Teaching Functional Programming

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Why Functional Programming?

- emphasis on *what* computation should be performed and not *how* to compute it, helps to understand programming methodology with abstractions (problem specification, problem refinement, pre- and postconditions, types, invariants, programming theorems)

- close to the specification due to their inherited mathematical nature.

```
[ x*x  \\ x <- [1..] | odd(x) ]
```

  $\{x^2 \mid x \in \mathcal{N} \wedge 2 \nmid x\}$

- referential transparency, equational reasoning for verification

```
take n xs ++ drop n xs == xs
```

Why Functional Programming?

- clean, simple, and composable abstractions (e.g. use of higher-order functions).

```
and = foldr (&&) True
```

- parallel evaluation, Paraphrase - refactoring for multicore parallel patterns

```
skel:do( [ { farm, [ { pipe, [ { seq, fun read/1 },
                                { seq, fun scan/1 },
                                { seq, fun parse/1 }
                              ] }
             ], 10 } ], Modules ).
```

- 5-10 times less SLOC, fewer errors, easier to maintain (improved distributed software robustness and productivity)

```
queens 0 = [[]]
queens n = [[q:b] \\ b <- queens (n - 1),q <- [0..7] | safe q b]
safe q b = and [not (checks q b i)  \\ i <- [0..(length b) - 1]]
checks q b i =   q ==  b !! i  ||  abs (q - b !! i)  ==  i + 1
```

Who uses Functional Programming - Erlang, Haskell, Caml, F#, Clean ..

- Ericsson – telecommunication (AXD301 ATM switch), simulation, testing, 3G, GPRS
- Amazon – Simple DB (DBMS)
- Yahoo – Online bookmarks service
- Facebook – chat server
- T-Mobile – SMS gateway
- Motorola – call processing
- CouchDb – document database server (multicore, multiserver clusters)
- YAWS – Yet Another Web Server
- Wings3D – 3D modeling
- Alcatel-Lucent- Haskell to prototype narrowband software radio systems, running in (soft) real-time
- Galois in application areas of security, information assurance and cryptography

Curricula - 2015

Level	Course title	Semester
BSc	Functional Programming	2nd
	Advanced Haskell	optional
	Erlang	optional
	λ - calculus	optional
	Web and mobile application programming in F#	optional
	Verification Tools of Functional Programming	optional
	Agda	optional
MSc	Concepts of Functional Programming Languages	1st
	Type systems	1st
	Advanced Functional Programming	2nd
	Software Technology Lab - RefactorErl, DSL	4 semesters
PhD	Distributed Functional Programming	freely chosen
	Verification of Functional Programs	freely chosen

Topics, concepts

- Higher order functions
- Algebraic types, type classes
- Higher-order types, existential types
- Uniqueness typing
- Dynamics, generic programming
- Purely functional data structures
- Parallel and distributed programming
- Combinators, combinator libraries
- Monadic programming
- Dependent types
- Interactive programs (functional reactive programming)
- Embedded domain-specific languages

Methods and tools in eductaion

- lecture, lab, consultation
- E-learning - ActiveHS (developed in Haskell)
- weekly test questions on concepts
- weekly home assignments to solve and upload via BE-AD
- complex home assignment
- lab programming test
- exam - ActiveHS

- lecture notes, textbooks, slides
- svn repository for assignments

ActiveHS – https://hackage.haskell.org/package/activehs

http://pnyf.inf.elte.hu/fp/Index_en.xml

Exercise: 10, 9, 8, ..., -9, -10

List the numbers from 10 to -10.

Solution>

Exercise: 10, 9, 8, ..., -9, -10

List the numbers from 10 to -10.

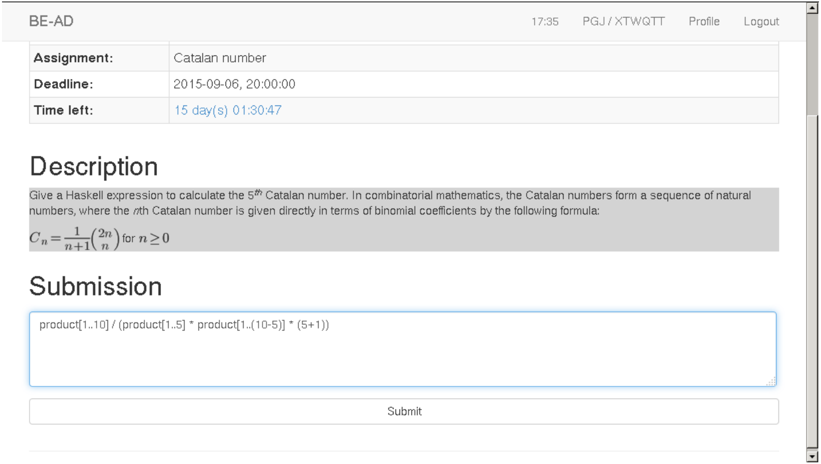
Solution> [10,9 .. -10]

```
[10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 0, -1, -2, -3, -4, -5, -6, -7, -8,
 -9, -10]
:: [Integer]
```

Jó megoldás! Szintén helyes megoldás:

```
[10,9.. -10] :: [Int]
```

BE-AD – https://github.com/andorp/bead

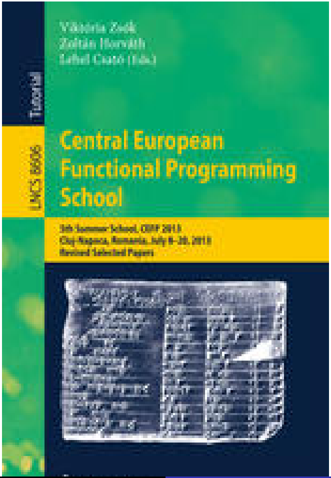


developed in Haskell, used by 14 courses, 40 groups of students, 208 assignments, 12407 submitted solutions

Recent results

- BSc: 128 of 193 students completed all assignments, 125 passed the exam
- MSc: 66 of 97 completed the course successfully

Central European Functional Programming Summer School
CEFP 2005, 2007, 2009, 2011, 2013, 2015 - LNCS volumes
supproted by CEEPUS, Erasmus IP and industry



Conclusions

- The precise formal definition of abstract concepts and experience in formal specification form a solid basis for better understanding on issues of functional programming and vice versa
- specification by pre- and postconditions, function compositions given in postcondition correspond to the structure of solution
- concepts with high expressive power (like higher order functions and types) need outstanding abilities, however not all of the students possess them.
- Industry needs a growing number of new staff members with expertise in functional programming.
- joint industry-university R&D labs are running in functional programming (static analysis, refactoring, defining FP embedded DSL-s for telecommunication)
- dozen of the PhD students have chosen functional programming as their main research domain.