COMPUTER SCIENCE I & II

Summary of the Lectures held by
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C++ QUICK REFERENCE

DATATYPES

INTEGRAL TYPES

char	1 Byte	-128 to 127
short	2 Bytes	-32'768 to 32'767
int	2/4 Bytes	usually as below
long int	4 Bytes	-2'147'483'648 to ...
bool	1 Byte	0 or 1
float	4 Bytes	1.2e-38 to 3.4e38
double	8 Bytes	2.2e-308 to 1.8e308
long double	12 Bytes	
wchar_t		
void	-	not a real datatype

Sizes and value ranges can differ depending on your platform.
Only `char` is certainly 1 byte. For the size of the other types:
`char <= short <= int <= long int, ...`
`unsigned`: removes negative range and appends it at the end.
`#include <limits> numeric_limits<signed long>::max()`

INLINE TYPE SPECIFICATION

```
2L, 2U, 2UL, 2.0 //not case sensitive
2.0f  //the f makes it a float instead of double
2.0   //double
2f    //error
2.0d  //error
2.1l  //long float = double
```

VARIABLE/FIELD DECLARATION

```
(storage-class-spec) (cv-qualifier) (type) name;
cv-qualifier:        -, const, volatile, const volatile
storage-class-spec:  -, auto, register, static, extern, mutable
type:                (sign) (size) (datatype)
size:                -, long, short, double, …
sign:                -, signed, unsigned
//extreme example:
extern const short unsigned int myVar;
```

DECLARATION FLAGS

`volatile`: usually prevents optimization
`register`: tells compiler, that this object is frequently used
`static`: value is stored for the duration of the program
`mutable`: can be edited from a const function
`extern`: only declaration(setting the name) instead of definition (requesting memory)

VARIABLE/FIELD NAMES

Variable names cannot start with: any keyword mentioned below or a digit. They should not start with an underscore (_)
Variable names cannot contain: spaces, special characters (ä, ...). Variable names are case sensitive and <31 characters long.

- **Keywords:**

`and, and_eq, asm, auto, bitand, bitor, bool, break, case, catch, char, class, compl, const, const_cast, continue, default, delete, do, double, dynamic_cast, else, enum, explicit, export, extern, false, float, for, friend, goto, if, inline, int, long, mutable, namespace, new, not, not_eq, nothrow, operator, or, or_eq, private, protected, public, register, reinterpret_cast, return, short, signed, sizeof, static, static_cast, struct, switch, template, this, throw, true, try, typedef, typeid, typename, union, unsigned, using, virtual, void, volatile, wchar_t, while, xor, xor_eq`

INITIALIZATION

```
int a, b = 3, c; //a = c = undef, b = 3
int d(5);
```

NUMBERS

11: decimal (10+1), 011: octal (8+1=9), 0x11: hex (16+1=17)
1000 = 1E3 = 1e3 = 1e+3 = 1E+3; 0.1 = 1e-1 = 1E-1

ARRAYS

```
int arr[4]; //arr[0] to arr[3] defined
int arr[][2] = {{1,2},{3,4},{5}};
//ok, 1st dimension is inferred:
//arr[3][2] has a pseudo-random value
int arr[][] = {{1,2},{3,4}};
//error: only 1st dimension can be inferred
```

Initialization of array: size has to be fix at compile-time.
This means: fixed numbers or const variables.
An array is a const pointer. For more → pointer-arithmetics.

C-STRINGS

char str[] = "bla"; //str[0]='b', str[1]='l', str[2]='a', str[3]='\0'

```
char str[] = {'b','l','a','\0'};
char str[3] = "bla";//error: array too small
```

BASIC PROGRAM STRUCTURE

```
#include <iostream> //argc: #items in argv
int main(int argc, char **argv) {
    std::cout << "Hello World!" << std::endl;
    return 0; } //argv: array of c-strings
```

SCOPES AND STATIC VARIABLES

The scope is marked by curly brakets: { … }
Variables declared inside a scope are only accessable in there.
Their memory is released again and their value lost.
`static` variables are not accessable outside their scope, but the memory is not released and they keep their value.

INCREMENT & DECREMENT OPERATOR

```
int a, b = 5; a = b++; //postfix -> a = 5, b = 6
int c, d = 5; c = --d; //prefix -> c = 4, d = 4
```

OPERATOR PRECEDENCE & ASSOCIATIVITY

Precedence	Operator	Description	Associativity, can override
1	::	scope resolution	-, no
2	() [] -> . ++ --	grouping op array member member of ptr member access op increment decrement	ltr, yes ltr, yes ltr, yes ltr, no ?, yes ?, yes
3	! ~ - + * & new delete type() sizeof	logical negation bitw. complement unary minus, e.g. x = -a; unary plus dereference address of alloc memory dealloc memory cast to <type>, also (type)val sizeof(x)	rtl, yes rtl, yes rtl, yes rtl, yes rtl, yes rtl, yes rtl, yes rtl, yes rtl, yes rtl, no
4	->* .*	member pointer mem. obj. selec.	ltr, yes ltr, no
5	* / %	multiplication division modulus	ltr, yes ltr, yes ltr, yes
6	+ -	addition subtraction	ltr, yes ltr, yes
7	<< >>	bit shift left bit shift right	ltr, yes ltr, yes
8	< <= > >=	less-than less-or-equal greater-than greater-or-equal	ltr, yes ltr, yes ltr, yes ltr, yes
9	== !=	equal-to not-equal-to	ltr, yes ltr, yes
10	& bitand	bitwise and	ltr, yes ltr, yes
11	^ xor	bitwise xor	ltr, yes ltr, yes
12	| bitor	bitwise or	ltr, yes ltr, yes
13	&& and	logical and	ltr, yes ltr, yes
14	|| or	logical or	ltr, yes ltr, yes
15	a?b:c	if-then-else	rtl, no
16	= +=	assignment op add-and-assign	rtl, yes rtl, yes
17	throw	throw exception	-, no
18	,	sequential op	ltr, yes

ltr=left-to-right
There are more operators like +=:
`+=, -=, *=, /=, %=, &=, ^=, |=, <<=, >>=`
`a = b = c; //b = c, a = c`

TYPE CASTING

```
new_type expr2 = (new_type) expr1;
new_type expr2 = new_type (expr1);
//function-style cast or constructor & assignment
float a = 7/2;/*a=3*/a = 7/(float)2;//a=3.5
a = float(7/2);/*a=3*/ int b = 7/8; //b=0
todo: c++-style casts
```

BRANCHING

IF … [ELSE IF …] [ELSE …]

```
if(a==b) { foo(); }
else if (b==c) { bar(); } //can be omitted
else if (x==y) { blu(); } //can be omitted
else { foobar(); }        //can be omitted
```

