

Engaging, Large-Scale Functional Programming Education in Physical and Virtual Space

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Technical University of Munich

Supported by

- Lecturer: Tobias Nipkow
- Manuel Eberl
- 2019: 13 student assistants
- 2020: 22 student assistants

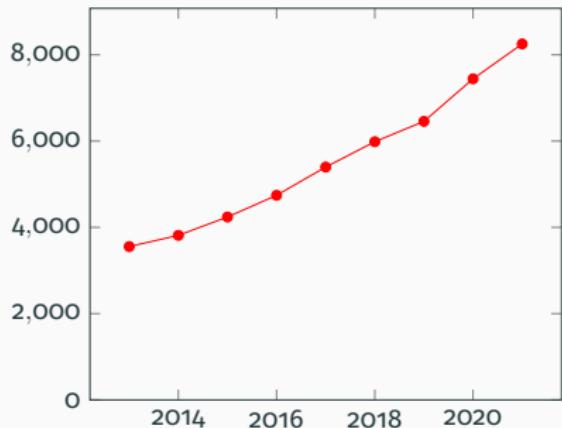
Challenges

Soaring Enrolments

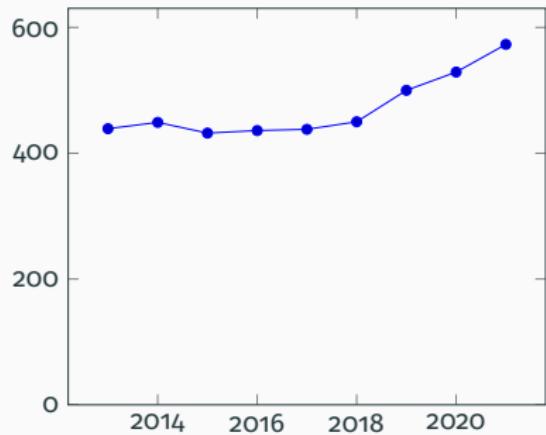
1. Number of Computer Science students exploded

Soaring Enrolments

Example: Computer Science at TU Munich



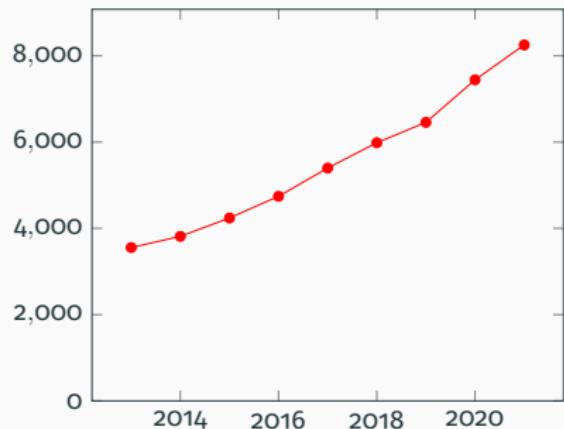
Number of CS students
(132% increase)



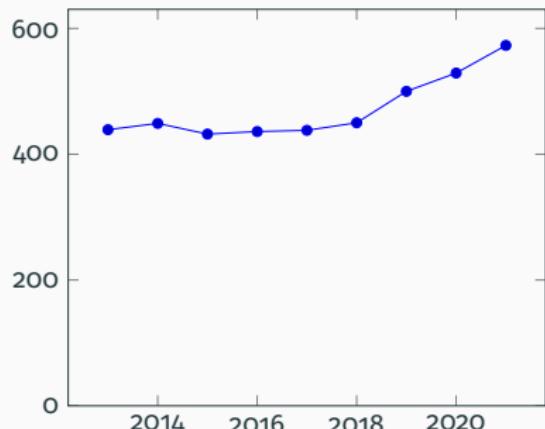
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1000+ students per course are the new normal

