Preparatory Course in Computer Science (D-ITET)

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Context of this Lecture

- **Computer Science 0** (Preparatory Course): Gain first programming experience
- **Computer Science 1**: Theoretical and practical foundations of computer science
- **Computer Science 2**: Algorithms and Data structures
- **Computer Engineering 1**: Logical and physical structures of digital systems
- **Computer Engineering 2**: Important components of operating systems
- ... and further courses (more or less directly) related to computer science

Course goals

- Provide first programming experience
- Scratch the “computer science surface”
- This course cannot, unfortunately, make up for years of programming experience (school, hobby) ...
- ... but it should ease the learning curve for Computer Science 1

Course Structure: Performance assessment

- No exam
- Two programming projects need to be passed instead

Course Structure: Schedule

Weeks	Program
1	Lecture: Thu 20.09., 13:15 – 15:00 C++ tutorial, 1. project
2	Contact hours: Mon 24.09. HG F1, Tue 25.09. HG E7, 17:00 – 19:00 1. project
3	Submission 1. project Lecture: Wed 03.10., 13:15 – 15:00 Contact hours: Mon 01.10. HG F1, Tue 02.10. HG E7, 17:00 – 19:00 2. project
4-7	Contact hours: Tue 9./16./23./30.10, HG E7, 17:00 – 19:00 2. project
7	Submission 2. project

1. Introduction

Computer Science: Definition and History, Algorithms, Turing Machine, Higher Level Programming Languages, Tools, The first C++Program and its Syntactic and Semantic Ingredients

What is Computer Science?

- The science of **systematic processing of informations**,. . .
- . . . particularly the automatic processing using digital computers.

(Wikipedia, according to “Duden Informatik”)

Computer Science vs. Computers

Computer science is not about machines, in the same way that astronomy is not about telescopes.

Mike Fellows, US Computer Scientist (1991)

http://larc.unt.edu/ian/research/cseducation/fellows1991.pdf

Computer Science vs. Computers

- Computer science is also concerned with the development of fast computers and networks. . .
- . . . but not as an end in itself but for the **systematic processing of informations**.

Computer Science $\neq$ Computer Literacy

Computer literacy: *user knowledge*

- Handling a computer
- Working with computer programs for text processing, email, presentations . . .

Computer Science *Fundamental knowledge*

- How does a computer work?
- How do you write a computer program?

Algorithm: Fundamental Notion of Computer Science

Algorithm:

- Instructions to solve a problem step by step
- Execution does not require any intelligence, but precision (even computers can do it)
- Oldest nontrivial algorithm:
  Euclidean algorithm, 3. century B.C.
- according to *Muhammed al-Chwarizmi*, author of an arabic computation textbook (about 825)

"**Dixit algorizmi. . .**" (Latin translation)

http://de.wikipedia.org/wiki/Algorithmus

Binary Search: Problem & Idea

Problem: find an element in an *ordered* list

Idee: search in a dictionary — open in the middle, continue left/right if necessary

Binary Search: Example

find 7 in the list $[1, 3, 4, 7, 9, 11, 12, 17]$

1	3	4	7	9	11	12	17
1	3	4	7	9	11	12	17
1	3	4	7	9	11	12	17
1	3	4	7	9	11	12	17
1	3	4	7	9	11	12	17
1	3	4	7	9	11	12	17

Binary Search: Pseudo Code

- Input: sorted list of numbers L, number to find n
- Output: “yes” (“no”) if n (not) in L

While output O is yet unknown:
  If L empty then: $O \leftarrow$ “no”
  Otherwise:
    Select central number L_m:
    If $L_m = n$ then: $O \leftarrow$ “yes”
    If $n < L_m$ then: $L \leftarrow$ left half of L
    Otherwise: $L \leftarrow$ right half of L

Binary Search: C++ Implementation

```
std::string binary_search(const int* begin, const int* end,
                          const int n) {
  while (true) {
    if (begin >= end) return "no";
    const int* mid = begin + (end - begin) / 2;
    if (*mid == n) return "yes";
    else if (n < *mid) end = mid;
    else begin = mid + 1;
  }
}
```

Don’t panic: the C++ code is only shown to illustrate the differences between an algorithm description in pseudo code and a concrete implementation. The used language constructs are only introduced in Computer Science 1.