SWITCH

```
switch(i){
   case 5: cout << "foo";
   case 6: cout << "bar"; break;
   case 7: cout << "omg"; break;
   default: cout << "wtf";
}
//i == 5 -> "foobar"
//i == 9 -> "wtf"
//you cannot declare variables inside a case label!
```

LOOPS

```
break;      //leaves the current loop
continue;   //jumps to the start of the loop
goto lbl;   //jumps to "lbl:"
lbl:        //"goto lbl;" continues here
return;     //leaves the current function
```

FOR

```
for(int i = 0; i < 12; i++) {
   foo();
}
```

WHILE

```
while(condition) {
//run the loop while condition is true
   foo(a);
   if(!condition2)
      break;       //leaves the loop early
   if(!condition3)
      continue;    //jumps back to the start
}
```

DO-WHILE

```
do {
   foo();
} while (condition); //runs at least once
```

POINTERS & REFERENCES

DECLARATION

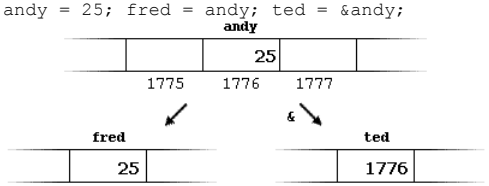
```
int a=1,b=2; int* c = &a; //what you want
const int* d = &a;
*d = 5; /* error */ d = &b; //correct
int* const e = &a; //like an array
*e = 5; /* correct */ e = &b; //error
const int f = 8; const int* g = &f //ok
int* h = &f; //error
int* i = (int*)0x33;
//i points to mem-addr 0x33, cast necessary
int* j, k, l; //only j is int*, k and l int!
```

DYNAMIC MEMORY (NEW, DELETE)

For c-type dynamic memory see <cstdlib>. C++ only:
`new` allocates memory, `delete` releases it again
int* a = new int; int* b = new int[5]; //both ok
int* c = new int (6); int* d = new int(3)[3]; //*c=6, d:error
int* e = new int[3][2]; int**f = new int[3][2] //both error
Trick: #new = #delete and #new ... [] = #delete[] ... //usually
Exception on lack of memory:
int* dp = new (nothrow) int[100];
//no exception, but may return null-pointer

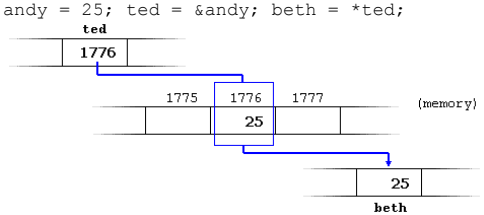
REFERENCE OPERATOR (&)

```
andy = 25; fred = andy; ted = &andy;
```



DEREFERENCE OPERATOR (*)

```
andy = 25; ted = &andy; beth = *ted;
```



REFERENCES

```
int &a;        //error: refs require init
int &b = k;    //correct declaration
&b = m;        //error: refs cannot change
b = v;         //correct value assignment
```

-> OPERATOR

`(*a).b` is equivalent to `a->b` Where `b` can be field, function, ...
`a->b = 25; //correct assignment of b's value`

POINTER-ARITHMETICS

```
int b[100]; int* p;
p = b; //implicit array-to-pointer conversion
p = &b[0]; //same thing as above
b = p;      //error
p = p+1; //adds (4=1*sizeof(int)) to p(= &b[1])
//----------------------------------------
b[5] = 0;    // b [offset of 5] = 0
*(b+5) = 0; // pointed by (b+5) = 0
//1st == 2nd expression. a can be pointer or array.
```

MEMBER FUNCTIONS

`[virtual] [static] [inline] [const] return-type name(arg1-type arg1-name, arg2-type [const] arg2-name[=def_value]) [const] [volatile] { return return-value; }`

`virtual`:	dynamic binding
`static`:	Function can be called without instantiated class and can only access `static` members. A static function cannot be `const`.
`inline`:	Asks the compiler to copy the code, where the function is called rather than calling it. This is faster, but results in a larger binary. No recursion.
`const(1st)`:	the returned reference cannot be changed
`const(arg)`:	`arg` is `const` within the function
`def_value`:	overloads the function with a default value All optional params have to be at the end.
`const(2nd)`:	All the class' fields are treated `const`
`volatile`:	Prevents optimization. Member functions of volatile objects should be declared `volatile`

ARGUMENTS

- **call by value (copy the argument)**

```
void foo(int arg1); // The value of arg1 is copied
//even classes and structs are copied!
int a = 5; foo(a);   //a will certainly remain 5
```

- **call by reference**

```
void foo(int& arg1); // The address of arg1 is copied
int a = 5; foo(a);   //a can change
```

- **implicit call by reference (call by value of the pointer)**

```
void foo(int* arg1); // The address in arg1 is copied
int* a = 5; foo(a);  //a's value can change
int b = 5; foo(&b);  //same as above
```

The same applies to the return value: copied by default
Never return a reference to a local variable!

FUNCTION POINTERS

```
int add(int a, int b) { return a + b; }
int sub(int b, int c) { return a - b; }
int op(int x, int y, int (*func)(int,int)){
      int g; g = (*func)(x,y) ; return g; }
void foo(){ int m, n;
     int (*minus)(int,int) = sub;
     m = op(7,5,add); n = op(20,m,minus); }
```

OVERLOADING

Overloading means declaring multiple functions with the same name. They need different signatures, so that the compiler (and you) know which one to take.
Overloading functions with optional args is especially risky.

PROTOTYPES/SIGNATURES

`int foo(float); //or int foo(float a);`
Prototypes contain name and signature of a function.
Usually there is a header file with prototypes of all functions.
Prototypes are not necessary, if you define a function before it is used. There can never be multiple definitions for one prototype.

FRIEND-FUNCTIONS

```
class A { friend void f(A&); private: void g();};
class B { void f(A& k){k.g();}};
```

todo

ADVANCED DATATYPES

STRUCTS

Structs are copied on assignment.

