Introduction to Functional Programming

Course introduction and first steps in programming

Some slides are based on Graham Hutton's public slides

Today

- Introduction to the course
- What is a computer?
- Programming languages
- Tools
- Writing code

General

- Functions
- Testing

Specific

Goal of the course

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- Start from the basics
- Introduce basic concepts of computer science
- Learn to write small-to-medium sized programs in Haskell

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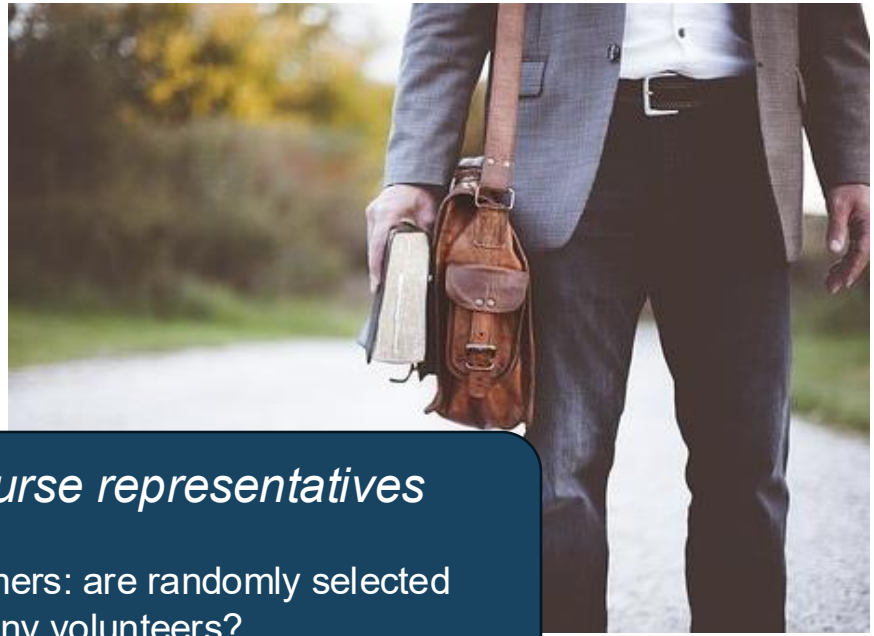
Teaching team

- Daniël Apol,
- Naïm Favier,
- Albin Jonzon,
- Nour Aldeen Dabora,
- Eli Uhlin,
- Alexander Appelin,
- Daniel Cole,
- Sebastian Sandstig,
- Linda Jonsson,
- David Bohman,
- Jonathan Otten,
- Nithit Sathornkit,
- Erik Dahlkvist.



Course representatives

- Chalmers: are randomly selected
- GU: any volunteers?

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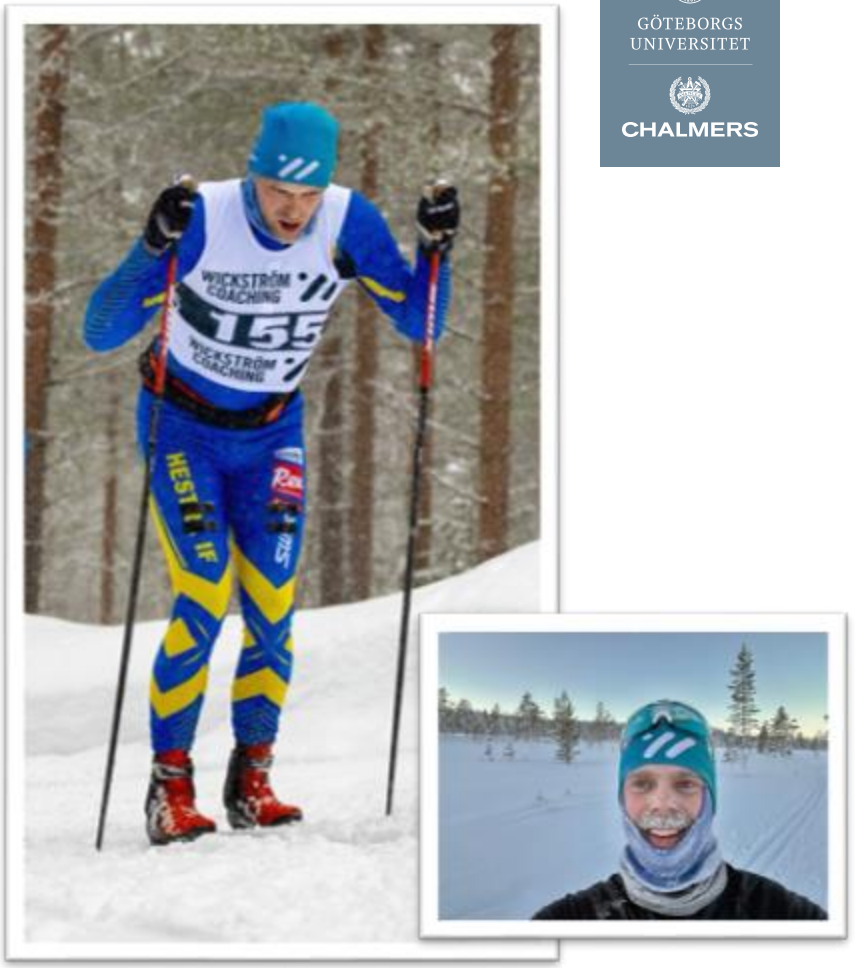
Alex Gerdes

- Dutchman living in Sweden
- MSc (civilingenjör) OU/UU
- PhD in Computer Science
- Senior Lecturer (universitetslektor)
- Programansvarig DV
- Enhetschef FP

- Teaching: FP, data structures
- Research:
  - FP in education,
  - Property-based testing



COURSE STRUCTURE

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Canvas

- The Canvas course room will have all up-to-date information relevant for the course:
  - Schedule (links to TimeEdit)
  - Lectures: slides, live code, videos, reading suggestions
  - Lab assignments
  - Exercises
  - Last-minute changes (also via Discord)
  - And more...

