19. Classes

Overloading Functions and Operators, Encapsulation, Classes, Member Functions, Constructors

Function Overloading

- A function is defined by name, types, number and order of arguments

```
double sq (double x) { ... }      // f1
int sq (int x) { ... }            // f2
int pow (int b, int e) { ... }    // f3
int pow (int e) { return pow (2,e); } // f4
```

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```
std::cout << sq (3);
```

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```
std::cout << sq (3);   // compiler chooses f2
std::cout << sq (1.414);
```

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- the compiler automatically chooses the function that fits “best” for a function call

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std::cout << sq (3);   // compiler chooses f2
std::cout << sq (1.414); // compiler chooses f1
std::cout << pow (2);
```

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double sq (double x) { ... }      // f1
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int pow (int b, int e) { ... }    // f3
int pow (int e) { return pow (2,e); } // f4
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- the compiler automatically chooses the function that fits “best” for a function call

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std::cout << sq (3);   // compiler chooses f2
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std::cout << pow (2);  // compiler chooses f4
std::cout << pow (3,3);
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double sq (double x) { ... }      // f1
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- the compiler automatically chooses the function that fits “best” for a function call

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std::cout << sq (3);   // compiler chooses f2
std::cout << sq (1.414); // compiler chooses f1
std::cout << pow (2);  // compiler chooses f4
std::cout << pow (3,3); // compiler chooses f3
```

Operator Overloading

- Operators are special functions and can be overloaded
- Name of the operator *op*:

```
operatorop
```

Adding `rational` Numbers – Before

```
// POST: return value is the sum of a and b
rational add (rational a, rational b)
{
    rational result;
    result.n = a.n * b.d + a.d * b.n;
    result.d = a.d * b.d;
    return result;
}
...
const rational t = add (r, s);
```

Adding `rational` Numbers – After

```
// POST: return value is the sum of a and b
rational operator+ (rational a, rational b)
{
    rational result;
    result.n = a.n * b.d + a.d * b.n;
    result.d = a.d * b.d;
    return result;
}
...
const rational t = r + s;
```

Adding `rational` Numbers – After

```
// POST: return value is the sum of a and b
rational operator+ (rational a, rational b)
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    rational result;
    result.n = a.n * b.d + a.d * b.n;
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}
...
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```

infix notation

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{
    rational result;
    result.n = a.n * b.d + a.d * b.n;
    result.d = a.d * b.d;
    return result;
}
...
const rational t = operator+ (r, s);
```


equivalent but less handy: functional notation

Unary Minus

Only one argument:

```
// POST: return value is -a
rational operator- (rational a)
{
    a.n = -a.n;
    return a;
}
```

Comparison Operators

can be defined such that they do the right thing:

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```
// POST: returns true iff a == b
bool operator== (rational a, rational b)
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```

$$\frac{2}{3} = \frac{4}{6} \quad \checkmark$$

Arithmetic Assignment

We want to write

```
rational r;
r.n = 1; r.d = 2;                    // 1/2

rational s;
s.n = 1; s.d = 3;                    // 1/3

r += s;
std::cout << r.n << "/" << r.d;      // 5/6
```

Operator +=

```
rational& operator+= (rational& a, rational b)
{
    a.n = a.n * b.d + a.d * b.n;
    a.d *= b.d;
    return a;
}
```

Operator +=

```
rational& operator+= (rational& a, rational b)
{
    a.n = a.n * b.d + a.d * b.n;
    a.d *= b.d;
    return a;
}
```

- The L-value `a` is increased by the value of `b` and returned as L-value

In/Output Operators

can also be overloaded.

- Before:

```
std::cout << "Sum is " << t.n << "/" << t.d << "\n";
```

- After (desired):

```
std::cout << "Sum is " << t << "\n";
```

In/Output Operators

can be overloaded as well:

```
// POST: r has been written to out
std::ostream& operator<< (std::ostream& out, rational r)
{
    return out << r.n << "/" << r.d;
}
```

In/Output Operators

can be overloaded as well:

```
// POST: r has been written to out
std::ostream& operator<< (std::ostream& out, rational r)
{
    return out << r.n << "/" << r.d;
}
```

writes `r` to the output stream
and returns the stream as L-value.

Input

```
// PRE: in starts with a rational number of the form "n/d"
// POST: r has been read from in
std::istream& operator>> (std::istream& in, rational& r){
    char c; // separating character '/'
    return in >> r.n >> c >> r.d;
}
```

reads `r` from the input stream
and returns the stream as L-value.