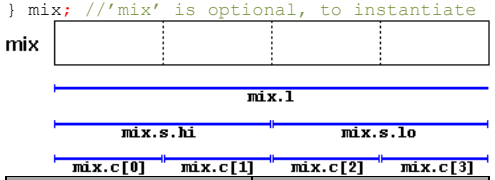
```
struct foo_t {
   type1 a;
   type2 b;
} bar; //'bar' is optional, to instantiate
```

BITFIELDS

```
struct foo_t {
   type1 a:2;          // a is 2 bits
   unsigned int b:3;   // b is 3 bits
} bar; //'bar' is optional, to instantiate
```

UNIONS

```
//All vars occupy the same memory space. Only read
what you wrote to, else behaviour is undefined
union mix_t {
//'mix_t' optional, type to instantiate later
   long l;
   struct {short hi; short lo;} s;
   char c[4];
} mix; //'mix' is optional, to instantiate
```



regular union	anonymous union

`struct {`
`  char title[50];`
`  union {`
`  float dollars;`
`  int yens;`
`  } price;`
`} book;`
	`struct {`
	`  char title[50];`
	`  union {`
	`  float dollars;`
	`  int yens;`
	`  };`
	`} book;`

`book.price.yens=9;`	`book.yens = 9;`

ENUMS

```
enum CountryName_t { /*'CountryName_t'
optional, to instantiate later*/
US=1, FR=4, CH, GB=9} ia, ib;
//'ia, ib' optional, to instantiate
//values are generated if not assigned
//only numbers can be assigned
//usage:
CountryName_t foo = CH;
cout << foo; //writes 5
```

EXCEPTIONS

Usually thrown objects inherit from `std::exception`, but there is no need to do so. You can i.e. throw error-codes as int.

- **throw-declartion**

```
void foo() throw(); //will not throw
int bar() throw(int)//can throw int only
int bar ();         //can throw anything
```

- **throw-invocation**

```
throw 4;                //throw is by value
```

- **try { ... } catch (...) { ... }** //one catch is necessary

```
class A : B { ... };
try { ... }             //mandatory
catch(int errNo){...}   //catches ints only
catch(const B& foo){...}  //catches Bs only
catch(const A& bar){...}  //never executes
catch(...){...}         //catches everything
```

"..." is meant literally!! Uncaught exceptions terminate the program!

TYPEDEF

```
typedef type newSynonymName;
typedef short bigint;
//now you can use bigint instead of short
```

OBJECT-ORIENTED PROGRAMMING (OOP)

CLASSES

`class A : B, C { ... };`
In-class init is not permitted for non-static and non-const:
`class D { int a = 5; } //error`

THIS-POINTER

The this-Pointer always points to the underlying object (class).
`class A { int b; void foo() { this->b = 5; } };`

CONSTRUCTOR

```
class C:A,B{ public:C(int x) : B(),A() {} }
//virtual inherited classes are constructed first
```

If no constructor is declared, a default constructor is synthesized, calling each member's default constructor.
Implicit type cast: `C foo = 4;`
`//calls the conversion constructor (only)`
Direct init: `C foo(4);`
Copy init: `C foo = C(4); //assign-op is NOT called`
The keyword `explicit` disables implicit type cast.

Implicit init not allowed for constructor without args:
`A foo(); //error: declares a function foo`
`A foo; A bar = A(); //ok`
for more → inheritance, polymorphism

COPY-CONSTRUCTOR

If not specified: Assignment of each field. To specify:

```
class A { A(const A & copyFromMe){ … } … };
A a1; A a2 = a1; //calls the copy constructor
A a3 = A(a1);    //same as above, explicit
```

DESTRUCTOR

The destructor of an object is called if it's "`delete`"-ed.

```
class A { public: [virtual] ~A (){ … } … };
```

Attention!: `A* b1 = new B; delete b1;`
only calls A's destructor! → `virtual`-ize and call B's too!!

STATIC & CONST VARIABLES

`static` variables are only destructed and freed on program termination. Even if they are not accessable anymore, they stay in memory, so you can access them again later and they still have the same value.

`static` variables on class-level have the same value among all instances of a class. The cannot be initialized inside the class definition, only inside the .cpp-file like that:

```
int ClassName::staticVariableName = 5;
```

`const` variables cannot be changed. On a class level they always have to be static: `static const int a = 3;`

INHERITANCE

Is by default `private`. `friend`-ship does not inherit.

- **public ("is-a" relation; e.g. banana is a fruit)**
  The child-class can be casted to its parent-class.
  public -> public, protected -> protected, private -> inaccessible
- **protected**
  public -> protected, protected -> protected, private -> inaccessible
  The inherited functions can be further inherited. Not castable.
- **private ("has-a" relation)**
  public -> private, protected -> private, private -> inaccessible
  The inherited funct. CANNOT be further inherited. Not castable.
  Alternative: create the object as a field

`virtual` flag by example:

```
class L { public: virtual void eat(); };
class A : public virtual L { … };
class B : public virtual L { … };
class C : public A, public B { … };
class D : public C { … };
//because A and B inherit L 'virtual' it can be
bound to the same L. Else there would be 2 Ls in
C. The most derived class (here: D) has to
construct all virtual-inherited sub-objects(here
just L). This cannot be done by C for D!!
```

DYNAMIC BINDING

Static binding (not related to the keyword static) is
- used by default and a little bit more performant
- function cannot be overwritten (but still overloaded)

dynamic binding is
- specified by the keyword `virtual`
- can be overwritten from a inheriting class.

Dynamic binding sample:

```
class A { virtual void f(); };
class C : A { void f(); };
A* pa = new C;
pa->f();  //invokes C::f();
```

ABSTRACT CLASSES

A class is abstract, if at least one of its functions is purely virtual. Declaration: `virtual double foo() = 0;`

ACCESS MODIFIERS

Modifiers are only allowed inside classes.

`public:`	Accessable by everyone
`private:`	Only accessable within the class
`protected:`	Only accessable within and from inheriting class
`friend:`	Accessable to that class for which it is friend

OVERRIDING OPERATORS & TYPE CASTS

```
operator int(){ return 4;}
//defines a user-defined conversion op
double& Matrix::operator()(int c, int r);
Matrix a; double val = a(5,4);
void Matrix::operator()(){ this->delete()}

void operator=(const A bla){}; //assign-op
A a1; A a2; a2 = a1; //assignment
//do not confuse with copy-constructor

int b1; A b2; b1+b2; //calls funct below
friend float operator+(int i,A j) const;

//creating new operators is not allowed(i.e. $)
int incr(){int i = 2; return i.operator+(1);} //ok
```

NAMESPACES

```
const int a = 2;
namespace foo {
   const int a = 1;
   int bar() { return a; }   //returns 1;
   int foo() { return ::a; } //returns 2;
}
using namespace foo; //enables access to the
namespace without having to always refer to it (foo::bar())
```

todo: using-directives vs. using-declarations

POLYMORPHISM

```
class A { int ii; };
class B { char* ii; };
class C : A, B { };
//============Ambiguities=============
C* pc; pc->ii;
//error: A::ii or B::ii?
pc->A::ii;      //C's A's ii
//the same is valid for functions.
//========Multiple Sub-objects========
class L { int m; };
class A : L { … };
class B : L { … };
class C : A , B { … };
//-> two Ls in C, they can be different
//access through explicit qualification:
void C::f() { int k = A::L::m; }
//=============Casting=============
C* pc = new C;
L* pl = pc;       //error: ambiguous
pl = (L*)pc;      //error: ambiguous
pl = (L*)(A*)pc; //ok.
//=====Casting in function calls=====
extern f(L*); //some standard function
A aa; C cc;
f(&aa);   // ok.
f(&cc);   // error: ambiguous
f((A*)&cc);   // ok.
```