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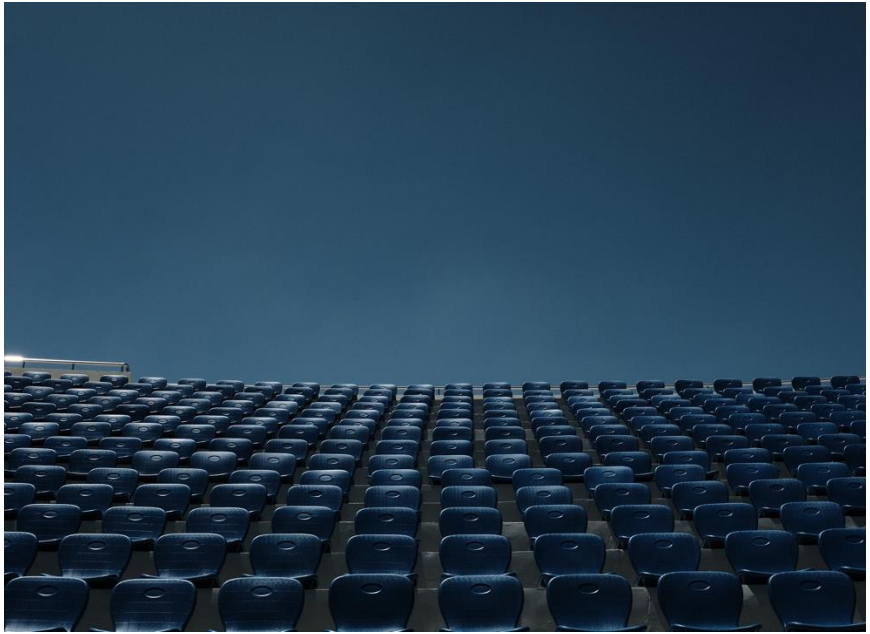
Lectures

Why come to the lectures?

- Will introduce some of the theory
- Lots of live coding
- Will spill over in each other
- You are welcome to:
  - follow live coding with your own computer
  - use smartphone or computer to take part in quizzes
  - ... but this is completely optional!
- Will be recorded… if you continue to turn up
- Come prepared!
  - preparation instructions on Canvas



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Exercise sessions

- Mondays 10:00 – 11:45 (usually)
- Again: come prepared!
- Work on exercises together or individually
- Discuss and get some help from us
  - I will select and introduce some exercises to work on
  - Will give hints half ways during the session
  - You mostly work on your own, not a laboration
- They are split in a self-check and extra exercises
- Make sure you understand the previous week's things before you leave

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Don’t stress about the deadlines!
Focus on other parts as well!!!

Lab assignments

- Four lab assignments
  - Some labs are divided into multiple parts
- Deadlines always on Fridays 18:00 (and are strict!)
- Submit via Canvas, read the instructions!
- Lab 2 and 3: also *present* your solution to a supervisor
- Create own groups of three
  - You could reuse the group you may have formed during the introduction weeks
  - Will freeze the groups after a while

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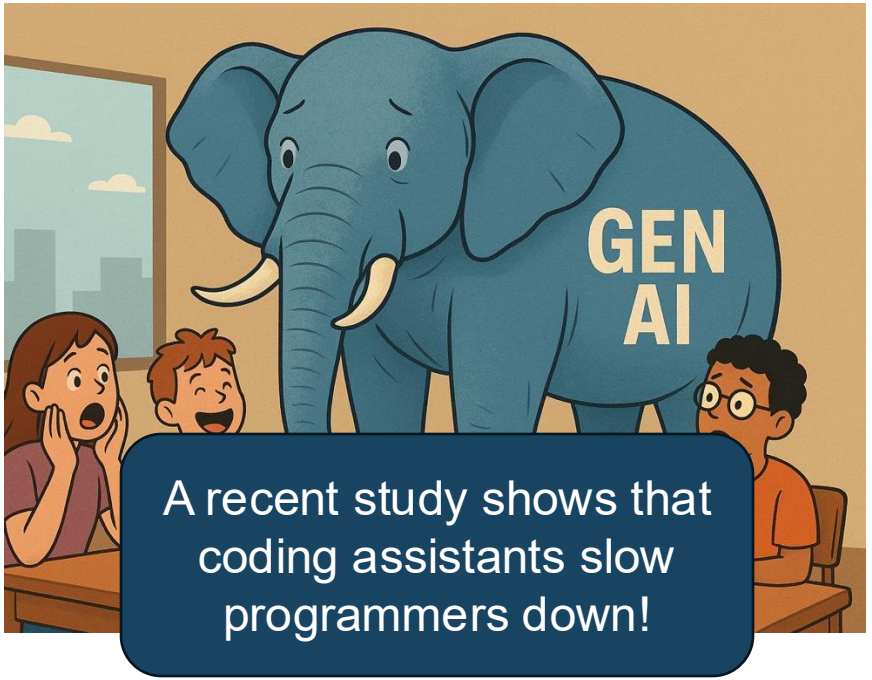
The elephant in the room!

