universität innsbruck

WS 2024/2025

Functional Programming

Week 1 – Organisation and Introduction

René Thiemann Diana Gründlinger Alexander Montag Adam Pescoller

Department of Computer Science

Organization

Lecture (VO 2)

- LV-Number: 703024
- lecturer: René Thiemann
  consultation hours: Tuesday 10:15 – 11:15 in 3M09 (ICT building)
- time and place: Monday, 12:00 – 13:30 in HS B
- course website: `http://cl-informatik.uibk.ac.at/teaching/ws24/fp/`
- lecture will be in German with English slides
- slides are available online and contain links
- online registration required by January 31, 2025
- lecture will be recorded; videos are accessible in OLAT-VO

Schedule

lecture 1	October	7	lecture 8	November	25
lecture 2	October	14	lecture 9	December	2
lecture 3	October	21	lecture 10	December	9
lecture 4	October	28	lecture 11	December	16
lecture 5	November	4	lecture 12	January	13
lecture 6	November	11	lecture 13	January	20
lecture 7	November	18	Q & A	January	27

- lecture on January 20
  - content is not relevant for exam
  - discussion of previous exam

Proseminar (PS 1)

- LV-Number: 703025
- new exercise sheets available online on Tuesday or Wednesday
- solved exercises must be entered in OLAT-PS
  - mark which exercises have been solved (Kreuzliste)
  - upload solutions to programming exercises
  - deadline: 8 pm on Tuesday before PS on Wednesday
- solutions will be presented in proseminar groups
- first exercise sheet: today
- proseminar starts on October 9 or October 16
- proseminar on October 9
  - voluntary, discussion of basic topics (command line, . . .)
- attendance is obligatory starting from October 16
- registration deadline was in September
- exercise sheets will be English, seminar groups in German

Proseminar Groups

- in total 9 groups, cf. LFU online
- all groups are completely full
  - still want to join → contact me to put name on waiting list
- change of groups only possible via the online swap-tool
  - in OLAT, there was a welcome message that included more details about swap-tool
  - if you don't care about the time of your group, enter an optional wish
  - deadline when changes will be conducted: today, October 7, 4pm

Tutorium

- opportunity to ask questions about topics of lecture and exercises
- presentation of more examples
- no new topics, no influence on grades, no solutions to exercises
- attendance voluntary
- tutor: Adam Pescoller
- Tuesday 17:15 – 18:00
  - starts tomorrow
  - HS 11

Weekly Schedule

- Monday 12:00–13:30: lecture on topic n
- Tuesday 17:15 – 18:00: tutorium on topic $n-1$ or n
- Tuesday or Wednesday: exercise sheet n on topic n available
- Tuesday 8 pm: deadline for upload of solution of exercise sheet $n-1$
- Wednesday: proseminars on exercise sheet $n-1$
- ...

Grading

- separate grades for lecture and proseminar
- lecture
  - grading solely via exam
  - 1st exam on February 3, 2025
  - online registration required from December 30 – January 20 via LFU online (deregistration still possible later on)
  - 2nd exam on April 24, 2025
  - 3rd exam: September (tentative)
  - it suffices to pass one of the three exams
- proseminar
  - 80 %: scores from weekly exercises
  - 20 %: presentation of solutions

Chat-GPT

- Chat-GPT is capable of generating functional programs
- positive aspects of using Chat-GPT
  - you might pass the proseminar, without being able to program on your own
  - you might get hints if you are stuck on a specific problem
- negative aspects of using Chat-GPT
  - if you did not learn to program on your own, there is no chance to pass the exam
  - if you are stuck on a specific problem, be social: discuss with student colleagues
- why are studying computer science?
  - to learn programming skills and more?
  - to learn to use systems that can solve easy programming tasks?
- overall: usage of Chat-GPT is highly discouraged

Literature

- slides
  - no other topics will appear in exam . . .
  - . . . but topics need to be understood thoroughly
    - read and write functional programs
    - apply presented techniques on new examples
    - not only knowledge reproduction
- Richard Bird. Introduction to Functional Programming using Haskell, 2nd Edition, Prentice Hall.