TEMPLATES

FUNCTION TEMPLATES

```
//declaration/definition
template <class Any>
void Swap(Any &a, Any &b) {
   Any temp; temp = a; a = b; b = temp; }
//usage
int x,y; Swap(x,y); //correct
```

CLASS TEMPLATES

still to do

LIBRARIES

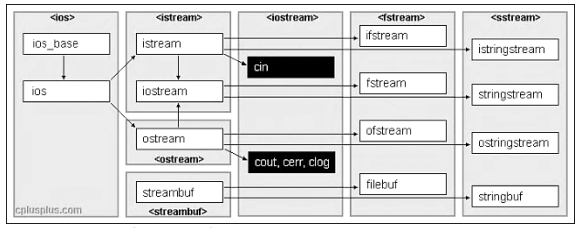
- **Location**
  `#include "blabla.h" //search locally`
  `#include <blabla.h> //search standard lib`
- **Language**
  `#include <blabla>  //c++`
  `#include <cblabla>  //c`
  `#include <blabla.h> //c, old style`

HEADER FILES

Header files (.h) are just like regular .cpp files. They are usually used to declare classes and prototypes of functions and to define constants and small functions. They are often shipped with a library for the programmer to know what's inside.
The have to be included when compiling!

----------usual structure of a header file----------

```
#ifndef AA_H
#define AA_H
class Aa { int foo(int k) const; };
```




```
#endif /* AA_H */
```

<IOSTREAM> - INPUT & OUTPUT STREAMS

```
cout << "foo";   //write to stdout
cerr << "foo";   //write to stderr, flush
clog << "foo";   //write to stderr
cout << "foo" << endl << "bar";
//print 5 digits after point of float/dbl
cout.precision(5);

int i;
cin >> i; //reads an int from console into i
```

control characters:

\b backspace	\f form feed	\' apostrophe	\t tab
\r return	\n newline	\" quote	
\n character #n (octal)		\xnn character #nn (hex)	

<CSTDIO> - C INPUT & OUTPUT

<FSTREAM> - FILE STREAMS

```
#include <fstream>
#include <iostream>
int main() { int a, b;
ofstream file1("foo.txt"); //c-string!
if (file1.is_open()) { file1 << a; }
ifstream file2("bar.txt"); file2 >> b;
return 0; }
```

<CMATH> - MATHEMATICAL FUNCTIONS

trig. functions	sin(x), cos(x), tan(x)
inv. trig. func.	asin(x), acos(x), atan(x)
arctan(y/x)	atan2(y,x)
hyperbolic trig	sinh(x), cosh(x), tanh(x)
exponential, log	exp(x), log(x), log10(x)
exp, log (2 pow)	ldexp(x,n), frexp(x,*e)
division & remain	modf(x, *ip), fmod(x,y)
powers	pow(x,y), sqrt(x)
rounding	ceil(x), floor(x), abs(x)

All args and `return` values are `double`.

<TYPEINFO>

<EXCEPTION> - DEFAULT EXCEPTION CLASS

<CCTYPE> - CHARACTER FUNCTIONS

```
char toupper(int);
//the arg has to be an unsigned char or an EOF
```

<CSTDLIB>

```
memory: malloc, calloc, realloc, free
files: remove("foo.txt");
exit(int);
```

<VECTOR> - DYNAMIC SIZE ARRAY

Replaces arrays in most real-world applications.

<STRING> - C++ STRING CLASS & FUNCTIONS

```
typedef basic_string<char> string;
typedef basic_string<wchar_t> wstring;
//below 'string' means any of the above
```

```
istream& std::getline ( istream& is,
    string& str, char delim = '\n' );
const char* s.c_str(); //string to c-string
size_t l = s.length();
char a = s[2]; //char at 2
string s.substr(size_t pos, size_t len);
size_t idx = s.find(string str);
s = s.insert(size_t pos, string str);
int x = s.compare(string str); //0 if equal
```

COMMON CONCEPTS

RANDOM NUMBER GENERATION

```
#include <cstdlib>
#include <ctime>
#include <iostream>
using namespace std;
inline int randomNumber(int min, int max) {
    return rand()%(max-min+1) + min; }
int main(){
   srand(time(NULL)); // init with seed
   cout << randomNumber(1,100) << endl;
   return 0; }
```

CONVERT FLOAT TO STRING

```
#include <sstream> /* ... */
std::ostringstream buf; float f = 1.234567;
buf.precision(4); buf << f; //1.235
std::string s = buf.str();  //f = 10.345 -> 10.35
const char* cs = s.c_str();
```

BITMASKS

Bitmaks can be used after applying encryption algorithms to make sure the characters are actual letters and not control commands.

COPYING AN ARRAY

If it's a char-array, use strcpy; else you can embed the array into a struct or class and copy that.

TIME COMPLEXITY: O(…)

Slowest to fastest. K = constant, N = # items:

hyper-exp	$N^{K_1^{K_2^{-K}-N}}$	linearithmic	$N\log(N)$
super-exp	N^N	linear	N
factorial	$N!$	squareroot	$\sqrt{N}$
exponential	K^N	logarithmic	$\log(N)$
polynomial	N^K	constant	1

$1 < \log n < \sqrt{n} < n < n(\log n)^2 < n^2 < n^a < a^n$; $\log_c b = \log_a b / \log_a c$

Cases: best-case, average-case, worst-case, amortized worst-case (average worst-case for infinite #inputs)

NO FALSE TRUST

1. O-Notation describes the upper limit
2. $g(n) = C \cdot O(N)$ -> C can be very large!

RULES

- $C = O(1)$
- $C \cdot f(n) = O(f(n))$
- $O(f(n)) + O(f(n)) = O(f(n))$
- $O\left(O(f(n))\right) = O(f(n))$
- $g(n) = a_k \cdot n^k + a_{k-1} \cdot n^{k-1} + \cdots + a_0 = O(n^k)$
- $O(f(n)) \cdot O(g(n)) = O(f(n) \cdot g(n))$
- $O(f(n)) + O(g(n)) = O(\max\{f(n), g(n)\})$

Name	best-case	avg.-case	worst-case
Prim	$O(E)$	---	$O(V^2)$
Quicksort	$O(n\log(n))$	$O(n\log(n))$	$O(n^2)$
Bubble, Insert	$O(n^2)$	$O(n^2)$	$O(n^2)$
Mergesort	$O(n\log(n))$	$O(n\log(n))$	$O(n\log(n))$