Goal Attained!

```
// input
std::cout << "Rational number r =? ";
rational r;
std::cin >> r;

std::cout << "Rational number s =? ";
rational s;
std::cin >> s;

// computation and output
std::cout << "Sum is " << r + s << ".\n";
```

Goal Attained!

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// input
std::cout << "Rational number r =? ";
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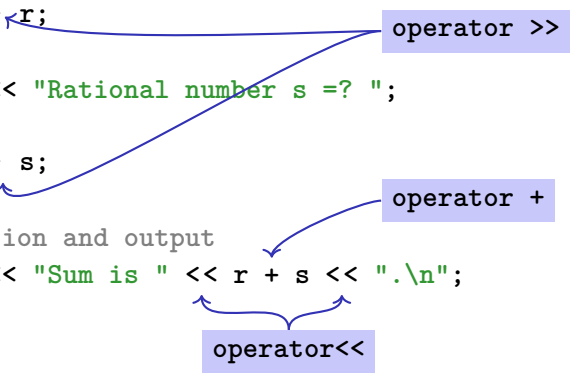

A new Type with Functionality...

```
struct rational {
    int n;
    int d; // INV: d != 0
};

// POST: return value is the sum of a and b
rational operator+ (rational a, rational b)
{
    rational result;
    result.n = a.n * b.d + a.d * b.n;
    result.d = a.d * b.d;
    return result;
}
...
```

...should be in a Library!

rational.h

- Definition of a struct `rational`
- Function declarations

rational.cpp

- arithmetic operators (`operator+`, `operator+=`, ...)
- relational operators (`operator==`, `operator>`, ...)
- in/output (`operator >>`, `operator <<`, ...)

Invariants and Representation

- We want to guarantee that invariants hold for our data structure.

Example 1: For each `Rational r` it always holds that $r.d \neq 0$.
Example 2: Each `Rational r` always is reduced.

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  `Vector v`: `v.size()`, `v[3]`

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- Provides to the user the “what” and not the “how”.

  `Vector v`: `v.size()`, `v[3]`

- It should be possible to change the internal representation without having to rewrit user code.

  `Complex`: polar coordinates vs. cartesian coordinates

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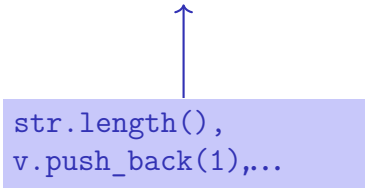

Classes

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- are a variant of structs
- are provided in many *object oriented programming languages*

Encapsulation: `public` / `private`

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class rational {
  int n;
  int d; // INV: d != 0
};
```

is used instead of `struct` if anything at all shall be “hidden”

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class rational {
  int n;
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```

is used instead of `struct` if anything at all shall be “hidden”

only difference

- `struct`: by default nothing is hidden
- `class` : by default everything is hidden

Encapsulation: `public` / `private`

```
class rational {
  int n;
  int d; // INV: d != 0
};
```

Application Code

```
rational r;
r.n = 1;      // error: n is private
r.d = 2;      // error: d is private
int i = r.n; // error: n is private
```

Encapsulation: `public` / `private`

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class rational {
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Good news: `r.d = 0` cannot happen any more by accident.

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Encapsulation: `public` / `private`

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class rational {
  int n;
  int d; // INV: d != 0
};
```

Good news: `r.d = 0` cannot happen any more by accident.

Bad news: we cannot do anything any more …

Application Code

```
rational r;
r.n = 1;      // error: n is private
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int i = r.n; // error: n is private
```

Member Functions: Declaration

```
class rational {
public:
   // POST: return value is the numerator of this instance
   int numerator () const {
     return n;
   }
   // POST: return value is the denominator of this instance
   int denominator () const {
     return d;
   }
private:
   int n;
   int d; // INV: d!= 0
};
```

Member Functions: Declaration

public area

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public area

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  int n;
  int d; // INV: d!= 0
};
```

public area

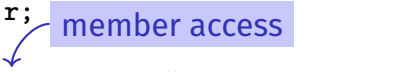
member function

member functions have access to private data

Member Functions: Call

```
// Definition des Typs
class rational {
    ...
};
...
// Variable des Typs
rational r;

int n = r.numerator();   // Zaehler
int d = r.denominator(); // Nenner
```



const and Member Functions

```
class rational {
public:
  int numerator () const
  { return n; }
  void set_numerator (int N)
  { n = N;}
...
}
```

```
rational x;
x.set_numerator(10); // ok;
const rational y = x;
int n = y.numerator(); // ok;
y.set_numerator(10); // error;
```

The const at a member function is to promise that an instance cannot be changed via this function.
const items can only call const member functions.

Member Functions: Definition

```
// POST: returns numerator of this instance
int numerator () const
{
  return n;
}
```

Member Functions: Definition ???

