Praktische Aspekte der Informatik

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https://graphics.tu-bs.de/teaching/ss19/padi/
Introduction
What you need to know.
You will learn...

... how to program in C++.
... how to work with libraries.
... how to debug your code.
... how to optimize your code.
... how to organize your code.
... much more!
Why?

• If you’re a bachelor’s student...
  ... you already know Java!
  ... you will have to do the SEP and the Teamprojekt.
  ... you will have to write a Bachelor’s thesis.

• If you’re a master’s student...
  ... you may want to write a Projektarbeit.
  ... you will have to write a Master’s thesis.

• Eventually, all of you will work in the real world!
How?

• **First Part:** Weekly Assignments
  - Brief talk (15-20 min).
  - Work on assignment in small groups.
  - Develop a proposal for a project.

• **Second Part:** Your Project
  - Brief talk (15-20 min).
  - Work on your own project.
  - Give regular updates on your progress.

• **Prototype:** Present your current state
  - 19.06.2019 + 21.06.2019

• **Final Week:** Present your Project
  - 10.07.2019 + 12.07.2019
About your Project

• Your software project…
  … can be anything you want  (more or less)
  … must be written in C++!
  … should highlight the skills you have learned.
  … must use at least one external library.
  … must have a visual component.

• Your project will be graded on…
  … function & quality.
  … polish & presentation.
  … whether you’re a Ba/Ma student.

• You alone are responsible for your project!

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TU Abalone

- Complete ruleset of the Abalone game.
- Various game setups.
- Local multiplayer.
- Responsive user interface.
- Fancy animations!
- Save / Load / Undo / …

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Project SnackmiX

• Complete ruleset of Chinese Chess.
• Movement Hints.
• Local multiplayer.

• Cool 3D graphics!
• Fancy animations!
• Special Effects!
Example: Master’s Project

Closer

• Jump & Run.
• Simple 2D graphics.
• Fancy design and animations.
• Levels loaded from custom format.
• Engine architecture from scratch.

• Various helpful debug views.
• Music and Sound Effects.

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Final remarks

• Be present!
  ▪ Otherwise, you might miss important announcements.
  ▪ Most importantly, I cannot help you if you’re not here.

• A computer scientist must work in any environment!
  ▪ You may do weekly assignments on your own computer.
  ▪ Your project *should* run in the CIP-Pool
    If it does not, you are responsible to be able to present it.
  ▪ Challenge: Set up your project for multiple platforms.

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Final remarks

• Do not underestimate the workload!

6 credits $\rightarrow$ 180 hours!

PADI is a lot of work!
Pick a project you love!

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C++ Basics

Compiler, Classes, Pointers, Inheritance and more!
Warning!

The following slides are meant to give you a very superficial introduction to C++ basics.

If you want to learn more, have a look at:

http://www.cplusplus.com
http://www.cppreference.com
http://www.learncpp.com
Outline

Introduction

Building, Classes and Structs

Standard Template Library

Pointers and References

Inheritance

File I/O

Assignment
What is C++?

Benefits:
- Very similar to Java (which you already know!)
- Object oriented
- Fast, powerful, and widely used
- Many libraries and much code already available
- A lot of tutorials and help.

Drawbacks:
- Not very intuitive / fast to program
- No Garbage Collector
- Error prone
main.cpp

// Import I/O functionality
#include <iostream>

// This is the main entry point.
int main() {

    // Print "Hello World!" and end the program
    std::cout << "Hello World!" << std::endl;
    return 0;

}
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Assignment
• When creating an executable, your code is...
  ... preprocessed ("glued" together)
  ... compiled (translated to be machine-readable)
  ... and linked (all the parts are connected)

• Different errors can occur at different stages
  ▪ Not always easy to understand.
  ▪ More on that next week.
MyClass.h

#ifndef MYCLASS_H
#define MYCLASS_H

class MyClass {

public:
    MyClass(); // Constructor
    void doMagic(); // Some member function

private:
    int counter; // Some member variable

};

#endif
Your first class (.cpp)

MyClass.cpp

#include <iostream>
#include "MyClass.h"

// Namespace::functionName() { definition; }

MyClass::MyClass() { // Constructor
    this->counter = 0;
}

void MyClass::doMagic() { // Some member function
    std::cout << "MyClass::doMagic has been called"
                << ++this->counter << " times."
                << std::endl;
}
main.cpp

#include "MyClass.h"

int main() {

    // Create an object of class MyClass
    MyClass my_object;
    for (int i = 0; i < 10; ++i)
        my_object.doMagic();  // Do magic!

    return 0;
}

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Building your code

1. Preprocessor

2. Compiler

3. Linker

Hello
Vector3D.h

#ifndef VECTOR3D_H
#define VECTOR3D_H

struct Vector3D {
    float x, y, z;    // public members
};

#endif

They work just like classes*!