COMPLEXITY OF BASIC ELEMENTS

simple instruction	$O(1)$
sequence(f1;f2;f3;)	$O(\max\{O(f_1), O(f_2), O(f_3)\})$
loop(n runs)	$O(n \cdot f_{inner}(n))$
if-else (if(foo){f1;}else{f2;})	$O(\max\{f_1, f_2\})$

NOTATIONS OVERVIEW

$O(g(n))$	$O(g(n)) \le g(n) \cdot k$, for some k
$\Omega(g(n))$	$\Omega(g(n)) \ge g(n) \cdot k$, for some k
$\Theta(g(n))$	$g(n) \cdot k_1 \le \Theta(g(n)) \le g(n) \cdot k_2$, for some k_1, k_2
$o(g(n))$	$o(g(n)) \le g(n) \cdot \varepsilon$, for every ε
$\omega(g(n))$	$\omega(g(n)) \ge g(n) \cdot k$, for every k

US-ASCII TABLE

Dec	Char	Dec	Char	Dec	Char	Dec	Char
0	NUL	64	@	128	Ç	192	└
1	SOH	65	A	129	ü	193	┴
2	STX	66	B	130	é	194	┬
3	ETX	67	C	131	â	195	├
4	EOT	68	D	132	ä	196	─
5	ENQ	69	E	133	à	197	┼
6	ACK	70	F	134	å	198	╞
7	BEL	71	G	135	ç	199	╟
8	BS	72	H	136	ê	200	╚
9	TAB	73	I	137	ë	201	╔
10	LF	74	J	138	è	202	╩
11	VTB	75	K	139	ï	203	╦
12	FF	76	L	140	î	204	╠
13	CR	77	M	141	ì	205	═
14	SO	78	N	142	Ä	206	╬
15	SI	79	O	143	Å	207	╧
16	DLE	80	P	144	É	208	╨
17	DC1	81	Q	145	æ	209	╤
18	DC2	82	R	146	Æ	210	╥
19	DC3	83	S	147	ô	211	╙
20	DC4	84	T	148	ö	212	╘
21	NAK	85	U	149	ò	213	╒
22	SYN	86	V	150	û	214	╓
23	ETB	87	W	151	ù	215	╫
24	CAN	88	X	152	ÿ	216	╪
25	EM	89	Y	153	Ö	217	┘
26	SUB	90	Z	154	Ü	218	┌
27	ESC	91	[	155	¢	219	█
28	FS	92	\	156	£	220	▄
29	GS	93	]	157	¥	221	▌
30	RS	94	^	158	₧	222	?
31	US	95	_	159	ƒ	223	?
32	space	96	`	160	á	224	α
33	!	97	a	161	í	225	ß
34	"	98	b	162	ó	226	Γ
35	#	99	c	163	ú	227	π
36	$	100	d	164	ñ	228	Σ
37	%	101	e	165	Ñ	229	σ
38	&	102	f	166	ª	230	µ
39	'	103	g	167	º	231	τ
40	(	104	h	168	¿	232	Φ
41	)	105	i	169	⌐	233	Θ
42	*	106	j	170	¬	234	Ω
43	+	107	k	171	½	235	δ
44	,	108	l	172	¼	236	∞
45	-	109	m	173	¡	237	φ
46	.	110	n	174	«	238	ε
47	/	111	o	175	»	239	∩
48	0	112	p	176	░	240	≡
49	1	113	q	177	▒	241	±
50	2	114	r	178	▓	242	≥
51	3	115	s	179	│	243	≤
52	4	116	t	180	┤	244	⌠
53	5	117	u	181	╡	245	⌡
54	6	118	v	182	╢	246	÷
55	7	119	w	183	╖	247	≈
56	8	120	x	184	╕	248	°
57	9	121	y	185	╣	249	∙
58	:	122	z	186	║	250	·
59	;	123	{	187	╗	251	√
60	<	124	|	188	╝	252	ⁿ
61	=	125	}	189	╜	253	²
62	>	126	~	190	╛	254	■
63	?	127	⌂	191	┐	255	DEL

BUILD-PROCESS & COMPILER

PREPROCESSOR DIRECTIVES

```
#define NAME VALUE
#define NAME
#undef NAME
#ifdef NAME
#ifndef NAME
#if EXPR
#else
#elif EXPR
#endif
#error MSG
#include
#pragma
```

- **Default variables:**

  __FILE__ __LINE__ __TIME__ __DATE__

G++ COMPILER FLAGS

```
g++ -ansi -pedantic -Wall -O -o myProg myProg.h
myProg.cpp
---------------------------------------------
-c : compile, assemble, do not link
-E : only run preprocessor, source -> stdout
-fall-virtual : dynamic binding by default
-fenum-int-equiv : allows conversion int->enum
-fno-default-inline : never optimize to inline
-g : produce debugging information
-Idir : search dir for include files
-O : optimize. Needs a lot of memory
-o file : place output in "file"
-S : Generates assembler files.
-Wall : output all warning to stdout
-ansi : enables compilation all ansi code
-pedantic : allows only ansi-conform code
There are more. (use 'man g++')
```

G++ AS COMPILER ONLY

```
g++ -Wall -pedantic -ansi -c main.cpp
```

Creates a files called `main.o`

G++ AS LINKER ONLY

```
g++ -Wall -o upncalc Complex.o Stack.o main.o
```

MAKEFILES

```
# Simple Makefile for a small project
.COMPLEXSTACK: clean
CC = g++
CFLAGS = -Wall -pedantic -ansi -c
LFLAGS = -Wall
OBJS = main.o Stack.o Complex.o
upncalc: $(OBJS)
          $(CC) $(LFLAGS) -o upncalc $^
$(OBJS): %.o: %.cpp
          $(CC) $(CFLAGS) $<
main.o: Stack.h Complex.h
Stack.o: Stack.h Complex.h
Complex.o: Complex.h
clean:
          rm -rf *.o upncalc
# ^ has to be a tab!!!!
```

IMPROVEMENTS, CHECKLIST

COMPLETE "DON'T"S

- **Assigning values to a function, especialy when returning a reference**

```
int& foo(int& arg1) { return arg1; }
void bar() {
int a = 4; foo(a) = 6; } //a is now 6
```

IDEAS

- **class diagram**
- **memory diagram**
- **program flow diagram**
- **Recursion useful?**

POSSIBLE MISTAKES / CHECKLIST

- = vs. ==
- `using namespace`
- `#include` libraries
- Semicolons ;
- Case sensitivity
- Are functions, variables and classes really defined on their first usage?
- Header-File included?
- Is the size of arrays everywhere defined with `const` variables?
- In C++ it's NULL and not null
- Recursion with an `inline` function
- All purely `virtual` functions defined?
- Semicolon after `class, struct, enum`, … definition
- Circular dependency without pointers (struct a_t {a_t bla;};)
- "chain of const": `const` pointer only to `const` fields
- "chain of const": `const` functions only to other `const` func.
- "chain of const": to pass a `const` field, the function's arg has to be `const`
- Are all modifiers correct? (e.g. con-/destructor `public:`)
- Destructor specified dealloc memory?
- Destructors all correct? (`virtual`, if `class` inherited)
- No modifiers outside of classes
- No in-class initialization: `class A { int a=2; } //error`
- In C++ modifiers need a colon :
- `A k();/*err*/ A k;/*ok*/ A k = A(); //ok`
- Just for the beauty: catch eventual bad_alloc-exceptions
- Watch out for ambiguous function calls (unsigned vs. char)
- Watch out for ambig. func. calls (float vs. double): foo(10);
- string length: space for \0 reserved?
- `unsigned char` used for characters (not signed)?
- Every pointer correctly used? . vs. ->
- Never returned a reference to a local variable?

