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

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KRAKÓW | POLAND

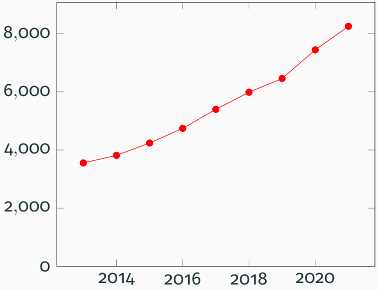
Challenges

Soaring Enrolments

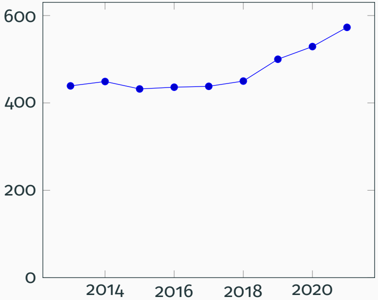
1. Number of Computer Science students exploded

Soaring Enrolments

Example: Computer Science at TU Munich



Number of CS students
(132% increase)



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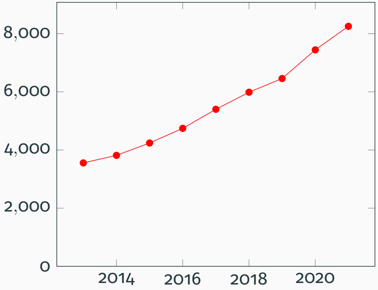

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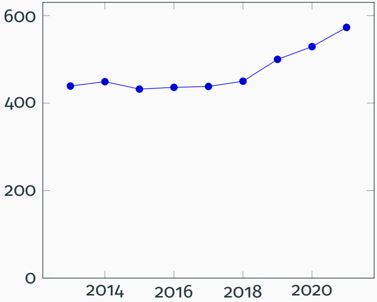


Number of CS academic staff
(31% increase)

1000+ students per course are the new normal

2. Radical transition to online classes

The Pandemic

How can we go from here...

The Pandemic

to here...

The Pandemic

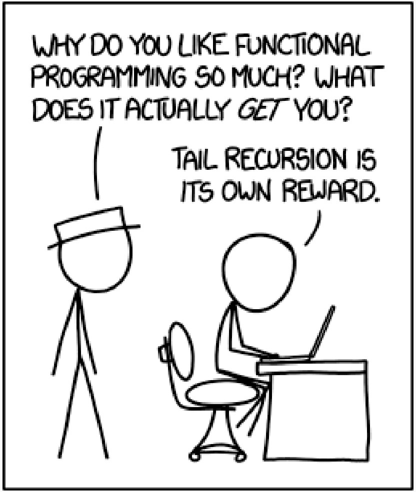
without ending up here?

Usefulness of Functional Programming

3. Students question the usefulness of functional languages beyond academia

Usefulness of Functional Programming

xkcd.com/1312



xkcd.com/1270

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

You can find our resources on:

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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

Instant Feedback

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    - *Check Your Proof* for automated proof checking

Instant Feedback

```
Lemma: xs ++ (ys ++ zs) .=. (xs ++ ys) ++ zs
Proof by induction on List xs
Case []
  To show: [] ++ (ys ++ zs) .=. ([] ++ ys) ++ zs
  Proof
                     [] ++ (ys ++ zs)
    (by def ++) .=. ys ++ zs
    (by def ++) .=. ([] ++ ys) ++ zs
  QED
Case x : xs
  To show: (x : xs) ++ (ys ++ zs) .=. ((x : xs) ++ ys) ++ zs
  IH: xs ++ (ys ++ zs) .=. (xs ++ ys) ++ zs
  Proof
  ...
```

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- Manual reviews turned out to be inefficient...
  - *HLint* offers feedback more directly

Workshops With Industry Partners

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Maybe you want to offer a workshop as well? :)

Diverse Challenges

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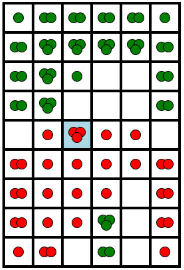
- Weekly competition exercises

