EDAF95/EDAN40: Functional Programming Introduction

Jacek Malec
Dept. of Computer Science, Lund University, Sweden

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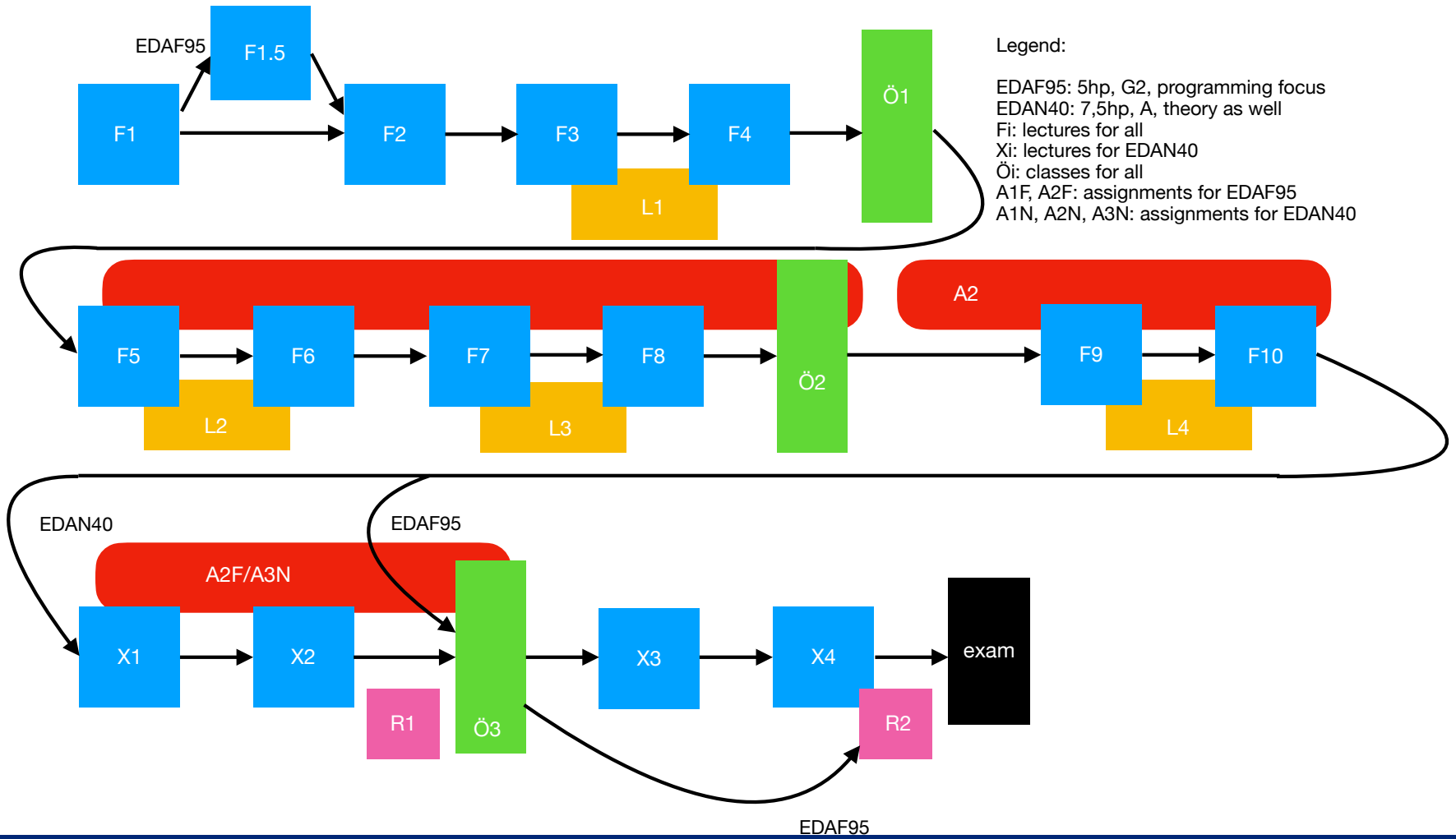
Administrativia



Administrativia

- Standard notification: 140/200h total compared with 20/28h with lecturer(s) + 16/6 with TAs.
- Language-learning period in the beginning (syntax, basics).
- Two/three not too tough programming assignments. (15, 10, 6 h for EDAN40)
- Kursombud (course representative) should be chosen. Preferably today!
- Programming asignments verified by you, then machine (you get tests) and then teaching assistants;
- Any problems (deadlines?) - please discuss **IN ADVANCE** with me!

Important!