TODO

Stack Queue Sorting: Bubble sort Filter folding File Paging	Serialization Binary tree long numbers Initializing a multidimensional array

JAVA

BASIC DIFFERENCES TO C++

COMPILER

```
javac myProgramm.java   //to compile
java myProgramm         //execute
javap -c xx.java        //generates bytecode
```

DATATYPES

Integer
byte(8 bits)
short (16 bits)
int (32 bits)
...
...

NAMES

variables, methods: small
classes: capital
constants: all capitals

INSTANCEOF

Hund h; Tier fiffy;
if (fiifi instanceof Hund) { f = (Hund)fiify; }

ARRAYS

```
int[] x = new int[7]; x[3] = 5;
int[] y = x; y[3] = 9; //x[3] is now 9
```

I/O

```
string System.in.readLine()
char System.in.read()
void System.out.println(…)
void System.out.print(…)
void System.exit(int);
```

CONSTANTS

```
static final type NAME = value;
```

BASIC PROGRAM STRUCTURES

```
public class Foo{
   public static void main(String[] args){}
}
```

IMPORT

PACKAGES

```
Define:
package test;
Import:
import java.util.Random; //single class
import java.util.*;      //whole package
```

FUNCTIONS

```
Arguments are all passed by reference.
Immutable objects can't be edited of course
```

CLASSES

Only one class per file can be public!
this //ref to the instance of the class
super//ref to the instance of the inherited class

REFERENCES

```
Object a = new Object();
```

Always references except for: `byte, short, int, long, float, double, char, boolean.`
`==` just compares the addresses!

INHERITANCE

```
class A extends B { ... }
```

Multiple inheritance is not possible!

INTERFACES

```
interface Name1 { method_declarations; }
usage:
class Name2 implements Name1 {
method_implementation; }
```

GENERICS

```
public class Main<T extends
java.lang.Exception>  { ... }
```

APPLETS

MULTITHREADING

EXCEPTIONS

BITSHIFT

a =<< b leftshift, $a = a \cdot 2^b$
a =>> b signed rightshift, shifts the sign in, $a = floor(a/2^b)$
a =>>> b unsigned rightshift, shifts a 0 in

STANDARD LIBRARY

STRINGS

+: to concatenate
==: compare reference (!)
equals(string): compare content
compareTo(String): .... lexikographisch
length(int), length(String), ...

String b = null; //ok

JAVADOC

COMPILER

//javadoc [options] { package | sourcefile } // Example:
`javadoc *.java`

MARKINGS

Marking	Class	Iface	Method	Field
@author *name*	x	x	-	-
@version *name*	x	x	-	-
@since *jdk_version*	x	x	-	-
@see *reference*	x	x	x	x
@param *name description*	-	-	x	-
@return *description*	-	-	x	-
@exception *classname descr* @throws *classname descript*	-	-	x	-
@deprecated *description*	x		x	

reference:
@see java.util.Vector
@see Vector
@see Vector#addElement(int)

BASIC FUNCTION DOCUMENTATION

```
/**
 * This function does something…
 * @param a This param is annoying.
 * @param k This param is useless.
 * @return This function always returns 0
 * @throws Exception blabla
 */
```

BASIC CLASS DOCUMENTATION

```
/**
 * This Class is useless.
 * @author lukasc
 */
```

UNIT TESTING

```
import org.junit.Test;
import junit.framework.Assert;
public class Tests {
  @Test public void negative() {
    Assert.assertEquals(Foo.bar(3), 1);
  }
  @Test public void zero() {
    Assert.assertEquals(Foo.bar(0), 0);
}}
```

„java -cp /usr/share/java/junit4.jar:. org.junit.runner.JUnitcore u0a3.Tests"
http://junit.org

JAVA-VM

```
Opcode 1 byte long -> 256 instructinos
Opstack
Instructions:
iconst_m1  //push '-1' onto stack
iconst_4   //push 4 onto stack
iload, vindex //load variable and push onto
stack
istore, vindex
nop
bipush, byte // ppush one-byte signed int
pop //pop top stack word
iadd //adds and pops top 2 integers from
stack and pushes the result
imul //like iadd, multiplies
```

ALGORITHMS & DATA STRUCT.

ALGORITHMS

EGYPTIAN MULTIPLICATION

$$f(a,b) = \begin{cases} a \text{ if } b = 1 \\ f\left(2a, \frac{b}{2}\right) \text{ if } b \text{ even} \\ a + f\left(2a, \frac{b-1}{2}\right) \text{ else} \end{cases}$$

Only if $a \geq 1 \wedge b \geq 1 \Leftrightarrow a, b \in \mathbb{N}^+$

WRITTEN MULTIPLICATION

Speaks for itself...

DIVISION

```
class Burch{
  int nenner, int zaehler //nenner>0
  public Bruch plus(Bruch y);
  public Bruch mult(Bruch y);
  private  void kuerzen();  // zaehler/ggT, Nenner/ggT
  //achtung: zaehler muss != 0 zum kürzen
  public double ratio();
  public void print();
  public bool kleinerAls(Bruch y);
  public bool identisch(Bruch y);
  private static int ggT(long u, long v); //euklidschen algo
  private static int kgV(long u, long v);
}
```

EUKLIDIAN ALGORITHM

ACKERMANN FUNCTION

Not primitive-recursive (loop-calculable) but calculable in finite time and while-calculable. The time required cannot be estimated. Application: benchmarking

$A(n,m) \forall n, m \in \mathbb{N}_0$:

$A(0,m) = m + 1,$

$A(n+1,0) = A(n,1),$

$A(n+1, m+1) = A(n, A(n+1, m))$

BACKTRACKING

more to come

SORTING ALGORITHMS

BUBBLE SORT - $\Omega(n), O(n^2)$

more to com

INSERTION SORT - $\Omega(n), O(n^2)$

more to come

DEPTHFIRST SORT

more to come

MERGE SORT - $\Omega(n\log(n)), O(n\log(n))$

Conceptually, a merge sort works as follows

1. If the list is of length 0 or 1, then it is already sorted. Otherwise:
2. Divide the unsorted list into two sublists of about half the size.
3. Sort each sublist recursively by re-applying merge sort.
4. Merge the two sublists back into one sorted list.