*but they are commonly used for storing data.
Vector3D.h

#ifndef VECTOR3D_H
#define VECTOR3D_H

struct Vector3D {
    Vector3D(float x = 0, float y = 0, float z = 0) {
        this->x = x; this->y = y; this->z = z;
    }
    float x,y,z;
};

#endif
#ifndef VECTOR3D_H
#define VECTOR3D_H

struct Vector3D {
    Vector3D(float x = 0, float y = 0, float z = 0) {
        this->x = x;  this->y = y;  this->z = z;
    }
    float x, y, z;
};

Vector3D operator+(Vector3D a, Vector3D b) {
    return Vector3D(a.x+b.x, a.y+b.y, a.z+b.z);
}

#endif
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Assignment
• Many generic containers already exist.
  - There are *lists*, *sets*, *stacks*, *maps*...

• There are algorithms, too!
  - You can *count*, *find*, *merge*, *sort*, *replace*...

• They are all fast and well documented.


**STL Vector**

```cpp
#include <vector>

// Create a vector and add some values
std::vector<float> values;
values.push_back(1.1);
values.push_back(2.3);
values.push_back(4.2);

std::cout << "Size of vector: " << values.size() << std::endl; // Size: 3
std::cout << "Value at index 1: " << values[1] << std::endl; // values[1]: 2.3
values.clear();
std::cout << "Size of vector: " << values.size() << std::endl; // Size: 0
```

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#include <vector>
#include "Vector3D.h"

// A vector of Vector3D objects
std::vector<Vector3D> vectors;

Vector3D v(1.1, 2.3, 4.2);
vectors.push_back(v);

vectors.push_back(Vector3D(1.1, 2.3, 4.2));
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Assignment
Pointers and References

• Easy to spot: & and *
  ▪ Reference: `float & value;`
  ▪ Pointer: `float * value;`

• References are easier to use.
  ▪ There is no special syntax.
  ▪ You cannot change where they point.

• Pointers give you more freedom.
  ▪ You can change pointers at runtime.
  ▪ You have to be careful where you point.
  ▪ You have to clean up after yourself: new and delete
int a = 5;  // integer save values
int a = 5;  // integer save values
int * b;    // pointer save addresses (NULL)
Pointers and References

```c
int a = 5;  // integer save values
int * b;    // pointer save addresses (NULL)
b = &a;     // b save address of a
```

[Diagram showing binary representation of a and the pointer `b`]

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int a = 5;  // integer save values
int * b;    // pointer save addresses (NULL)
b = &a;     // b save address of a
int & c;    // error! NULL not allowed
int a = 5;  // integer save values
int * b;    // pointer save addresses (NULL)
b = &a;     // b save address of a
int & c;    // error! NULL not allowed
int & c = a; // reference to a
Pointers and References

```c
int a = 5;  // integer save values
int * b;   // pointer save addresses (NULL)
b = &a;    // b save address of a
int & c;   // error! NULL not allowed
int & c = a;  // reference to a
*b = 6;    // change value of a
```
```c
int a = 5; // integer save values
int * b;  // pointer save addresses (NULL)
b = &a;   // b save address of a
int & c;  // error! NULL not allowed
int & c = a; // reference to a
*b = 6;   // change value of a
int d = 7;
```
int a = 5;    // integer save values
int * b;      // pointer save addresses (NULL)
b = &a;       // b save address of a
int & c;      // error! NULL not allowed
int & c = a;  // reference to a
*b = 6;       // change value of a
int d = 7;
b = &d;       // change saved address
int a = 5;  // integer save values
int * b;  // pointer save addresses (NULL)
b = &a;  // b save address of a
int & c;  // error! NULL not allowed
int & c = a;  // reference to a
*b = 6;  // change value of a
int d = 7;
b = &d;  // change saved address
c = d;  // change value of a
float fooCopy(float float_copy) {
    return ++float_copy;
}
float fooRef(float & float_reference) {
    return ++float_reference;
}
float fooConstRef(float const& float_const_reference) {
    return float_const_reference + 1;
}
float fooPtr(float * float_pointer) {
    return ++(*float_pointer);
}
float fooConstPtr(float const* float_const_pointer) {
    return (*float_const_pointer) + 1;
}
Prevent unwanted changes using \texttt{const}!

\texttt{const} usually applies to what’s \textit{left} of it…

\begin{verbatim}
float \texttt{const} value=.5f; // const float
float \texttt{const}* ptr;     // pointer to a const float
float *\texttt{const} ptr;    // const pointer to a float
float \texttt{const}*\texttt{const} ptr; // const pointer to const float
\end{verbatim}

… except when it doesn’t…

\begin{verbatim}
\texttt{const} float value=.5f; // float const value
\texttt{const} float * ptr;    // float const* ptr;
\texttt{const} float *\texttt{const} ptr; // float const*const ptr;
\end{verbatim}
• By default, objects are allocated on the **stack**.
  - Automatically deleted at the end of their scope.
  - You can access memory addresses using pointers*
    *but be careful with that!