```
// POST: returns numerator of this instance
int numerator ()  const
{
  return n;
}
```

Member Functions: Definition

```
// POST: returns numerator of this instance
int numerator () const
{
  return n;                          r.numerator()
}
```

- A member function is called for an expression of the class.

Member Functions: Definition

```
// POST: returns numerator of this instance
int numerator () const
{
  return n;
}
```

```
r.numerator()
```

- A member function is called for an expression of the class. in the function, `this` ~~is the name of this~~ *implicit argument*.

Member Functions: Definition

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// POST: returns numerator of this instance
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- A member function is called for an expression of the class. in the function, `this` is the name of this *implicit argument*.
- *const* refers to the instance `this`

Member Functions: Definition

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// POST: returns  numerator of this instance
int numerator () const
{
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}
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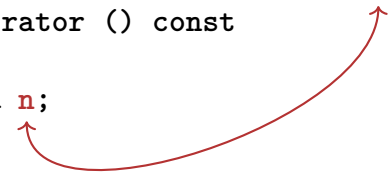

- A member function is called for an expression of the class. in the function, `this` is the name of this *implicit argument*.
- *const* refers to the instance `this`
- `n` is the shortcut for `this->n` (precise explanation of "->" next week)

Comparison

```
class rational {
    int n;
    ...
public:
    int numerator () const
    {
        return n;
    }
};

rational r;
...
std::cout << r.numerator();
```

Comparison

```
class rational {
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rational r;
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Comparison

Roughly like this it were ...

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Comparison

Roughly like this it were ...

```
class rational {
    int n;
    ...
public:
    int numerator () const
    {
        return this->n;
    }
};

rational r;
...
std::cout << r.numerator();
```

... without member functions

```
struct bruch {
    int n;
    ...
};

int numerator (const bruch& dieser)
{
    return dieser.n;
}

bruch r;
..
std::cout << numerator(r);
```

Initialisation? Constructors!

```
class rational
{
public:
    rational (int num, int den)
        : n (num), d (den)
    {
        assert (den != 0);
    }
...
};
...
rational r = rational(2,3); // r = 2/3
```

Initialisation? Constructors!

```
class rational
{
public:
    rational (int num, int den)
        : n (num), d (den)
    {
        assert (den != 0);
    }
...
};
...
rational r = rational(2,3); // r = 2/3
```

Initialization of the member variables

function body.

The Default Constructor

```
class rational
{
public:
    ...
    rational ()
       : n (0), d (1)
    {}
...
};
...
rational r;   // r = 0
  // Shorthand for rational r = rational();
```

The Default Constructor

```
class rational
{
public:
    ...
    rational ()
       : n (0), d (1)
    {}
...
};
...
rational r;   // r = 0
  // Shorthand for rational r = rational();
```

$\Rightarrow$ There are no uninitiatlized variables of type rational any more!

Alterantively: Deleting a Default Constructor

```
class rational
{
public:
    ...
    rational () = delete;
...
};
...
rational r;   // error:  use of deleted function 'rational::rational()
```

$\Rightarrow$ There are no uninitiatlized variables of type rational any more!

Initialisation “rational = int”?

```
class rational
{
public:
    rational (int num)
       : n (num), d (1)
    {}
...
};
...
rational r = rational(2); // explicit initialization with 2
rational s = 2; // implicit conversion
```

Initialisation “rational = int”?

```
class rational
{
public:
    rational (int num)
       : n (num), d (1)
    {}   ←——— empty function body
...
};
...
rational r = rational(2); // explicit initialization with 2
rational s = 2; // implicit conversion
```

User Defined Conversions

are defined via constructors with exactly *one* argument

```
rational (int num)
    : n (num), d (1)
  {}
```

User defined conversion from `int` to `rational`. values of type `int` can now be converted to `rational`.

```
rational r = 2; // implizite Konversion
```

Member-Definition: In-Class

```
class rational {
    int n;
    ...
public:
    int numerator () const
    {
        return n;
    }
    ....
};
```

- No separation between declaration and definition (bad for libraries)

Member-Definition: In-Class vs. Out-of-Class

```
class rational {
    int n;
    ...
public:
    int numerator () const
    {
        return n;
    }
    ....
};
```

- No separation between declaration and definition (bad for libraries)

```
class rational {
    int n;
    ...
public:
    int numerator () const;
    ...
};

int rational::numerator () const
{
  return n;
}
```

- This also works.