Diverse Challenges

Tobias Markus vs. Severin Schmidmeier

Winner: Severin Schmidmeier



90 / 184

1x

Stats

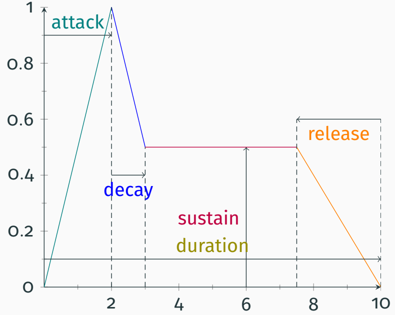
Statistic	Tobias Markus	Severin Schmidmeier
Moves made	49	49
Orbs captured	40	89
Capture/loss ratio	0.4494	2.2250

Diverse Challenges

Scoreboard (FROZEN)

Place	Team						
1.	haskellhackers						
	0 17:23:27	5 17:42:00	0 17:16:05	5 18:29:07	0 19:35:35	0 17:47:02	5 19:31:05
2.	ghzi						
	0 17:15:27	1 18:36:54	13 20:27:54	1 18:17:40	0 19:52:40	1 17:29:31	4 20:42:05
3.	maol						
	0 17:11:54	7 17:59:03	0 17:10:48	7 19:27:56	2 18:46:35	3 18:30:55	2 21:00:30
4.	gbs2021						
	6 18:33:43	1 17:28:10	3 18:19:06	7 19:06:18	2 19:51:59	1 17:52:30	5 20:52:36
5.	ninjaturtles						

Diverse Challenges




```haskell
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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Maybe you want to offer awards or challenges as well? :)

I/O Mocking

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So how do we test I/O in Haskell?

The Standard Way

```
copyFile :: FilePath -> FilePath -> IO ()
copyFile = _
```

The Standard Way

```haskell
copyFile :: MonadFileSystem m =>
            FilePath -> FilePath -> m ()
copyFile = _
```

The Standard Way

```haskell
import qualified Prelude
import Prelude hiding (readFile, writeFile)

class Monad m => MonadFileSystem m where
  readFile :: FilePath -> m String
  writeFile :: FilePath -> String -> m ()


copyFile :: MonadFileSystem m =>
            FilePath -> FilePath -> m ()
copyFile = _
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The Standard Way

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class Monad m => MonadFileSystem m where
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copyFile :: MonadFileSystem m =>
            FilePath -> FilePath -> m ()
copyFile source target = do
  content <- readFile source
  writeFile target content
```

Multiple Instantiations

```haskell
instance MonadFileSystem IO where
  readFile = Prelude.readFile
  writeFile = Prelude.readFile
```

Multiple Instantiations

```haskell
instance MonadFileSystem IO where
  readFile = Prelude.readFile
  writeFile = Prelude.readFile

data MockFileSystem =
  MockFileSystem (Map FilePath String)
instance MonadFileSystem (State MockFileSystem) where
  readFile = _
  writeFile = _
```

The Problem

What is the problem with

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Lack of transparency!

The Solution

Delay mocking to the compliation stage

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by replacing the IO module with a mixin.

The Mixin

```haskell
data RealWord = RealWord {
  workDir :: FilePath,
  files :: Map File Text,
  handles :: Map Handle HandleData,
  user :: IO (),
  ...
}
```

The Mixin

```haskell
data RealWord = RealWord {
  workDir :: FilePath,
  files :: Map File Text,
  handles :: Map Handle HandleData,
  user :: IO (),
  ...
}

newtype IO a = IO { unwrapIO ::
  ExceptT IOException (PauseT (State RealWorld)) a }
```

The Pause Monad

```haskell
class Monad m => MonadPause m where
  pause :: m ()
  stepPauseT :: m a -> m (Either (m a) a)
```

An Example Interaction

Student submission

```haskell
main = do
  x <- getLine
  putStrLn $ "Hi " ++ x
```

Mock user

```haskell
user s = do
  hPutStrLn stdin s
  out <- hGetLine stdout
  when (out /= _)
       (fail $ _)
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Find more in our repository!

- Games, music synthesiser, turtle graphics,...
- Proof checker for inductive and equational reasoning
- More engagement mechanisms and insights, our technical setup,...

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

Any questions?

Thanks to Tobias Nipkow, Manuel Eberl, our student assistants, our industry partners (Active Group, QAware, TNG Technology Consulting, and Well-Typed), and our 2000 Haskell students