- Generative AI can certainly be helpful when coding
- Tempting to use a coding assistant during the labs, but don't!!!
- You need to know how to program yourselves, before you can take full advantage
- GenAI is well trained on basic stuff, but not as much on challenging tasks
- We need to have a focus on *specification* and *validation*, nothing new on the horizon!
- We are going to have a lecture on this, and a part of a lab



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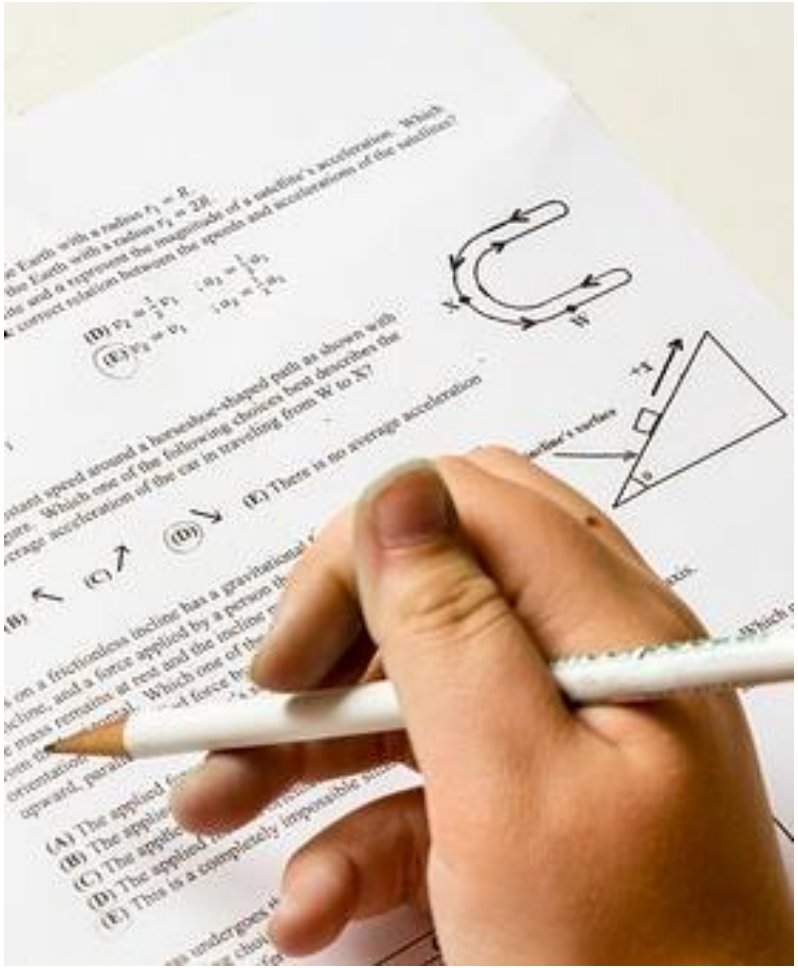
Getting help

- Weekly exercise sessions
  - Personal help to understand material
- Lab supervision
  - Specific questions about lab assignment at hand
  - Done on campus, come prepared
- Discord
  - General questions, worries, discussions
  - Finding lab partners

First exercise session on Tuesday will be dedicated to installing the development environment! (and getting started with the labs/exercises)