• If you use **new**, objects are stored in the **heap**.
  - Manually clean up using **delete**.
  - Pointers themselves are often on the stack, i.e. they are automatically cleaned up, but the allocated object they point to is not!
  - If no valid pointer to an allocated object remains, you have created a **memory leak**!
Explicitly allocate/deallocate memory:

```cpp
Vector3D* my_ptr = new Vector3D(1.1, 2.3, 4.2);
// ... do stuff ...
delete my_ptr;
```

You can also allocate arrays:

```cpp
// allocate 3 consecutive floats in memory
float* my_ptr = new float[3];
my_ptr[0] = 4.2f; // initialize your values...
    // ...
float val = my_ptr[1]; // access the second float
float err = my_ptr[5]; // this might/should crash!
delete[] my_ptr; // deallocate the entire array
```
Important Operators when working with pointers:

- Dereference using . and ->
- Unfortunately, there’s also & and *.

```cpp
Vector3D* vec = new Vector3D;
vec->x = 4.2f;
(*vec).x = 4.2f;

// [...]
Vector3D other_vector;
vec = &other_vector;

// [...]
float value = fooPtr(&vec->x);
```
Why use pointers?

• When you use pointers...
  ▪ you can decide when your variables die.
  ▪ you can control memory allocation.
  ▪ You can share them—but beware!

• Helpful advice:
  ▪ When passing anything bigger than a primitive, pass a `const&`
  ▪ When an argument variable is altered by a function, pass a `pointer`
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Assignment
• Classes may inherit from **multiple** other classes

• Classes can be abstract (just like in JAVA)

• You can define your own…
  ... Constructors,
  ... Destructors,
  ... and (assignment) operators

• Virtual classes allow method overriding
main.cpp

class A { // Parent class
    virtual std::string foo() { return "I am A!"; }
};
class B : public A { // Child class
    std::string foo() { return "I am B!"; }
};

int main() {
    std::vector< A* > vec;
    vec.push_back(new A);
    vec.push_back(new B); // an A* pointer is also valid for B*
    for (int i = 0; i < vec.size(); ++i)
        std::cout << vec[i]->foo() << std::endl;
    return 0;
}
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Assignment
void MyClass::readFile(std::string const & filename) {
  // Open the file for reading
  std::ifstream fin(filename.c_str());
  // Read the title (string)
  fin >> this->title;
  // Read the points (float)
  int num_points;
  fin >> num_points;
  for (int i = 0; i < num_points; ++i) {
    float value;
    fin >> value;
    this->values.push_back(value);
  }
  fin.close();
}
```cpp
void MyClass::writeFile(std::string const& fname) const {
    // Open the file for writing
    std::ofstream fout(fname.c_str(), std::ios::out);

    // Write the title and number of points
    fout << this->title + "*1.5" << std::endl;
    fout << this->values.size() << std::endl;

    // Write the point values (multiplied by 1.5)
    for (int i = 0; i < values.size(); ++i)
        fout << (values[i]*1.5f) << std::endl;

    fout.close();
}
```
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File I/O

Assignment
world.txt

block 0 -0.125 0 20 0.25 20  # x,y,z, width, height, depth
sphere 8 6 7 2 16            # x,y,z, radius, tessellation
sphere 8 8 7 1.5 16
block 8 3 7 0.5 6 0.5
block -6 2.5 2 6 5 8
block -4 3.5 -5 10 7 6
Wavefront .obj file format

# List of vertices (nodes), with (x,y,z) coordinates
v 0.25 0.53 0.763  # vertex 1
v ...  # vertex 2
v ...

# List of polygons (faces), with vertex indices
f 1 2 3  # triangle
f 2 3 4
f 2 5 6 4  # quad
f ...
A. Look at the examples
   Have a look at, compile, and understand all examples.

B. Hello World!
   Implement a small C++ program that reads the world.txt file and converts it to an .obj file.

   Look at assignment_stub/main.cpp for more information.

   Hint: If you’re stuck, the internet will help!

C. Have Fun!
   How about adding more object types? (Cylinders, Pyramids, …)
   How about adding rotation?
   …
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Assignment
Closing thoughts

• PADI Philosophy
  ▪ Gap knowledge.
  ▪ Practical skills that glue together different aspects of CS.

• Heterogeneous Audience
  ▪ Some of you know nothing, some know a lot.
  ▪ Adjust your ambitions for the final project.
  ▪ Help each other!

• Improve your individual programming skills!
Wichtig!

Die Termine für die abschließenden Kolloquien sind:

10.07.2019 13:15 Uhr
12.07.2019 13:15 Uhr

Ihr müsst PADI beim Prüfungsamt anmelden!