Algorithms: 3 Levels of Abstractions

1. **Core idea** (abstract)**:**
   the essence of any algorithm (“Eureka moment”)
2. **Pseudo code** (semi-detailed)**:**
   made for humans (education, correctness and efficiency discussions, proofs
3. **Implementation** (very detailed)**:**
   made for humans & computers (read- & executable, specific programming language, various implementations possible)

Why programming?

- Do I study computer science or what ...
- There are programs for everything ...
- I am not interested in programming ...
- because computer science is a mandatory subject here, unfortunately...
- ...

Mathematics used to be the lingua franca of the natural sciences on all universities. Today this is computer science.

Lino Guzzella, president of ETH Zurich, NZZ Online, 1.9.2017

((BTW: Lino Guzzella is not a computer scientist, he is a mechanical engineer and prof. for thermotronics 😉)

This is why programming!

- Any understanding of modern technology requires knowledge about the fundamental operating principles of a computer.
- Programming (with the computer as a tool) is evolving a cultural technique like reading and writing (using the tools paper and pencil)
- Programming is *the* interface between engineering and computer science – the interdisciplinary area is growing constantly.
- Programming is fun (and is useful)!

Programming

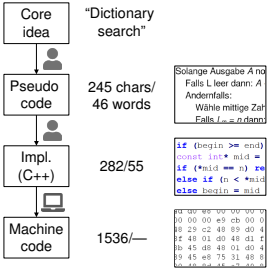
- With a *programming language* we issue commands to a computer such that it does exactly what we want.
- The sequence of instructions is the *(computer) program*

The Harvard Computers, human computers, ca.1890

http://en.wikipedia.org/wiki/Harvard_Computers

Programming Languages

- The language that the computer can understand (machine language) is very primitive.
- Simple operations have to be subdivided into (extremely) many single steps
- The machine language varies between computers.



Computing speed

In the time, on average, that the sound takes to travel from me to you ...

$30\ \text{m} \mathrel{\widehat{=}}$ more than $100.000.000$ instructions

a contemporary desktop PC can process more than 100 millions instructions [1]

[1] Uniprocessor computer at 1 GHz.

Higher Programming Languages

We write programs (implementations) in a *high-level programming language*:

- Can be *understood* by humans
- is *hardware-independent*
- Includes *reusable* function libraries

Why C++?

Other popular programming languages: Java, C#, Python, Javascript, Swift, Kotlin, Go, ...

- C++ is practically relevant, widespread and "runs everywhere"
- C++ is standardized i.e. there is an official
- C++ is one of the "fastest" programming languages
- C++ well-suited for systems programming since it enables/requires careful resource management (memory, ...)

Syntax and Semantics

- Like our language, programs have to be formed according to certain rules.
  - *Syntax*: Connection rules for elementary symbols (characters)
  - *Semantics*: interpretation rules for connected symbols.
- Corresponding rules for a computer program are simpler but also more strict because computers are relatively stupid.

Deutsch vs. C++

Deutsch

Alleen sind nicht gefährlich, Rasen ist gefährlich!
(Wikipedia: Mehrdeutigkeit)

C++

```
// computation
int b = a * a; // b = a^2
b = b * b;     // b = a^4
```


C++: Kinds of errors illustrated with German sentences

Das Auto fuhr zu schnell.	Syntaktisch und semantisch korrekt.
DasAuto fuh r zu sxhnell.	Syntaxfehler: Wortbildung.
Rot das Auto ist.	Syntaxfehler: Satzstellung.
Man empfiehlt dem Dozenten nicht zu widersprechen	Syntaxfehler: Satzzeichen fehlen .
Sie ist nicht gross und rothaarig.	Syntaktisch korrekt aber mehrdeutig. [kein Analogon]
Die Auto ist rot.	Syntaktisch korrekt, doch semantisch fehlerhaft: Falscher Artikel. [Typfehler]
Das Fahrrad galoppiert schnell.	Syntaktisch und grammatikalisch korrekt! Semantisch fehlerhaft. [Laufzeitfehler]
Manche Tiere riechen gut.	Syntaktisch und semantisch korrekt. Semantisch mehrdeutig. [kein Analogon]

Syntax and Semantics of C++

Syntax:

- When is a text a $C++$ *program?*
- I.e. is it *grammatically* correct?
- → Can be checked by a computer

Semantics:

- What does a program *mean*?
- Which algorithm does a program *implement*?
- → Requires human understanding

Syntax and semantics of C++

The ISO/IEC Standard 14822 (1998, 2011, 2014, ...)

