On Teaching *How to Design Programs*

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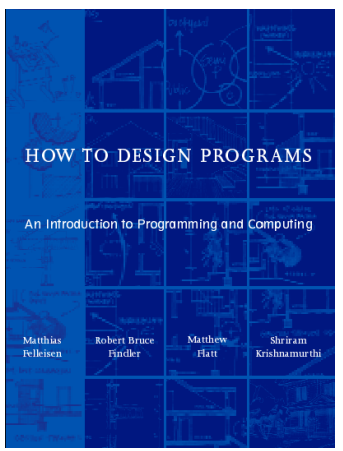
I want to help teachers

How to teach

How to Design Programs

(Felleisen, Findler, Flatt, Krishnamurthi)



(Even if you have never touched Racket)

Paper has hints, observations, problems

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This talk:

- **The design method**
- **What's hard for students**
- **An outsider's view of the technology**
- **One open problem**

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- The design method
- What's hard for students
- An outsider's view of the technology
- One open problem

In the paper:

- Traps and pitfalls
- Much more of all the above

“Systematic problem-solving,” not “functional programming”

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“Systematic problem-solving,” not “functional programming”

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Describe data

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Review and refactor

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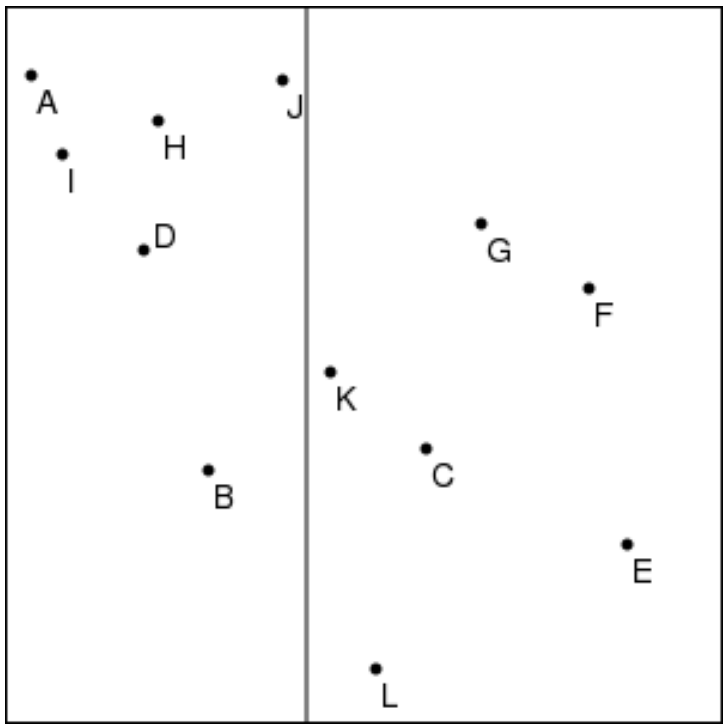
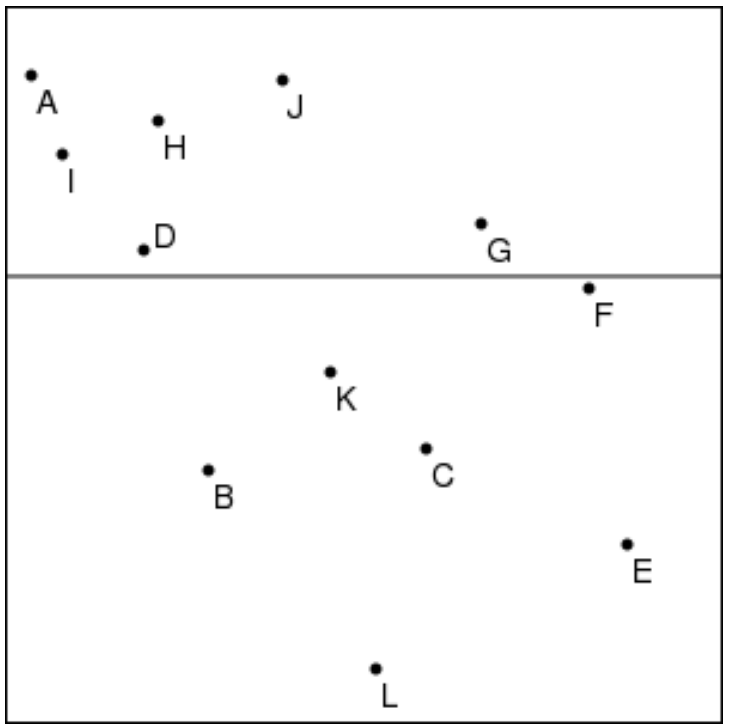
Review and refactor

Example: Beginners can work with 2D-trees

Data examples:





Example: 2D-tree data definition

A `(2Dpoint A)` is a structure `(make-point x y value)`
where `x` and `y` are numbers and `value` is an `A`.