The Pandemic

2. Radical transition to online classes

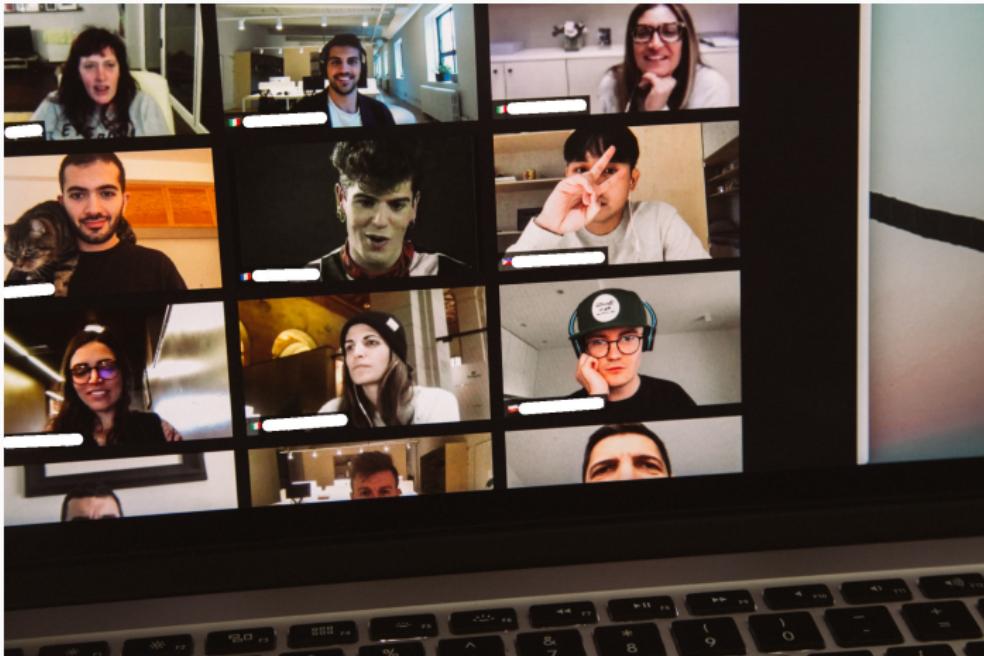
The Pandemic

How can we go from here...



The Pandemic

to here...



The Pandemic

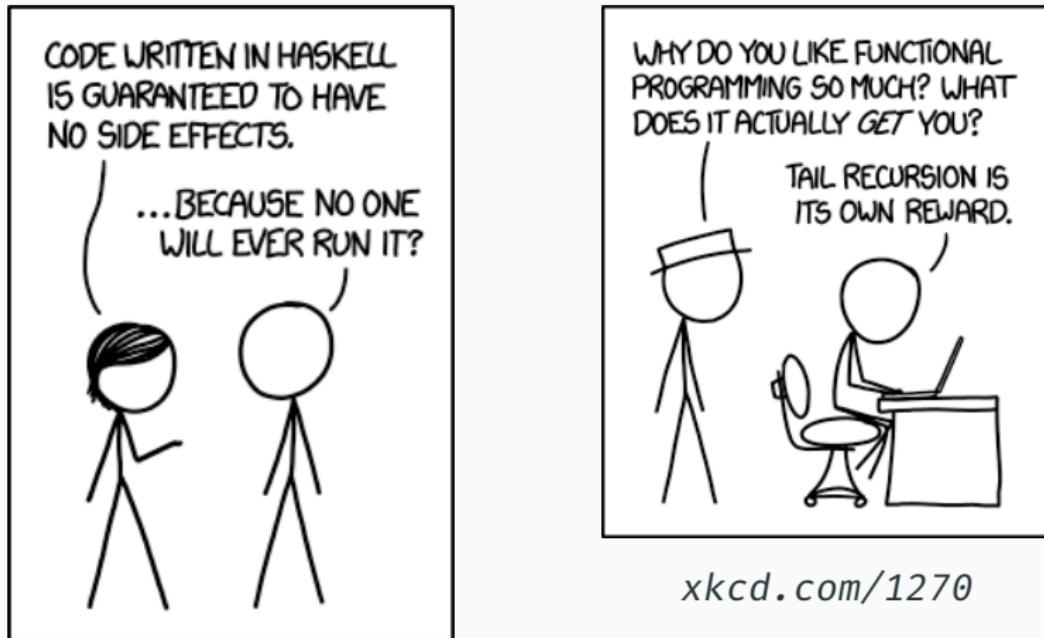
without ending up here?