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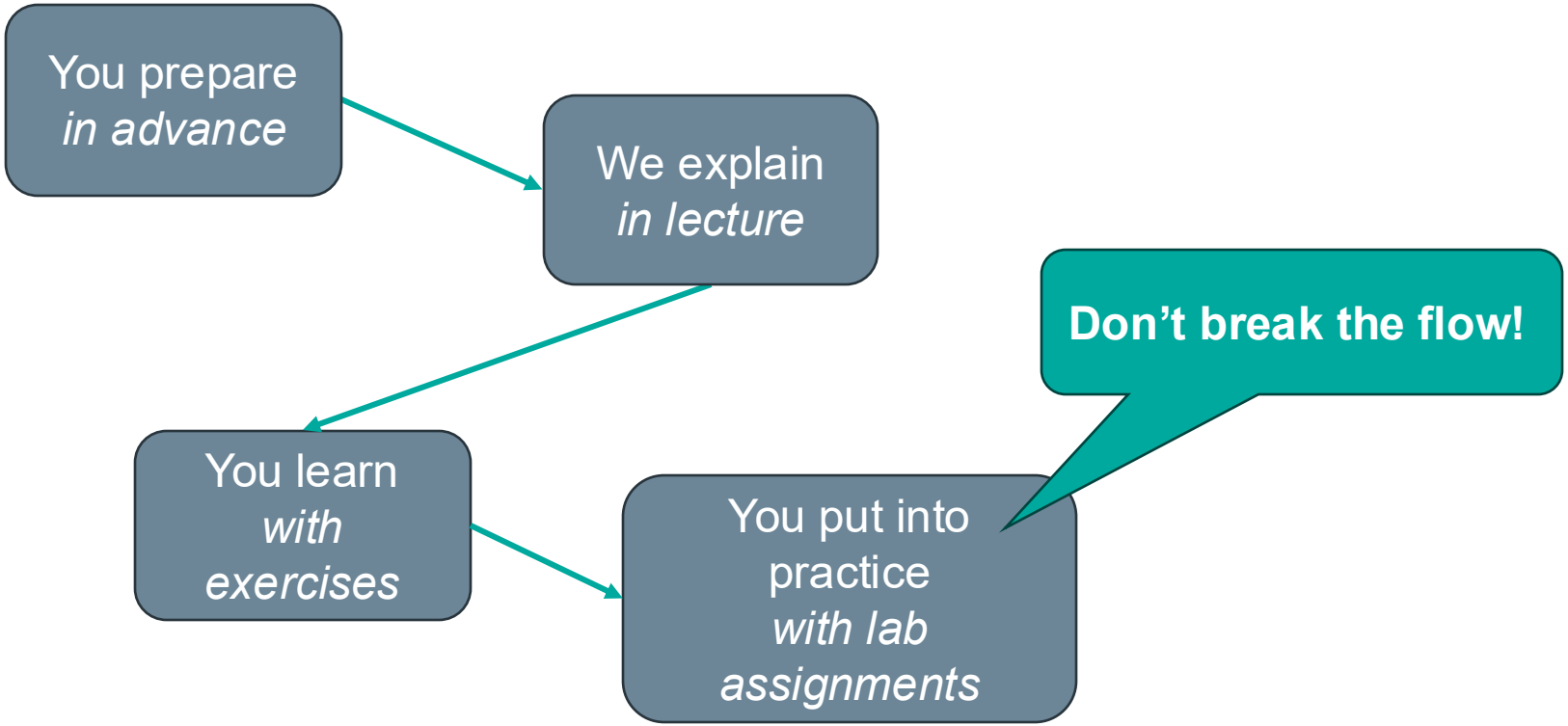
Assessment

New for this year!

- Written (digital) exam (4.5 hp)
  - Consists mostly of small programming problems to solve
  - You need Haskell “in your fingers”
  - More details in Canvas
  - U-3-4-5 grading scale
- Course work (3 hp)
  - Complete all labs successfully
  - Pass/Fail grading scale

The Flow


You prepare
in advance
We explain
in lecture
You learn
with exercises
You put into practice
with lab assignments
Don't break the flow!

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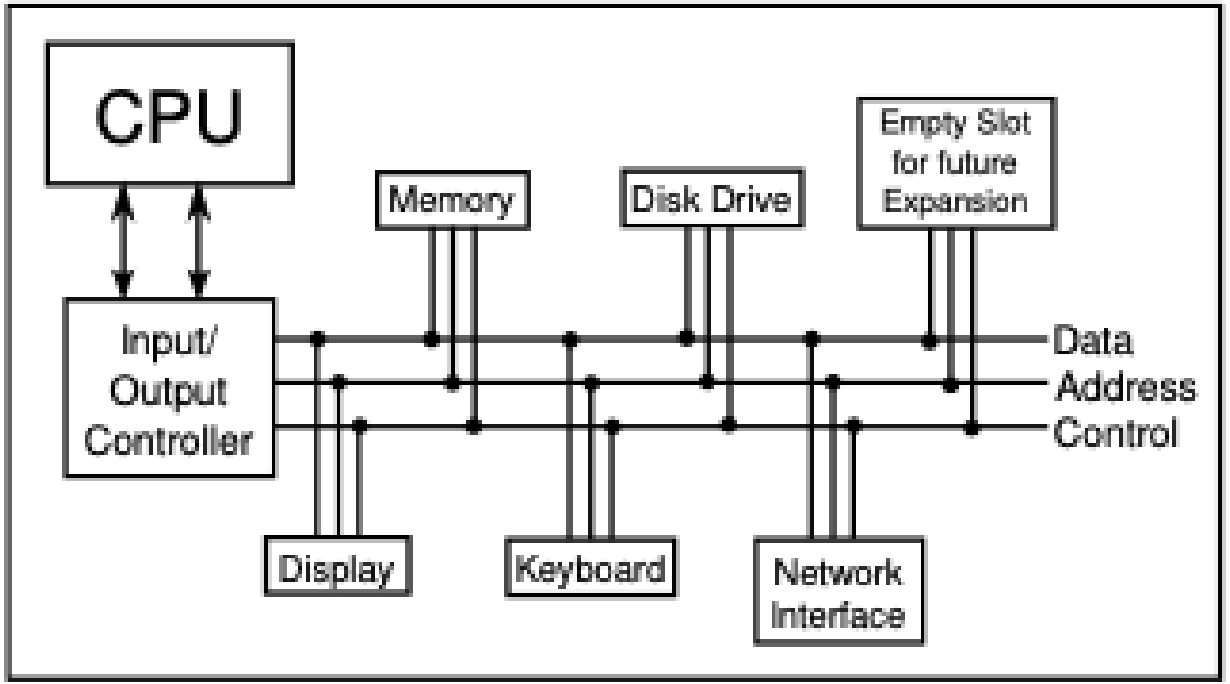
A risk

- 8 weeks is a short time to learn programming
- The course is fast paced
  - Each week we learn a lot
  - Catching up again is hard
- So do keep up!
  - Read the material for each week
  - Make sure you can solve the problems
  - Reflect and plan! (remember ‘framtidskoden’ course)
  - Go to the weekly exercise sessions
  - From the start!