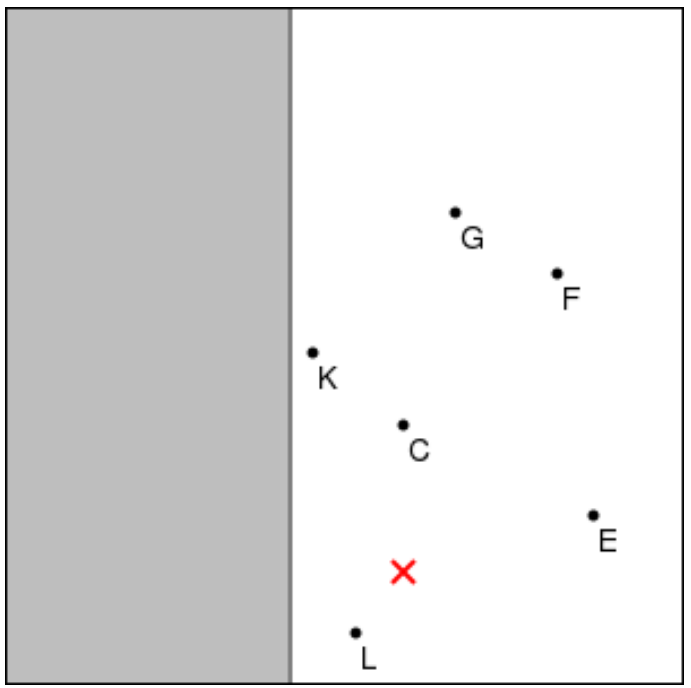
A `(2Dtree A)` is one of the following:

- A `(2Dpoint A)`
- A structure `(make-v-boundary left x right)`, where
  - `x` is a number,
  - `left` is a `(2Dtree A)` in which every point has an x coordinate at most `x`, and
  - `right` is a `(2Dtree A)` in which every point has an x coordinate at least `x`
- A structure `(make-h-boundary above y below)` ...

Nearest point: functional example

Problem 5, homework 9 (of 11)

Find the point nearest ×:



Answer: L

Nearest point: functional example

Problem 5, homework 9 (of 11)

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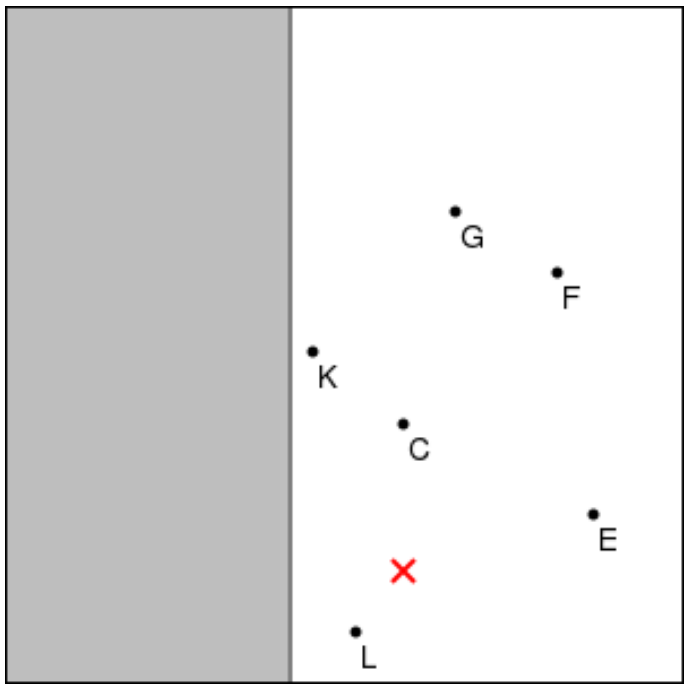

Answer: L

(Later: nearest hospital)

Nearest point: description

```
; nearest-point :
;     number number (2Dtree A) -> (2Dpoint A)
; *efficiently* returns the point in the given tree
;   that is closest to the given (x, y) coordinates
(define (nearest-point x y tree)
  (cond [(point? tree) tree]
        [(h-boundary? tree)
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Part II

What's Hard?

Type-directed programming is hard

Templates are constructed based on type of input.

If input is		
	Atomic	use library functions
	Sum	use `cond`
	Product	use selector functions
	Arrow	Apply it

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OMG the flaws!

Most common: repeated elimination of sums, products

(Paper, Section 3)

“Purpose statements” are hard

Hard in semesters 1, 2, 3, and 4

Reasonably good early examples:

