
SICP


???
HTDP
Wadler '87
SICP

haskell for mac screenshot

3 + False

```
<interactive>:1:1: error:
    • No instance for (Num Bool) arising from a use of ‘+’
    • In the expression: 3 + False
      In an equation for ‘it’: it = 3 + False
```

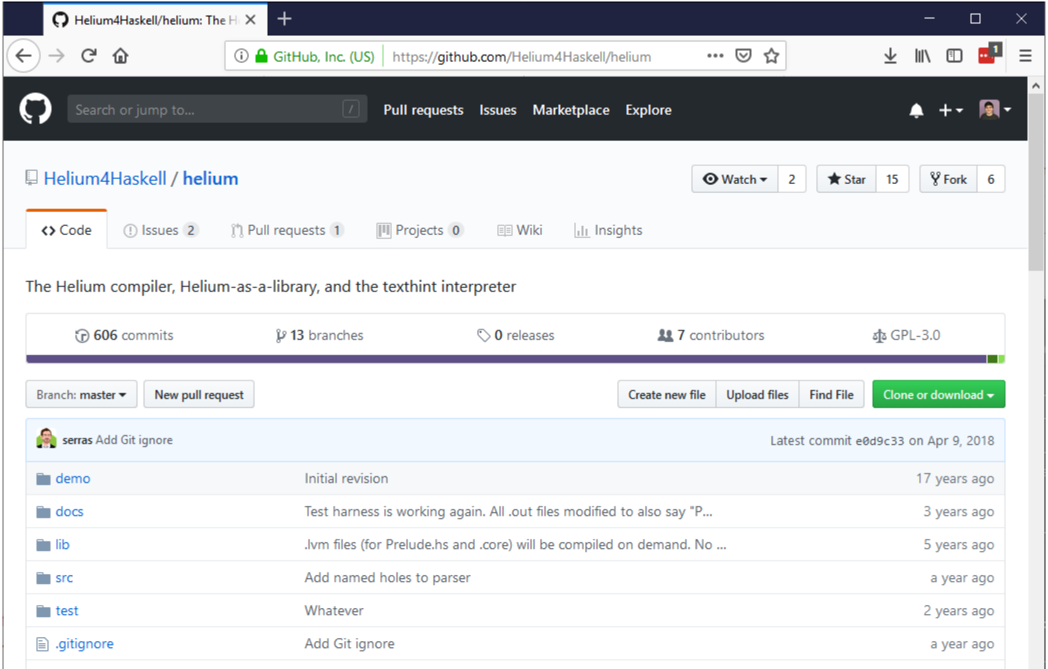
Prelude.hs

```haskell
module Prelude
   ( N.Integer, (+)
   , (==), Bool (..)
   )
where

import Data.Bool (Bool (..))
import qualified Data.Eq as E
import GHC.Num (Integer)
import qualified GHC.Num as N

(+) :: Integer -> Integer -> Integer
(+) = (N.+)

(==) :: Integer -> Integer -> Bool
(==) = (E.==)
```


Helium4Haskell/helium: The H
GitHub, Inc. (US)
https://github.com/Helium4Haskell/helium
Search or jump to...
Pull requests
Issues
Marketplace
Explore
Helium4Haskell / helium
Watch 2
Star 15
Fork 6
Code
Issues 2
Pull requests 1
Projects 0
Wiki
Insights
The Helium compiler, Helium-as-a-library, and the texthint interpreter
606 commits
13 branches
0 releases
7 contributors
GPL-3.0
Branch: master
New pull request
Create new file
Upload files
Find File
Clone or download
serras Add Git ignore
Latest commit e0d9c33 on Apr 9, 2018
demo
Initial revision
17 years ago
docs
Test harness is working again. All .out files modified to also say "P...
3 years ago
lib
.lvm files (for Prelude.hs and .core) will be compiled on demand. No ...
5 years ago
src
Add named holes to parser
a year ago
test
Whatever
2 years ago
.gitignore
Add Git ignore
a year ago

custom type error machinery in GHC

Thanks for listening!