INTRODUCTION TO COMPUTING

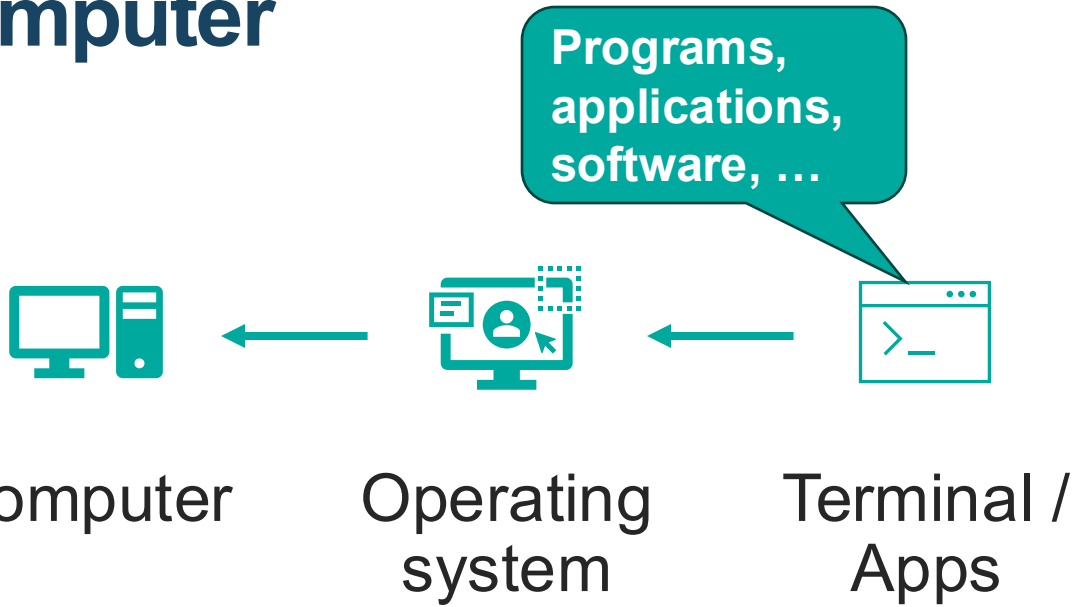
What is a computer?



Source: Introduction to Programming Using Java, D. Eck

Controlling a computer

- Computer consists of hardware resources:
  - Processor
  - Memory
  - Many other parts
- The Operating System controls the hardware
  - Allows applications to run
  - Shares the resources between apps
- Apps/terminal instructs computer what to do
  - With help from the OS



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Software = Programs + Data

- Data is any kind of storable information, e.g.:
  - numbers, letters, email messages
  - maps, video clips
  - mouse clicks, *programs*
- Programs compute new data from old data:
  - A computer game computes a sequence of screen images from a sequence of mouse clicks
  - vasttrafik.se computes an optimal route given a source and destination bus stop

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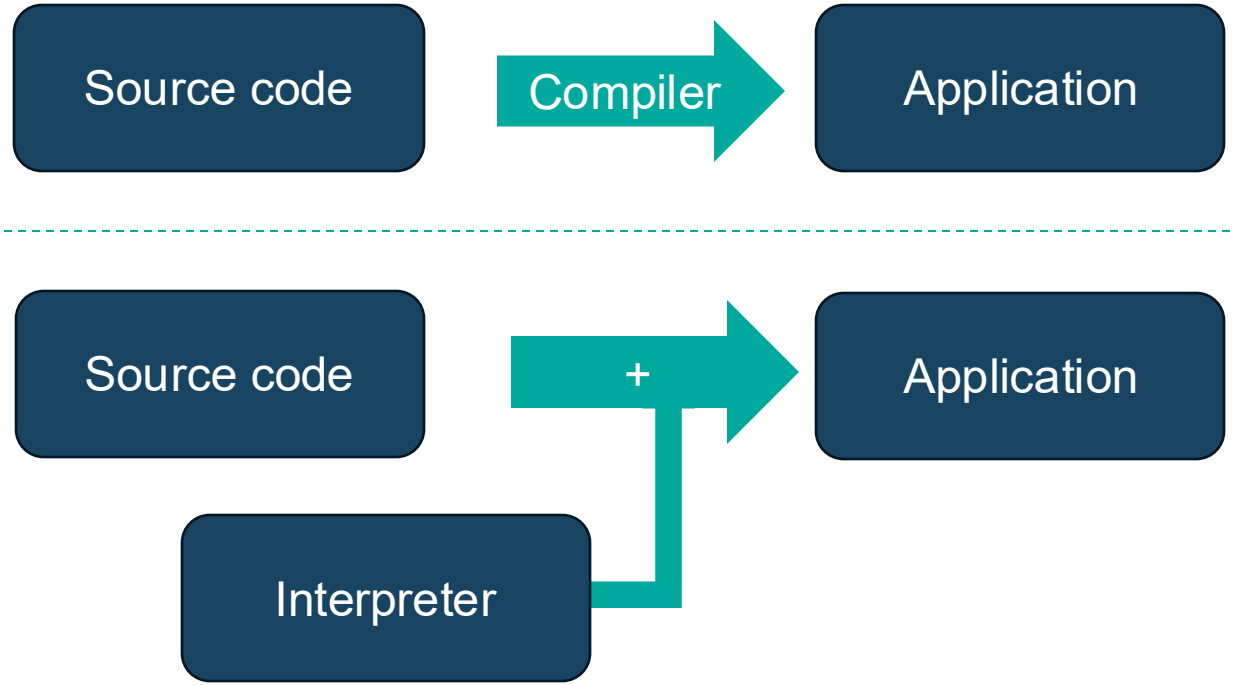
Programming languages