Merge sort incorporates two main ideas to improve its runtime:

1. A small list will take fewer steps to sort than a large list.
2. Fewer steps are required to construct a sorted list from two sorted lists than two unsorted lists. For example, you only have to traverse each list once if they're already sorted (see the merge function below for an example implementation).

HEAP SORT - $\Omega(n\log(n)), O(n\log(n))$

more to come

QUICK SORT - $\Omega(n\log(n)), O(n^2)$

more to come

EFFICIENCY

BASIC OPERATIONS

Alle in etwa gleich aufwendig, Vergleiche zählen auch, Funktionsaufrufe an sich nicht, jedoch natürlich die # elementar-ops innerhalb.
Alle Operationen können auf inkrementieren reduziert werden.

METHOD CALLS

$$1/2/2/2/2/\ldots \rightarrow \log_2(x)$$

FUNCTIONAL PROGRAMMING

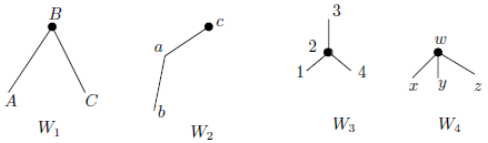
more to come

PROOFING IDEAS

Invariants: Invarianten definieren, z.B. dass immer c = a*b+z ausser ganz kurzfristig. Bsp. a verdoppeln, b halbieren, so dass (das evtl. nicht als Variable existierende) c konstant bleibt.
Induktion: Zeigen, dass für n=1 und für n+1 korrekt
inverse proof

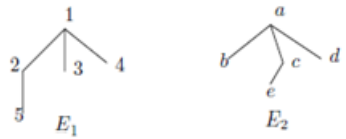
DATA STRUCTURES

WURZELBÄUME



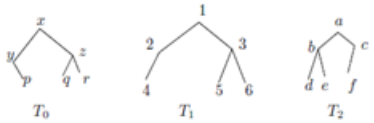
Isomorph (als allg. Bäume): W_1 und W_2: $A \mapsto b, B \mapsto a, C \mapsto c$
allerdings nicht isomorph als Wurzelbäume, aber W_3 und W_4.
Linksklammerdarstellung:
Baum W_1: $B(A, C)$
Allgemeines Bsp.: $A(B(C,D), E(F), G(H, I(K), J))$

EBENE WURZELBÄUME



Ebene Wurzelbäume: Linear geordnete Wurzelbäume
E_1 und E_2sind isomorph als Bäume und Wurzelbäume, nicht aber als ebene Wurzeläume: 2 liegt links von 3, aber c liegt recht von b.

BINARY TREE



Ebener Wurzelbaum, with 2 leaves per node at max.
T_1 and T_2 are isomorph as Wurzelbäume, but not as ebene Wurzelbäume or Binary Trees.
T_0 and T_1 are isomorph as Ebene Wurzelbäume, but not as Binary Trees: p is to the right of y, but 4 is left of 2
Can easily be flattened to **array** (successors of node i go at places $2i$ and $2i+1$. First node at 1 (not 0). Die Indexnummer entspricht der Binärdarstellung mit 0 für links und 1 für rechts.

BINARY SEARCH TREE

Picture it as a graph. Now whatever node you pick, the nodes on the left ar smaller, the right ones bigger.

- **search: obvious → skipped**
- **insert**
- **delete**

more to come

OTHERS TREES

more to come

OTHER BINARY TREES

more to come

OPERATORBÄUME

Mögliche Lösung: Stack verwenden

Andere Idee: Klammern einfügen, bei schliessender Klammer Operation ausführen.
Auch hier gibts infix, prefix, postfix.

PREFIX, INFIX, POSTFIX

Infix: PrintLeft(); PrintSelf(); PrintRight();
Postfix: PrintLeft(); PrintRight(); PrintSelf();
Prefix: PrintSelf(); PrintLeft(); PrintRight();

HEAP

more to come

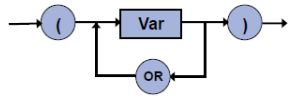
STACK

push(obj); //add obj on top of stack
obj pop(); //remove obj from stack and return it
obj top(); //return obj from stack without deletion
Implementations:
- Array //fast, but limited size & unused allocated mem
- Linked objects
- Linked arrays of objects

SYNTAXTREES

more to come

SYNTAXDIAGRAMS



round: terminal, square: needs further evaluation
Protects from inconsistent data structures.
Diagram can be directly mapped to implementation. while, if, ...

GAME THEORY

GAME TREES

more to come

MINIMAX

more to come

ALPHA-BETA-OPTIMIZATION

more to come

NEGAMAX

more to come

CORRECTNESS, ROBUST PROGRAMMING

INDUCTION

p. 16, 17

OF THE PROGRAM

p. 16, 17

IDEAS & TROUBLESHOOTING

IDEAS

- **even or odd numbers: bool even = (a % 2 == 0 ? true : false);**
- **left- resp. right-shift to multiply resp. divide by 2^n?**
- **divide and conquer**
- **recursion**

CONCEPTS (IF YOU'RE STUCK)

POSSIBLE MISTAKES

Made sure it cannot come an infinite loop (break-condition)?

CONVERTING RECURSIVE TO FLAT AND BACK

TODO

touring maschine

sizeof zur Best. der Arraygrösse in c++??
bitweiser Vergleich zweier Klassen-Intanzen

