EDAF40/EDAN40: Functional Programming Introduction

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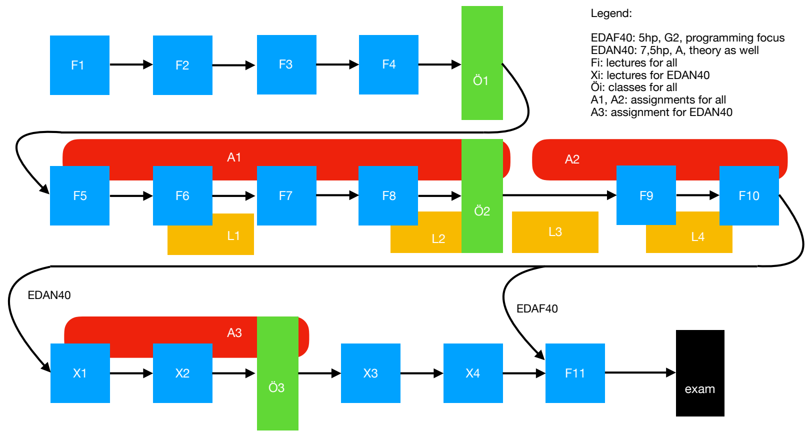
Administrativia



Administrativia

- Standard notification: 140/200h total compared with 20/28h with lecturers + 14/6 with TAs.
- Language-learning period in the beginning (syntax, basics).
- Two/Three not too tough programming assignments. (15, 10, 6 hrs)
- Kursombud (course representative) must be chosen. Today!
- Programming asignments verified by you, then machine and then teaching assistants (Christian Söderberg and Sven Gestegård Robertz, possibly more).
- Any problems (deadlines?) – please discuss **IN ADVANCE** with me!
- Slides based a lot on Lennart Andersson and Lennart Ohlsson's material. Thank you.

Textbooks

1. Graham Hutton, *Programming in Haskell*, 2nd ed., Cambridge University Press, 2016, ISBN 978-1316626221
2. Bryan O'Sullivan, Don Stewart, and John Goerzen, *Real World Haskell*, O'Reilly Media, 2008, ISBN 0-596-51498-0
3. Miran Lipovača, *Learn You a Haskell for Great Good!*, No Starch Press, 2011, ISBN 1-59327-283-9
4. Paul Chiusano and RÃžnar Bjarnason, *Functional Programming in Scala*. Manning Publications, 2014, ISBN: 9781617290657.
5. Simon Thompson, *Haskell - The Craft of Functional Programming*, 3rd edition, Addison-Wesley 2011, ISBN 0-201-88295-7

Software

- Glasgow Haskell Compiler, or `ghc`
- Interpreter is called `ghci`
- Currently in its version 7.10.3. (@ login.student.lth.se), or higher
- *.student.lth.se all run this version (please report issues)
- consider installing haskell-stack environment on your machine (`http://haskellstack.org`)

Suggestions

- Read the assignment completely before you begin coding;
- Read the assignment text **after** the official announcement date;
- Complain to me or to a course student representative, if something does not work or is unclear;
- Check the course web;
- Do not mail `fp@cs.lth.se` unless you are filing in a **working** solution to an assignment;
- Do not mail `edan40@cs.lth.se` if you want to contact a human;
- Plan your time!
- Use our time (JM Mo 15.30-16.30, CS ..., SGR ...)!

What is functional programming?

> *"Functional programming is so called because a program consists entirely of functions. [...] These functions are much like ordinary mathematical functions [...] defined by ordinary equations."*
>
> (John Hughes)

A function

Let A and B be arbitrary sets.

Any subset of $A \times B$ will be called a *relation* from A to B.