- Programs are written in *programming languages*
  - Not natural language, must be unambiguous
  - Syntax and semantics
- There are hundreds of different programming languages, each with their strengths and weaknesses
- A large system will often contain components in many different languages

Compiler/interpreter



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Two major paradigms

Imperative programming:

- Instructions are used to change the computer's state:
  - `x := x+1`
  - `deleteFile(”slides.pdf”)`
- Run the program by following the *instructions* top-down
- Describing *how* to solve

Functional programming:

- Functions are used to *declare* dependencies between data values:
  - `y = f(x)`
  - `x = 32`
- Dependencies drive evaluation
- Describing *what* to solve

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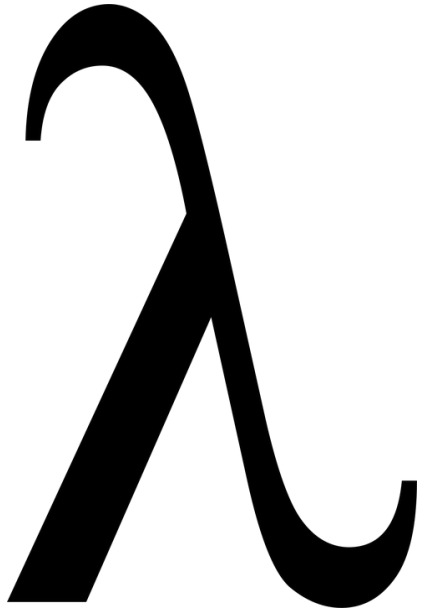
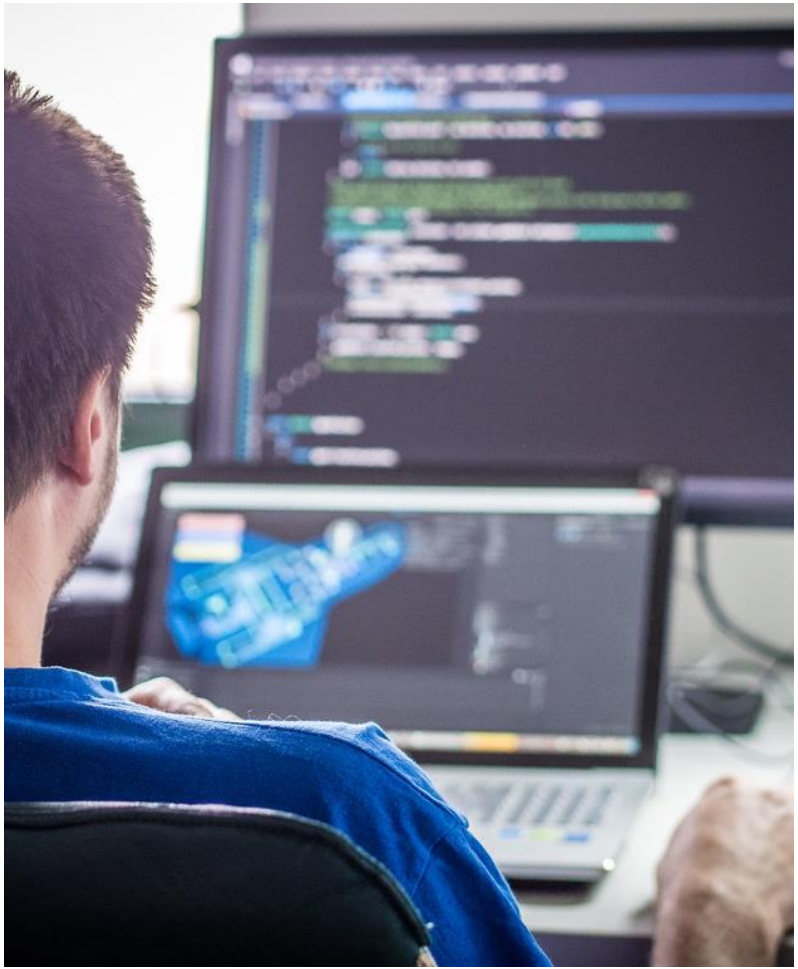
Functional programming

- *Functions* are:
  - used to declare dependencies between data values: `y = f(x)`
  - the basic building blocks of (functional) programs
  - used to *compose* functions into other functions
  - *only* dependent on the argument (in so-called pure functions)
- *Functional programming* is a *style* of programming in which the basic method of computation is the *application of functions to arguments*
- A *functional programming language* is one that *supports* and *encourages* the functional style





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Teaching programming

- We want to give you a broad basis
  - Easy to learn more programming languages
  - Easy to adapt to new programming languages
  - Appreciate differences between languages
  - Become a better programmer!
- This course uses the functional programming language *Haskell* (http://haskell.org/)

Why Haskell?