Introduction

(Functional) Programming

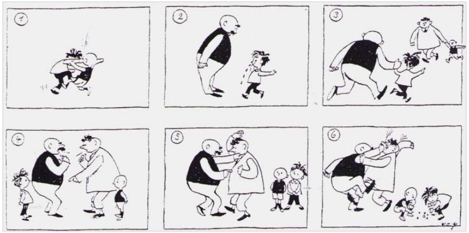
- task: solve problems
  - sort a list
  - generate a website
  - navigate from Innsbruck to Cologne
- distinguish between data . . .
  - input `[1,5,2]` and output `[1,2,5]`
  - query “search for ‘functional programming’” and resulting website
  - map of Europe, two locations and route
- . . . and programs
  - control over how data should be processed
  - mostly written by humans
- usually computers are used for executing a program on some input, but computation can also be done on paper or in mind

How to Learn Programming

+ read, study and write programs (many)
+ actively attend lecture and proseminar
+ try to solve exercises (alone or discuss in small teams)
− copy solutions from other students or from the internet

Algorithms and Programs

story (language agnostic)



text (language dependent)

- Tom and Paul were struggling until

  . . .
- Thomas und Paul rauften solange bis

  . . .
- 토마스와 파울은 싸우고 있었는데...

algorithm (prog. language agnostic)

- task: determine the maximum of m and a list of numbers
- if list is empty, result is m
- otherwise, change m to maximum of first element of list and m
- continue with rest of list

program (language dependent)

-
  ```
  maxlist m [] = m
  maxlist m (x : xs) =
    maxlist (max m x) xs
  ```

-
  ```
  while (list != null) {
    m = max(m, list.head);
    list = list.next; }
  return m;
  ```

Different Programming Styles

- Imperative Programming (VO Introduction to Programming)
  - state is mapping of variables to data
  - assignments instruct computer to update state
  - example
    - consider assignment `x := (x + y) / 2;`
    - if in a state `x` stores value 7 and `y` stores 3
    - then after executing assignment `x` stores value 5 and `y` still stores 3
- Functional Programming (this lecture)
  - define functions (mathematical: same input implies same output)
  - new results (of function invocations) are computed,
    but there is no notion of state that can be updated
  - example
    - consider function definition `average x y = (x + y) / 2` where `x` and `y` are parameters;
    - function invocation `average 7 3` is evaluated, e.g.,
      `average 7 3 = (7 + 3) / 2 = 10 / 2 = 5`
    - 7 is not changed into 5, there is no state with variable `x`
- Logic Programming, Object Oriented Programming, . . .

Different Programming Styles

- fact: most programming languages are of equal power
- demand for different styles still reasonable
  - each style has its own distinguishing features and limitations (like in real languages: translate “Ohrwurm” or “Internetbrowser”)
  - good programmer should know about alternatives:
    choose suitable style and language depending on problem and context
- advantages of functional programming
  - intuitive evaluation mechanism
  - suitable for verification
  - expressive language features
  - suitable for parallelization
- disadvantages of functional programming
  - more difficult to model state, side-effects, and I/O
  - not main-stream in industry, but getting more popular

Different Functional Programming Languages

- combinatory logic (Moses Schönfinkel 1924, Haskell Curry 1930): foundation of FP
- λ-calculus (Alonzo Church 1936): foundation of FP
- LISP (John McCarthy, 1958): List Processing
- ML (Robin Milner, 1973): Meta Language, several dialects
- Erlang (Ericsson, 1987): distributed computing
- Haskell (Paul Hudak and Philip Wadler, 1990): language in this course
- F# (Microsoft, 2002) and Scala (Martin Odersky, 2003): combine different programming styles, including FP

Syntax and Semantics

- syntax of a (programming) language defines valid sentences (programs)
  - "This is a proper English sentence."
  - "this one not propper"
  - computers refuse programs that contain syntactical errors!
- semantics defines the meaning of valid sentences / programs
  - "Clean your room!" ✔
  - `let xs = 1 : 1 : zipWith (+) xs (tail xs) in take 9 xs` ✘
- we will learn both syntax and semantics of Haskell