Please read:

`https://cs.lth.se/utbildning/samarbete-eller-fusk/`

or in English

`https://cs.lth.se/english/education/cooperation-or-plagiarism/`

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. 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 9.8.2
- Consider installing Haskell toolchain (`https://www.haskell.org/downloads/`)
- You may get some help with installation during the coming two weeks: 12–13, any weekday, E:3316

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;
- Use canvas to submit stuff and contact us;
- Use discord to contact us and discuss among yourselves;
- Plan your time!
- Use our time: contact hours will be displayed this week

Registration

Any issues with registration? Mail me, or `expedition@cs.lth.se`.

Any issues with accessing course canvas? Mail me on or after Wednesday!

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)
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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!

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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;
}
```

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Example:

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public int f(int x) {
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Then **of course**

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

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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 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)
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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:

```
sieve (n:ns) =
   n : sieve [ x | x <- ns, x `mod` n > 0 ]
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Let's start the process:

```
primes = sieve [2..]
   where
      sieve (n:ns) =
         n : sieve [ x | x <- ns, x `mod` n > 0 ]
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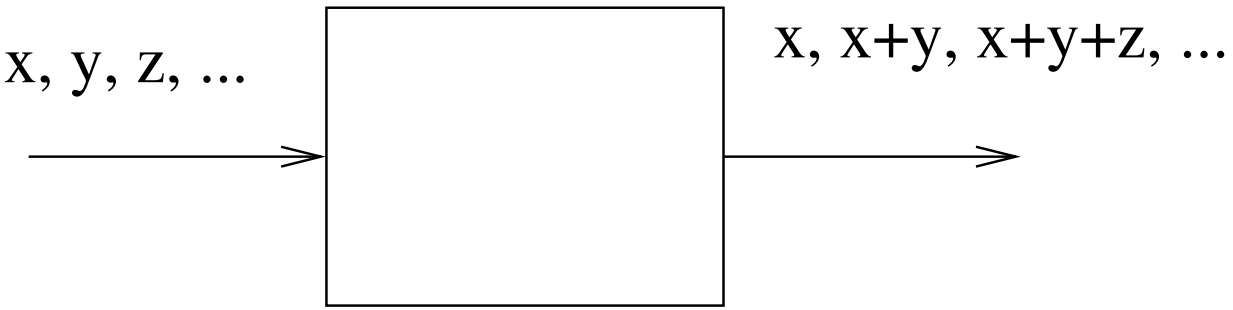
Is this programming? Or just math? Does it matter?

Stream programming

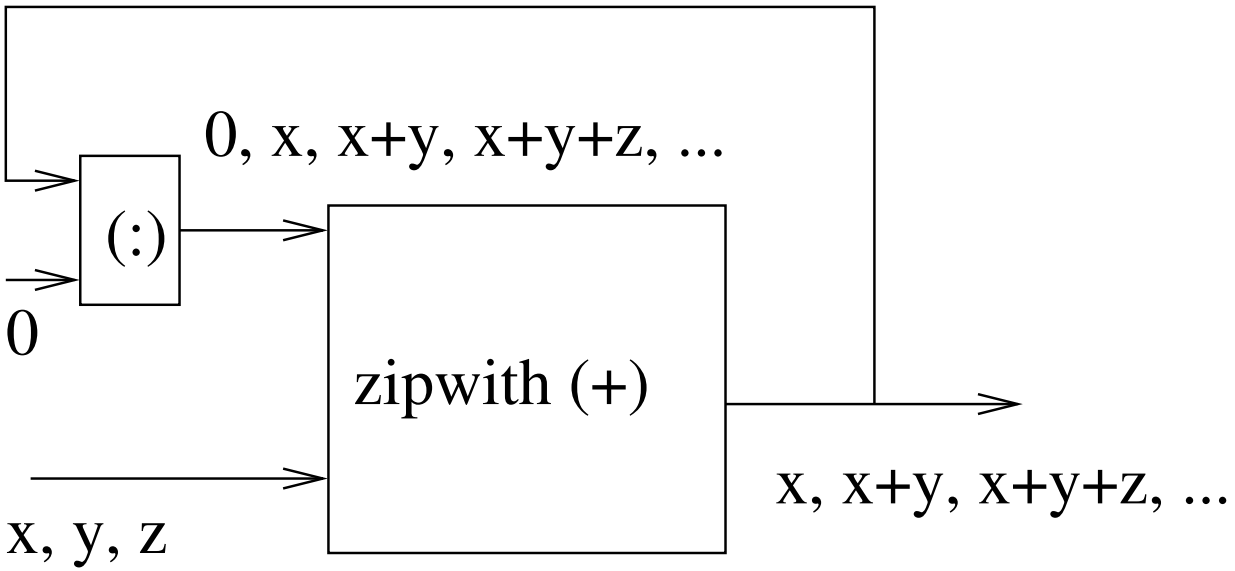
The running sums of a list of numbers:



Running sums

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

Stream 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..] ]
```