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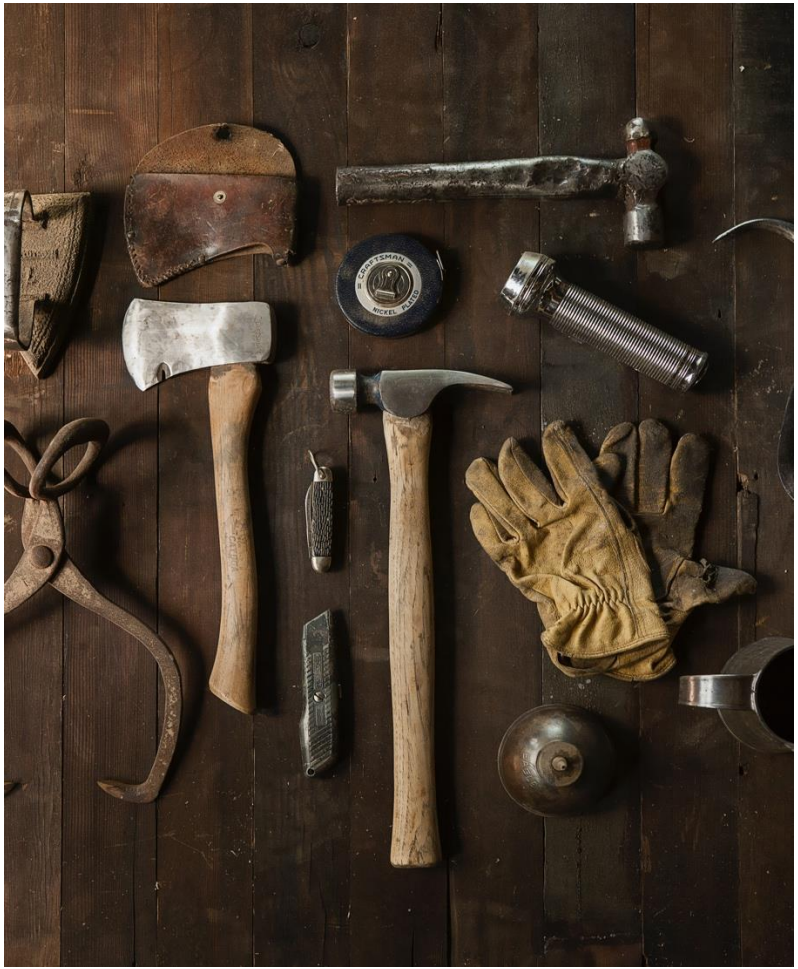
- Haskell is a very *high-level language*
  - Lets you focus on the important aspects of programming
- Haskell is expressive and concise
  - Can achieve a lot with a little effort
- Haskell is good at handling complex data and combining components
- Haskell is defining the state of the art in programming language development
- Haskell is *not* a particularly high-performance language
  - Prioritizes programmer-time over computer-time



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We need tools!

- Editors
  - Many out there, we recommend *Visual Studio Code*
  - Integrated Development Environment (IDE)
- Terminal
  - Giving commands to OS: `ls`, `pwd`, `cp`, `cd`, …
  - Starting the interpreter or compile
- Files, directories
  - Organize!
- Docker
  - Virtualisation technique, a kind of mini OS
  - We offer a stable and complete development environment

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MENTI!

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Glasgow Haskell Compiler

- GHC is the leading implementation of Haskell, and comprises a compiler and interpreter
- The interactive nature of the interpreter makes it well suited for teaching and prototyping
- GHC is freely available
- Starting GHCi:
  - The interpreter can be started from a terminal command prompt by simply typing `ghci`
  - The GHCi prompt `ghci>` means that the interpreter is ready to evaluate an expression

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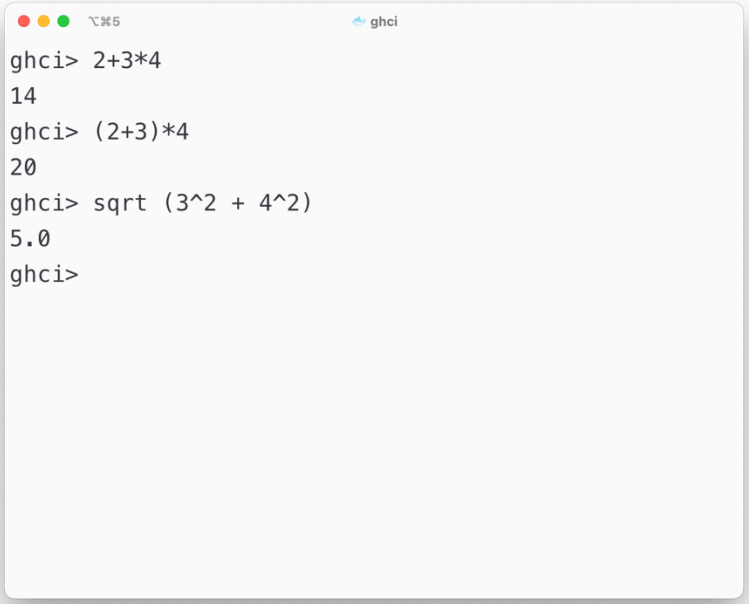
GHCi example