Haskell Scripts

```haskell
-- This script is stored in file script_01.hs

average x y = (x + y) / 2

{- the following function takes a temperature in
   degree Fahrenheit and converts it into Celsius -}

fahrenheitToCelsius f = (f - 32) * 5 / 9
```

- a Haskell script (= program) has file extension `.hs`
- a script is a collection of (several) function definitions
- comments are just for humans, ignored by computer
- single-line and multi-line comments
  - single: `-- everything right of -- is a comment`
  - multi:
    ```haskell
    {- multi-line comments can deactivate
    areaRectangle width height = width * height
    parts of script easily -}
    ```

Writing Haskell Scripts

```haskell
-- This script is stored in file script_01.hs
average x y = (x + y) / 2
fahrenheitToCelsius f = (f - 32) * 5 / 9
```

- coloring
  - when entering a Haskell script, one does not add colors in a text editor
  - syntax highlighting: often editors for computer programs automatically add colors to simplify reading; quickly distinguish
    - comments, keywords, names of functions, names of parameters, . . .
- function- and parameter-names (`average`, `x`, . . .)
  - always start with a lowercase letter, may contain digits
  - convention: long names use camelCase (`fahrenheitToCelsius`, . . .)
- white-space (spaces, tabs, newlines, . . .)
  - in Haskell white-space matters
  - for the moment, start every new line without blanks
  - the following script is not accepted

    ```haskell
    average x y = (x + y) / 2
     fahrenheitToCelsius f = (f - 32) * 5 / 9
    ```

Functional Programming – Sessions

- starting a session is like activating your calculator
- we use ghci, an interpreter for Haskell

```
rene$ ghci                     -- start the interpreter
Prelude> 42                    -- enter a value
42
Prelude> 5 * (3 + 4)           -- evaluate an expression
35
Prelude> :load script_01.hs      -- load script from file
[1 of 1] Compiling Main  ( script_01.hs, interpreted )
Ok, 1 module loaded.           -- script was accepted
*Main> fahrenheitToCelsius 95  -- invoke our function
35.0
*Main> :quit
```

Workflow for Functional Programming

- define functions in script
- load script (will compile script or deliver error message)
  - parse error: `5 +` (argument missing)
  - type error: `5 + "five"` (cannot add number and text)
  - error-messages are sometimes cryptic
- enter expression and start evaluation to get result (read-eval-print loop, REPL)
  - result: value which cannot be further simplified, e.g., `42`, `"hello"`, `[7,1,3]`, . . . , but not `5 + 7`, `fahrenheitToCelsius 8`, . . .
  - evaluation uses
    - built-in functions (`+`, `*`, `:`, `++`, `head`, `tail`, . . .), defined in Prelude
    - user-defined functions (`fahrenheitToCelsius`,. . .) from script-files

Compare FP to Calculator

- enter expression and let it compute result
- restricted to numbers and built-in functions

Comparison: FP vs Calculator

- task: convert many temperatures from Fahrenheit to Celsius: 8, 9, 300, . . .
- calculator: enter the following expressions
  - $(8 - 32) * 5/9$
  - $(9 - 32) * 5/9$
  - $(300 - 32) * 5/9$
  - . . . (quite tedious: enter same formula over and over again)
- FP
  - write one program: `fahrenheitToCelsius f = (f - 32) * 5 / 9`
  - just evaluate the function on the various inputs
    - `fahrenheitToCelsius 8`
    - `fahrenheitToCelsius 9`
    - `fahrenheitToCelsius 300`
    - . . . (concise, readable, easy: just invoke function)
  - or just: `map fahrenheitToCelsius [8,9,300,...]`
- program(s): a recipe to turn inputs into desired outputs

Summary

- Haskell scripts are stored in .hs-files
- functional programming: specify functions (input-output-behaviour)
- ghci loads scripts and evaluates expressions
- next lecture: beyond numbers – structured data