Usefulness of Functional Programming

3. Students question the usefulness of functional languages beyond academia

Usefulness of Functional Programming



xkcd.com/1270

xkcd.com/1312

There is hope!

- We managed to cope with all these challenges

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- We share our insights, tools, and exercises for other educators

You can find our resources on:

hub.com/kappelmann/engaging-large-scale-functional-programming

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Note: We used Haskell, but most ideas apply to any functional programming course

Practical Part

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Engagement Mechanisms

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Result: number of homework submissions severely decreased

Instant Feedback

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 - Student assistants create engaging exercises instead

Workshops With Industry Partners

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- Little organisational work

Social Interactions

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- Online courses are isolating...
so let us foster social interaction:
 - Pair-programming in tutorials
 - ACM-ICPC-like programming contest
 - Get-together hangout sessions
 - Award ceremonies

Competitions

Offer challenges to go beyond the syllabus!

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- Diverse, weekly competition exercises

Competitions

Code Golf

```
numberToEo = unwords <<< catMaybes <<< reverse <<< flip lookup `zipWith` table <<< chunksOf 3
    <<< pack <<< reverse

topCycle = concatMap snd . ap zip (iterate . fmap nub . concatMap . dominators <*> copeland)

traceFractran rs n = n : fromMaybe [] (traceFractran rs <$> numerator <$>
    (liftM2 eqInteger truncate numerator) `find` map (fromIntegral n *) rs)

bernoulli = genericIndex $ map head $ iterate ((*) `zipWith` enumFrom 1 <<< zipWith subtract
    $ recip `map` enumFrom 1
```

Competitions

Optimization

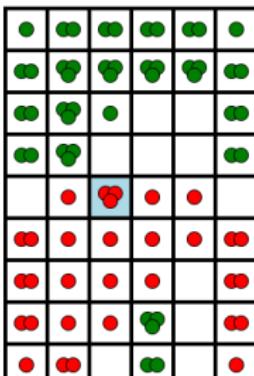
Rank	Name	Time [seconds]
1.	MC Jr	0.02
2.	Florian Hübler	0.13
2.	Luis Bahners	0.19
4.	Tobias Markus	0.35
4.	Robert Imschweiler	0.37
6.	Julian Pritzi	0.76