- For example, it can be used as a desktop calculator to evaluate simple numeric expressions



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Function application

- In *mathematics*, function application is denoted using parentheses, and multiplication is often denoted using juxtaposition or space

```
f(a, b) + c d
```

Apply the function `f` to `a` and `b`, and add the result to the product of `c` and `d`

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Function application

- In *Haskell*, function application is denoted using a space, and multiplication is denoted using `*`

- Moreover, function application is assumed to have a *higher priority* than all other operators:

```
f a + b
```

means `(f a) + b`

rather than `f (a + b)`

```
f a b + c * d
```

As previously, but in Haskell syntax

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Function application, examples

Mathematics:

```
f(x)

f(x,y)

f(g(x))

f(x,g(y))

f(x)g(y)
```

Haskell:

```
f x

f x y

f (g x)

f x (g y)

f x * g y
```

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Variables and arguments

- Functions are *abstractions* of calculations, which we want to perform with varying values
- To capture the varying parts of a calculation we can introduce *variables*, which abstract away from particular values and thus *vary*
- When we apply a function on a value, we *substitute* the variable with the given value
- The given value in a function application is also called an *argument*
  - An argument or the given value can be regarded as the input to a function
- A different name for a variable in a function is a *parameter*
  - A function is parametrized over a variable

```
f x = x * 3 + 1

ghci> f 3
10
```

`f` is applied to an argument in this case the value 3. In the calculation (definition) of `f` we can substitute `x` with the value 3.

LIVE CODING!

I may not have time to cover everything in each lecture.

You are expected to do/learn/read the rest on your own!

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Composing functions

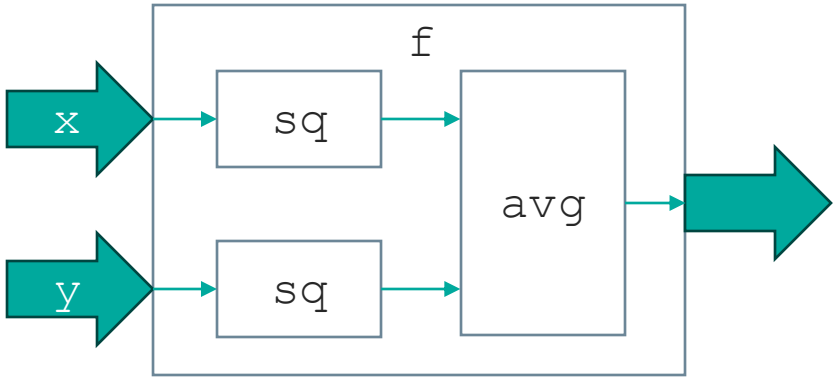
- We can create more complex functions by reusing *composing* other existing functions.
- An application written in a functional programming languages consists of many functions that work together to solve (complex) problems.

```
avg x y = (x + y) / 2

sq x = x * x

f x y = avg (sq x) (sq y)
```

- We can regard functions as boxes, which we can connect to other boxes. The output of a particular box can be the input of another box.



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Haskell scripts

- As well as the functions in the standard library (`Prelude`), you can also define your own functions
- New functions are defined within a *source code file* (also called a script), which is a text file with a sequence of definitions
- By convention, Haskell source code files usually have a `.hs` suffix (also called extension) on their filename.

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My first source code

- When writing Haskell source code, it is useful to keep two windows open,
  - one running an editor for the source code,
  - and the other running GHCi

- Start an editor, type in the two function definitions to the left, and save the script as

  `test.hs`

```
double x = x + x

quadruple x = double (double x)
```

My first source code

- Leaving the editor open, in another window start up GHCi with the new script:

```
$ ghci test.hs
```

- Now both the standard library and the file `test.hs` are loaded, and functions from both can be used:

`test.hs`

```
ghci> quadruple 10
40
ghci> even (double 3)
True
```

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My first source code

- Leaving GHCi open, return to the editor, add the following two definitions, and resave:

```
dec x = x - 1

pytha a b = sqrt (a^2 + b^2)
```

- GHCi does not automatically detect that the script has been changed, so a *reload* command must be executed before the new definitions can be used

```
ghci> :reload
Ok, one module loaded.
ghci> dec 10
9
ghci> pytha 3 4
5.0
```

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Useful GHCi commands

Command	Meaning
`:load <name>`	load source file *<name>*
`:reload`	reload current source file
`:type <expr>`	show type of *<expr>*
`:?`	show all commands
`:quit`	quit GHCi

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Naming requirements

- Function and argument names must begin with a lower-case letter. For example:

```
myFun    fun1    arg_2    x'
```

- By convention, list arguments usually have an *s* suffix on their name. For example:

```
xs    xss    ns
```

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Conditional expressions

- As in most programming languages, functions can be defined using *conditional expressions*
- Conditional expressions can be nested:
- Note: in Haskell, conditional expressions must always have an `else` branch, which avoids any possible ambiguity problems with nested conditionals

`abs` takes an integer `n` and returns `n` if it is non-negative and `-n` otherwise

```
abs n = if n >= 0 then n else -n


signum n = if n < 0 then -1 else
             if n == 0 then 0 else 1
```

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MENTI!

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