- is the “law” of C++
- defines the grammar and meaning of C++programs
- since 2011, continuously extended with features for *advanced* programming

2. C++ Language Constructs by Example

Programming Tools

- **Editor:** Program to modify, edit and store C++program texts
- **Compiler:** program to translate a program text into machine language
- **Computer:** machine to execute machine language programs
- **Operating System:** program to organize all procedures such as file handling, editor-, compiler- and program execution.

A First C++ Program: Prelude

The next slides show a first, interesting program, which is used to illustrate various important ingredients of the C++ programming language. The slides are basically a short summary of the C++ tutorial, and it is therefore recommended to first study the tutorial.

The shown program is *not* the program from the lecture — reproducing the letter is a subtask of the first project ☺.

Language constructs with an example

- Comments/layout
- Include directive
- the main function
- Values effects
- Types and functionality
- literals
- variables
- identifiers, names
- objects
- expressions
- operators
- statements

The Basics: Statements and Expressions

```
// Program: power8.cpp
// Raise a number to the eighth power.
#include <iostream>
int main(){
    // input
    std::cout << "Compute a^8 for a =? ";
    int a;
    std::cin >> a;
    // computation
    int b = a * a; // b = a^2
    b = b * b;     // b = a^4
    // output b * b, i.e., a^8
    std::cout << a << "^8 = " << b * b << "\n";
    return 0;
}
```

Statements: Do something (read in a)!

Expressions: Compute a value (a^2)!

Behavior of a Program

At compile time:

- program accepted by the compiler (syntactically correct)
- Compiler error

During runtime:

- correct result
- incorrect result
- program crashes
- program does not terminate (endless loop)

“Accessories:” Comments

```
// Program: power8.cpp
// Raise a number to the eighth power.
#include <iostream>
int main() {
    // input
    std::cout << "Compute a^8 for a =? ";
    int a;
    std::cin >> a;
    // computation
    int b = a * a; // b = a^2
    b = b * b;     // b = a^4
    // output b * b, i.e., a^8
    std::cout << a << "^8 = " << b * b << "\n";
    return 0;
}
```

comments

Comments and Layout

Comments

- are contained in every good program.
- document *what* and *how* a program does something and how it should be used,
- are ignored by the compiler
- Syntax: “double slash” `// until the line ends.`

The compiler *ignores* additionally

- Empty lines, spaces,
- Indendations that should reflect the program logic

Comments and Layout

The compiler does not care...

```
#include <iostream>
int main(){std::cout << "Compute a^8 for a =? ";
int a; std::cin >> a; int b = a * a; b = b * b;
std::cout << a << "^8 = " << b*b << "\n";return 0;}
```

... but we do!

“Accessories:” Include and Main Function

```
// Program: power8.cpp
// Raise a number to the eighth power.
#include <iostream>
int main() {
    // input
    std::cout << "Compute a^8 for a =? ";
    int a;
    std::cin >> a;
    // computation
    int b = a * a; // b = a^2
    b = b * b;     // b = a^4
    // output b * b, i.e., a^8
    std::cout << a << "^8 = " << b * b << "\n";
    return 0;
}
```

include directive

declaration of the main function

Include Directives

C++ consists of

- the core language
- standard library
  - in-/output (header iostream)
  - mathematical functions (cmath)
  - ...

`#include <iostream>`

- makes in- and output available

The main Function

the `main`-function

- is provided in any C++ program
- is called by the operating system
- like a mathematical function ...
  - arguments
  - return value
- ... but with an additional *effect*
  - Read a number and output the 8th power.

Statements: Do something!

```
int main() {
    // input
    std::cout << "Compute a^8 for a =? ";
    int a;
    std::cin >> a;
    // computation
    int b = a * a; // b = a^2
    b = b * b;     // b = a^4
    // output b * b, i.e., a^8
    std::cout << a << "^8 = " << b * b << "\n";
    return 0;
}
```

expression statements

return statement

Statements

- building blocks of a C++ program
- are *executed* (sequentially)
- end with a semicolon
- Any statement has an *effect* (potentially)

Expression Statements

- have the following form:

  expr;

  where *expr* is an expression
- Effect is the effect of *expr*, the value of *expr* is ignored.