```
;;meters->english; number -> string
;;input the distance in meters then
;;    converts them to english
```

```
;; move-big-hand : time -> time
;; adds one minute to time structure
```

After 5 weeks:

```
;; stations-on : railway -> list-of-stations
;; returns an ordered list of all stations
;;   on the railway, southernmost first
```

Recommendation: “Review and refactor”

Purpose statement's acid test: recursion

Vague purpose statement? Mentally inline the code.

- **"Works" until functions become recursive**

Students are very aggressive inliners

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Diagnosis: difficulty with procedural abstraction

Part III
The technology

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⋮	
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The major win:

Don’t be fooled by the DrRacket IDE

GUI often distracted or frustrated students

- **Designed for full Racket, including Help**
- **Mysterious program analyses (colored arrows)**

The major win:

Every time you compile,
untested code is thrown in your face

Result: students think testing is essential

Go deep into “world programs”

ICFP’09:

- **Interactive apps by composing pure functions**
- **“Build a program like applications students use”**

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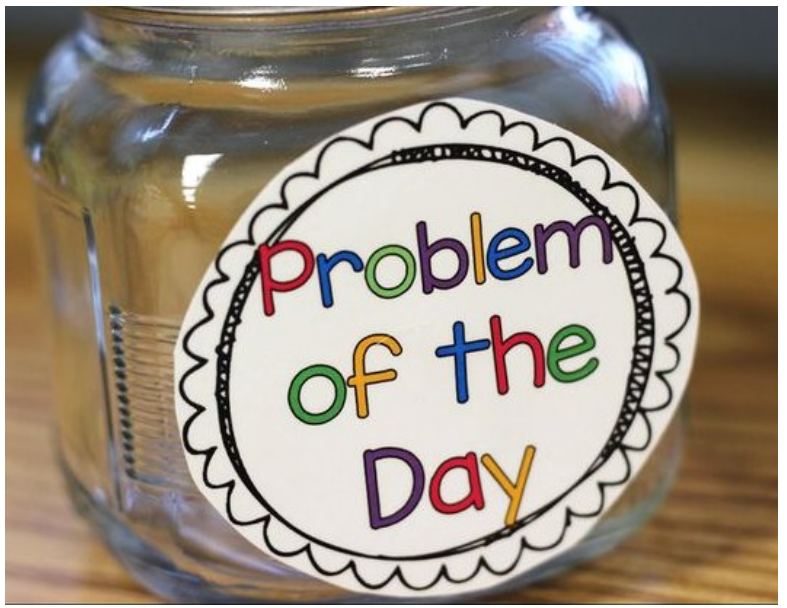
- **Look at world; see data; define representation**
- **Design *programs*, not just functions**
- **Make choices that matter**

Part IV: An open problem



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Open problems: Find a middle ground

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Open problems: Find a middle ground

Identify "primary traits?"

Conclusion:

Try it yourself

HtDP: low cost, high reward

- Delivers effective problem-solving
  - Good for students
  - Easy to sell “systematic software development”
- The technology really helps
- Plenty of functional-programming goodness
- I had lots of fun

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Please contribute!

- Dare to make changes
- Help solve some open problems
  (Paper, Section 6)

From end-of-term self-assessment

I didn't grasp the importance of laying out a template. I got into the habit of coding without templates. . . I didn't understand that by outlining the function based on input data, the design of the function was in many ways simplified and structured, making it harder to veer off course. Unfortunately, when data began to grow more complex, I failed to transition to using the template approach, and this resulted in a few uncomfortable weeks of coding. Without knowing how to establish a template based on the data of a function, I often felt very lost.

From end-of-term self-assessment

. . . As the problems became more complicated with more conditions, I realized that I couldn't do everything in my head. Writing [functional] examples concretizes each condition, its input and expected output, so that I can focus on solving one case at a time, which is significantly less daunting. Functional examples are also test cases which help me debug my code part by part.

From end-of-term self-assessment

While purpose statements are only written into the code for each individual function, they are useful for thinking about a problem as whole. [When] the entire problem is executed through one function which uses multiple helper functions, the signature and purpose statement make it easy to break down a problem into the individual parts addressed in each helper function. Often the change from one type of data with a certain meaning into another cannot be done in one step. Here it is the purpose statements and signatures that show each smaller step of the problem.