A relation $R \subset A \times B$ is a *function* if and only if

$$\forall x \in A \, \forall y_1, y_2 \in B \, ((x, y_1) \in R \wedge (x, y_2) \in R) \rightarrow (y_1 = y_2)$$

A function

Our domain and range here: natural numbers

```
f 0 = 1
f n = n * f (n-1)
```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mathematical induction vs. computational recursion vs. mathematical recursion

Equals for equals

If

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f 0 = 1
f n = n * f (n-1)
```

then what is `f 3`?

Equals for equals

If

```
f 0 = 1
f n = n * f (n-1)
```

then what is `f 3`?


```
f 3 = 3 * f 2
    = 3 * 2 * f 1
    =     6 * 1 * f 0
    =         6 * 1
    = 6
```

called also *rewrite semantics*

Imperative programming

Think like a computer:

```
public int f(int x) {
   int y = 1;
   for (int i=1; i<=x; i++) {
      y = y*i;
   }
   return y;
}
```

Then

```
f(3) = y = y*i = ????
```


The basic principle

NO ASSIGNMENTS!

The basic principle

NO ASSIGNMENTS!

not exactly, but the meaning is:

NO SIDE EFFECTS!

The problem with side effects

Example:

```
public int f(int x) {
   int t1 = g(x) + g(x);
   int t2 = 2*g(x);
   return t1-t2;
}
```

The problem with side effects

Example:

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public int f(int x) {
   int t1 = g(x) + g(x);
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Then **of course**

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f(x) = t1-t2 = g(x) + g(x) - 2*g(x) = 0
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The problem with side effects

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}
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Then **of course**

```
f(x) = t1-t2 = g(x) + g(x) - 2*g(x) = 0
```


But suppose:

```
public int g(int x) {
   int y = input.nextInt();
   return y; }
```


The concept of a variable

Is a variable the name of a

memory cell

or the name of an

expression?

The core of functional programming

Functional programming
=
ordinary programming − assignments / side effects

It provides good support for

- higher order functions
- infinite data structures
- lazy evaluation

Recursion: The sum of a list

```
sum1 [] = 0
sum1 (x:xs) = x + (sum1 xs)
```

Note1: *recursion* is intimately connected to *computability*.

Note2: `(x:xs)` - a very important idiom in FP/Haskell.

Higher order functions

```
sum1 [] = 0
sum1 (x:xs) = x + (sum1 xs)

ackumulate f i [] = i
ackumulate f i (x:xs) = f x (ackumulate f i xs)
```


Higher order functions

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sum2 = ackumulate (+) 0

product2 = ackumulate (*) 1
anyTrue2 = ackumulate (||) False
allTrue2 = ackumulate (&&) True
```

Infinite lists

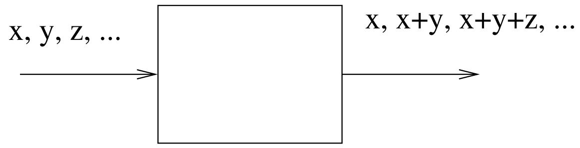
Primes computed with Eratosthenes sieve:

```
primes = sieve [2..]
   where
      sieve (n:ns) =
         n : sieve [ x | x <- ns, x `mod` n > 0 ]
```

Is this programming? Or just math?

Data flow programming

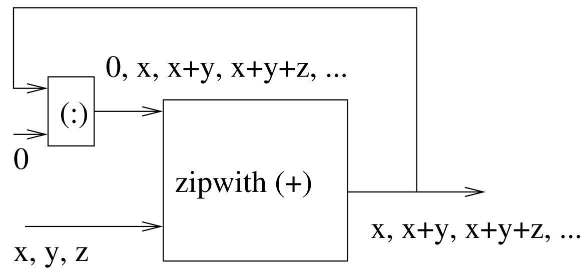
The running sums of a list of numbers:



Running sums

```
runningSums xs = theSolution
   where
      theSolution = zipWith (+) xs (0:theSolution)
```


Data flow programming



Exact approximations

The Taylor series of the exponential function:

$$e^x = \sum_{i=0}^{\infty} \frac{x^i}{i!}$$

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for example like a list of approximations:

```
eExp x = runningSums [ (x^i)/(fac i) | i <- [0..] ]
```