Example: `b = b*b;`

Return Statements

- do only occur in functions and are of the form

  `return` expr;

  where *expr* is an expression
- specify the return value of a function

Example: `return 0;`

Statements – Effects

```
int main() {
    // input
    std::cout << "Compute a^8 for a =? ";
    int a;
    std::cin >> a;
    // computation
    int b = a * a;      // b = a^2
    b = b * b;          // b = a^4
    // output b * b, i.e., a^8
    std::cout << a << "^8 = " << b * b << "\n";
    return 0;
}
```

effect: output of the string `Compute ...`

Effect: input of a number stored in a

Effect: saving the computed value of a*a into b

Effect: saving the computed value of b*b into b

Effect: return the value 0

Effect: output of the value of a and the computed value o

Values and Effects

- determine what a program does,
- are purely semantical concepts:
  - Symbol 0 means Value $0 \in \mathbb{Z}$
  - `std::cin >> a;` means effect "read in a number"
- depend on the program state (memory content, inputs)

Statements – Variable Definitions

```
int main() {
    // input
    std::cout << "Compute a^8 for a =? ";
    int a;
    std::cin >> a;
    // computation
    int b = a * a;      // b = a^2
    b = b * b;          // b = a^4
    // output b * b, i.e., a^8
    std::cout << a << "^8 = " << b * b << "\n";
    return 0;
}
```

declaration statement

type names

Declaration Statements

- introduce new names in the program,
- consist of declaration and semicolon

  Example: `int a;`
- can initialize variables

  Example: `int b = a * a;`

Types and Functionality

`int`:

- C++ integer type
- corresponds to $(\mathbb{Z}, +, \times)$ in math

In C++ each type has a name and

- a domain (e.g. integers)
- functionality (e.g. addition/multiplication)

Fundamental Types

C++ comprises fundamental types for

- integers (`int`)
- natural numbers (`unsigned int`)
- real numbers (`float`, `double`)
- boolean values (`bool`)
- ...

Literals

- represent constant values
- have a fixed *type* and *value*
- are "syntactical values"

Examples:

- `0` has type `int`, value 0.
- `1.2e5` has type `double`, value $1.2 \cdot 10^5$.

Variables

- represent (varying) values
- have
  - *name*
  - *type*
  - *value*
  - *address*
- are "visible" in the program context

Example

`int a;` defines a variable with

- name: `a`
- type: `int`
- value: (initially) undefined
- Address: determined by compiler

Objects

- represent values in main memory
- have *type*, *address* and *value* (memory content at the address)
- can be named (variable) ...
- ... but also anonymous.

Remarks

A program has a *fixed* number of variables. In order to be able to deal with a variable number of value, it requires "anonymous" addresses that can be address via temporary names (→ Computer Science 1).

Identifiers and Names

(Variable-)names are identifiers

- allowed: A,...,Z; a,...,z; 0,...,9;_
- First symbol needs to be a character.

There are more names:

- `std::cin` (Qualified identifier)

Expressions: compute a value!

- represent *Computations*
- are either primary (`b`)
- or composed (`b*b`)...
- ...from different expressions, using operators
- have a type and a value

Analogy: building blocks

composite expression

```
// input
std::cout << "Compute a^8 for a =? ";
int a;
std::cin >> a;

// computation
int b = a * a;  // b = a^2
b = b * b;

// output b * b, i.e., a^8
std::cout << a<< "^8 = " << b * b << ".\ n";

return (
```

Two times composed expression

Four times composed expression

Expressions

- represent *computations*
- are *primary* or *composite* (by other expressions and operations)

`a * a`
composed of
variable name, operator symbol,variable name
variable name: primary expression

- can be put into parantheses

`a * a` is equivalent to `(a * a)`

Expressions

have *type*, *value* und *effect* (potentially).

Example

`a * a`

- type: `int` (type of the operands)
- Value: product of `a` and `a`
- Effect: none.

Example

`b = b * b`

- type: `int` (Typ der Operanden)
- Value: product of `b` and `b`
- effect: assignment of the product value to `b`

The type of an expression is fixed but the value and effect are only determined by the *evaluation* of the expression

left operand (output stream)
output operator
right operand (string)

```
// input
std::cout << "Compute a^8 for a =? ";
int a;
std::cin >> a;

// computation
int b = a;
b = b * b;      // b = a^4

// output a^8
std::cout << a << "^8 = " << b * b << "\n";
return 0;
```

right operand (variable name)
input operator
left operand (input stream)
assignment operator
multiplication operator

Operators

Operators

- combine expressions (*operands*) into new composed expressions
- specify for the operands and the result the types and if the have to be L- or R-values.
- have an arity (number of operands)

Multiplication Operator *

- expects two values of the same type as operands (arity 2)
- returns the product as value of the same type
- The composite expression represents a value; its value is the product of the value of the two operands

Examples: `a * a` and `b * b`

Assignment Operator =

Assigns to the left operand (typically a variable) the value of the right operand

Examples: `b = b * b` and `a = b`

Attention, Trap!