Competitions

Strategy

🕹 Tobias Markus vs. Severin Schmidmeier

🏆 Winner: 🟢 Severin Schmidmeier

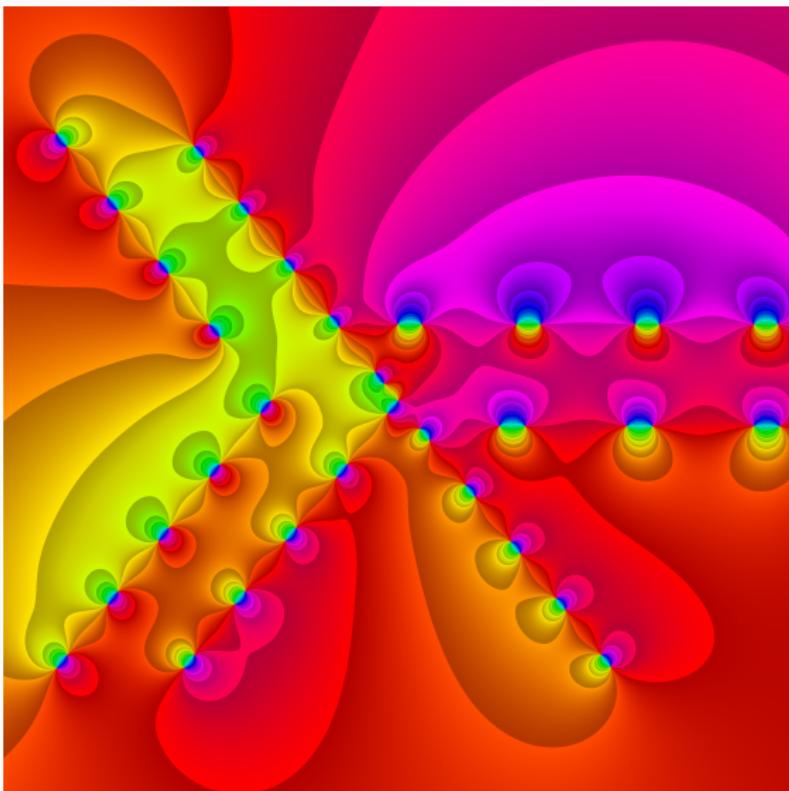


📊 Stats

🔴 Statistic	🔴 Tobias Markus	🟢 Severin Schmidmeier
Moves made	49	49
Orbs captured	40	89
Capture/loss ratio	0.4494	2.2250

Competitions

Creativity



Competitions

Creativity

```
module Exercise_13 where

import Data.Bool (bool)
import Data.Maybe (fromMaybe)
import Data.List (stripPrefix, isPrefixOf, findIndex, genericIndex)
import Data.Char (ord)
import Data.Word (Word8)
import qualified Data.ByteString as B
import Transform

animate :: [(String, Transform -> Transform)] -> String -> [String]
animate a s = map svg $ scanl (flip applyAnim) (parseInput s) $ map (:) [] a

paint :: String -> String
paint = svg . parseInput
```

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- Diverse, weekly competition exercises
- Awards for top 30 students
- Works extremely well to motivate talented students...
but it is very time-consuming.

Check Your Proof

CYP In A Nutshell

- Operates on a strict, untyped subset of Haskell

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- Integrates with Tasty

Background Theory

```
data List a = [] | a : List a
```

```
[] ++ ys = ys
```

```
(x : xs) ++ ys = x : (xs ++ ys)
```

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

The [] Case

Lemma: $xs \text{ ++ } (ys \text{ ++ } zs) \text{ .=} (xs \text{ ++ } ys) \text{ ++ } zs$

Proof by induction on List xs

Case []

To show: $[] \text{ ++ } (ys \text{ ++ } zs) \text{ .=} ([] \text{ ++ } ys) \text{ ++ } zs$

Proof

$$[] \text{ ++ } (ys \text{ ++ } zs)$$

(by def ++) $\text{.=} ys \text{ ++ } zs$

(by def ++) $\text{.=} ([] \text{ ++ } ys) \text{ ++ } zs$

QED

The Cons Case

Case $x : xs$

To show: $(x : xs) ++ (ys ++ zs)$

$$\therefore= ((x : xs) ++ ys) ++ zs$$

IH: $xs ++ (ys ++ zs) \therefore= (xs ++ ys) ++ zs$

Proof

$$\begin{aligned} & (x : xs) ++ (ys ++ zs) \\ (\text{by def } ++) \quad & \therefore= x : (xs ++ (ys ++ zs)) \\ (\text{by IH}) \quad & \therefore= x : ((xs ++ ys) ++ zs) \end{aligned}$$

$$\begin{aligned} & ((x : xs) ++ ys) ++ zs \\ (\text{by def } ++) \quad & \therefore= (x : (xs ++ ys)) ++ zs \\ (\text{by def } ++) \quad & \therefore= x : ((xs ++ ys) ++ zs) \end{aligned}$$

QED

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Our Experience With CYP

- Student feedback 18 positive, 3 negative

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- Main criticism: lack of documentation

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- Student feedback 18 positive, 3 negative
- Main criticism: lack of documentation
- Mostly well-structured inductive proofs in the exam

Find more in our repository!

- IO mocking framework
- ACM-ICPC-like programming contest framework
- A music synthesiser
- More engagement mechanisms and insights, our technical setup,...

[thub.com/kappelmann/engaging-large-scale-functional-programmi](#)

Future Work

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Preventing collaboration/cheating



Any questions?