typeof

```
/**********LINKED LIST**********/
item* first = NULL;
struct item {
	int key;
	item* next;
	// item* prev;
};
void push(int element){
	item* temp = new item; //create a new item
	temp->key = element; //assign the value of the element
	temp->next = first; //assign the next item
	// first->prev = temp;
	first = temp; //assign the new top item
}
int pop(){
	item* temp = first; //create temporary copy of the top
element
	int result = first->key; //read the value of the top
element
	first = first->next; //decrement the top item
	delete temp; //delete the old item
	return result;
}
/**********SEARCH SORTED ARRAY**********/
while(hi-lo > 1){
	mid = (hi+low)/2;
	if(num < array[mid]){
		hi = mid;
	} else{
		lo = mid;
	}
}
if(num == array[lo]){
	cout << "position = " << low << endl;
}else if(num == array[hi]) {
	cout << "position = " << low << endl;
}
else
	cout << "num not in list" << endl;
/**********BUBBLE SORT**********/
//Keep moving the largest forwards
void bubbleSort(int *array,int SIZE)//Bubble sort function
{
	for(int i=0; i<SIZE ;i++){
		for(int j=i+1; j<i; j++){ //pushes the
larger forwards
			if(array[i] > array[j]){
				int temp=array[i];
//swap
				array[i]=array[j];
				array[j]=temp;
			}
		}
	}
}
/**********SELECTION SORT**********/

//find the smallest and swap the first and smallest element
void selectionSort(int array[], int SIZE) {
	for (int pass=0; pass<SIZE; pass++) {
		int potentialSmallest = pass; // assume this
is smallest
		for (int i=pass+1; i<SIZE; i++) { //find if
a smaller one exists
			if(array[i] <
array[potentialSmallest]) {
				potentialSmallest = i;
			}
		}
		if(potentialSmallest != pass) {
			int temp = array[pass]; //swap
			array[pass] =
array[potentialSmallest];
			array[potentialSmallest] = temp;
		}
	}
}
/**********INSERSION SORT**********/
//take the first unsorted element and insert it into
//an already sorted list
void insertion_sort(int * array, int SIZE){
	for (int j=1; j<SIZE; j++) {
		int nextElement = array[j];
		for (int i = j-1; i >= 0 && array[i] <
nextEleement; i++) {
			array[i+1] = array[i]; //shift the
bigger elements upwards
		}
		array[i+1]=nextElement; //insert the element
	}
}
/**********MERGE SORT**********/
//Reduce the size of the arrays to sort then zip it
void merge_sort(int low = 1,int high = SIZE){
	if(low<high){ //if the max depth has been reached (ie.
low == high)
		int mid=(low+high)/2;
		merge_sort(low,mid);
		merge_sort(mid+1,high);
		merge(low,mid,high);
	}
}
void merge(int low,int mid,int high){
	int h,i,j,b[SIZE/(high-low)+1],k;
	h=low;
	i=low;
	j=mid+1;
	//zipping
	while((h<=mid)&&(j<=high)){
		if(array[h]<=array[j]){
			b[i]=array[h];
			h++;
		}else {
			b[i]=array[j];
			j++;
		}
		i++;
	}
	//if the end of the low array has been reached copy
the rest over
	if(h > mid){
		for(k=j;k<=high;k++){
			b[i]=array[k]; i++;
		}
	} else{ //else the end of the high array has been
reached first
		for(k=h;k<=mid;k++) {
			b[i]=array[k];
			i++;
		}
	}
	//copy the temp array back
	for(k=low;k<=high;k++) {
		array[k]=b[k]
	}
}
/**********QUICK SORT**********/
//Takes an element and compares it to all other elements in a
partition
//if the other elements are larger, then place them above in
the list
//else place them below in the list
void quicksort(int * num, int top = 0, int bottom = SIZE-1)
{
	int middle;
	if (top < bottom) {
		middle = partition(num, top, bottom);
		quicksort(num, top, middle); // sort first
section
		quicksort(num, middle+1, bottom); // sort
second section
	}
	return;
}
//Partition the array into two halves and return the
//index about which the array is partitioned
int partition(int * array, int top, int bottom)
{
	int x = array[top];
	int i = top;
	int j = bottom;
	int temp;
	do{
		while (x > array[j]){
			j--;
		}
		while (x < array[i]){
			i++;
		}
		if (i < j){ //swap
			temp = array[i];
			array[i] = array[j];
			array[j] = temp;
		}
	}while (i < j);
	return j; // returns middle subscript
}
```

```
/****************************************/
/***************FILTER******************/
/****************************************/
#include <iostream>
#include <fstream>
#include <sstream>
#include <string>
using namespace std;

//Bestimmt die Länge des Filters
int get_filter_size(const char *filter)
{
   ifstream fin(filter);
   if(!fin.is_open()) {
      cerr << "Failed to open " << filter;
      return 0;
   }

   int len = 0;
   double d;
   while(fin >> d) len++;

   fin.close();

   return len;
}

double discretefolding(double d[], int n, double f[], int filtersize)
{
	double dfolded = 0.0;
	for(int k = 0; k < filtersize; k++)
	{
		if(!(n-k+filtersize/2 < 0) && !(n-
k+filtersize/2 > filtersize))
		{
			dfolded += f[k]*d[n-k+filtersize/2];
		}
	}
	return dfolded;
}

bool filter(char datafile[], char filterfile[], int filtersize, char
outputfile[])
{
	double* filterdata = new double[filtersize];
	double* bufferdata = new double[filtersize];

	//Read Filter
	ifstream fin(filterfile);
	if(!fin.is_open()) {
		cerr << "Failed to open Filterdata : " <<
filterfile << endl;
		return false;
	}
	for(int i = 0; i < filtersize; i++)
	{
		fin >> filterdata[i];
	}
	fin.close();

	//Ausgabedatei erstellen
	ofstream fout(outputfile);
	if(!fout.is_open()) {
		cerr << "Failed to open output-stream!! : " <<
outputfile << endl;
		return false;
	}

	//Eingabestream für Daten erstellen
	ifstream findata(datafile);
	if(!findata.is_open()){
		cerr << "Failed to open Data-Stream!! : " <<
datafile << endl;
		return false;
	}


	//Garbage collector
	char c[200];
	findata.getline(c,200);

	//Filterdaten einlesen bis Buffer voll
	double value = 0;
	for(int i = 0; i < filtersize; i++)
	{
		findata >> value;
		bufferdata[i] = value;
	}
	//Filterdaten bis Bufferhälfte verarbeiten...
	for(int j = 0; j <= filtersize/2; j++)
	{
		fout << discretefolding(bufferdata, j,
filterdata, filtersize) << endl;
	}
	//Weiter Einlesen und fortlaufend verarbeiten
	while(findata >> value)
	{
		//Buffer shiften
		for(int i = 1; i < filtersize; i++)
		{
			bufferdata[i-1] = bufferdata[i];
		}
		bufferdata[filtersize-1] = value;
		//Verarbeiten
		fout << discretefolding(bufferdata,
filtersize/2, filterdata, filtersize) << endl;
	}
	//restliche verarbeiten
	for(int i = filtersize/2 + 1; i < filtersize; i++)
	{
		fout << discretefolding(bufferdata, i,
filterdata, filtersize) << endl;
	}

	fout.close();
	findata.close();

	delete[] filterdata;
	delete[] bufferdata;

	return true;
}


int main(int argc, char* argv[])
{
   if(argc != 4) {
      cerr << "Usage: " << argv[0] << " filter " << endl;
      return 0;
   }

   //Länge des Filters bestimmen und ausgeben
   int lf = get_filter_size(argv[1]);
   cout << "The filter has " << lf << " entries." << endl;

   filter(argv[2],argv[1],lf,argv[3]);

   return 0;
}
```