The operator = corresponds to the assignment operator of mathematics ($:=$), not to the comparison operator ($=$).

Input Operator >>

- left operand is the *input stream*
- assigns to the right operand (typically a variable) the next value read from the input stream, *removing it from the input stream* and returns the input stream

Example `std::cin >> a` (mostly keyboard input)

Output Operator <<

- left operand is the *output stream*
- outputs the value of the right operand, appends it to the output stream and returns the output stream

Example: `std::cout << a` (mostly console output)

Output Operator <<

Why returning the output stream?

- allows bundling of output

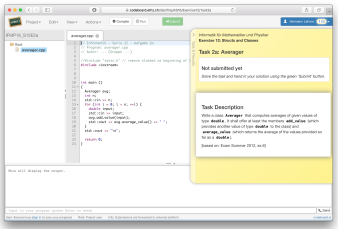
```
std::cout << a << "^8 = " << b * b << "\n"

is parenthesized as follows

((((std::cout << a) << "^8 = ") << b * b) << "\n")
```

- `std::cout << a` is the left hand operand (i.e. output stream) of the next <<

3. Organisation of Programming Projects

Codeboard

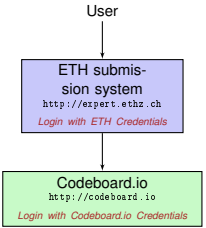
Codeboard is an online IDE: programming in the browser!



Code Expert

Our exercise system consists of two independent systems that communicate with each other:

- **The ETH submission system:** Allows us to evaluate your tasks.
- **The online IDE:** The programming environment



Projects = Exercise

- Code Expert aims at a “regular” exercise work-flow, hence the terminology “exercises”, “exercise groups”, etc.
- On Code Expert, our programming projects as thus listed as exercises, and there is only one exercise group

Registration

Codeboard.io Registration

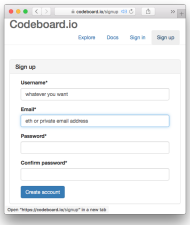
Go to `http://codeboard.io` and create an account, stay logged in.

Enrol on Code Expert

Go to `http://expert.ethz.ch/inf0itet18` and enrol in exercise group `Students`.

Codeboard.io Registration

If you do not yet have an **Codeboard.io** account ...



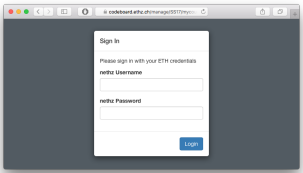
- We use the online IDE **Codeboard.io**
- Create an account to store your progress and be able to review submissions later on
- Credentials can be chose arbitrarily *Do not use the ETH password.*

Codeboard.io Login

If you have an account, log in:

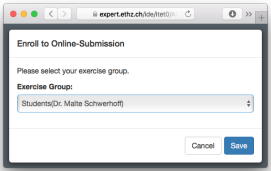
Exercise group registration I

- Visit `http://expert.ethz.ch/inf0itet18`
- Log in with your nethz account.



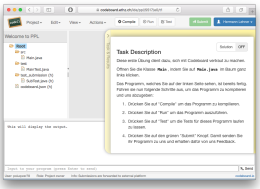
Exercise group registration II

In this dialogue, enrol in exercise group `Students`.



The first exercise.

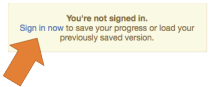
You are now registered and the first exercise is loaded. Follow the instructions in the yellow box.



(Screenshot isn't recent)

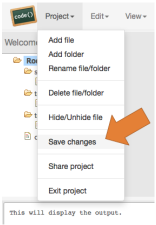
Attention: Codeboard.io Login

Attention If you see this message, click on Sign in now and register with you **codeboard.io** account.



Attention: Saving Progress

Attention! Store your progress regularly. So you can continue working at any different location.



Academic integrity

The ETH Zurich Ordinance on performance assessments applies

Rule: You submit solutions that you have written yourself and that you have understood.

We check this (partially automatically) and reserve our rights to adopt disciplinary measures

The way to go (see slides on algorithms):

- Code idea: consider discussing in groups
- Pseudo code: consider discussing in groups
- Implementation: *Individual work!*