Software↵
Languages.Lab

Structuur van Computerprogramma's 2

dr. Dirk Deridder
Dirk.Deridder@vub.ac.be
http://soft.vub.ac.be/

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Chapter 3 - User Defined Types

Structuur van Computerprogramma's 2

Rational Example

Rational Example: main.cpp

```cpp
#include <iostream>
#include "rational.h"

using namespace std;

int main() {
    Rational leftoperand;
    Rational rightoperand;
    char operation;

    while (cin) { // as long as there are data on the standard input stream
        cin >> leftoperand >> operation >> rightoperand;
        switch (operation) {
        case '+':
            cout << leftoperand + rightoperand << "\n";
            break;
        case '*':
            cout << leftoperand * rightoperand << "\n";
            break;
        case '-':
            cout << leftoperand - rightoperand << "\n";
            break;
        case '/':
            cout << leftoperand / rightoperand << "\n";
            break;
        }
    }
}
```

```
2/3+5/3
 7/3
1/2*5/3
 5/6
5/3-2/2
 2/3
2/2/2/2
 1
```

Rational Example: rational.h (1)

```cpp
#ifndef RATIONAL_H
#define RATIONAL_H
#include <assert.h>
#include <iostream>
#include "gcd.h"
using namespace std;

class Rational { //ADT representing rational numbers
public:
    Rational(int num = 0, int denom = 1) :
        numerator_(num), denominator_(denom) {
        assert(denominator_ != 0);
    }
    Rational inverse() { return Rational(denom(), num()); }
    bool isnegative() {    return denom() * num() < 0; }
    void simplify() {
        int g(gcd(num(), denom()));
        numerator_ /= g;
        denominator_ /= g;
    }
    int num() { return numerator_; }
    int denom() { return denominator_;    }
    friend istream& // reads 2/3 as well as 4, the latter is understood as 4/1
            operator>>(istream&, Rational&);

private:
    int numerator_;
    int denominator_; // must not be 0!
};
```

Rational Example: rational.h (2)

```
//overloaded arithmetic operators

inline Rational operator+(Rational r1, Rational r2) {
    return Rational(r1.num() * r2.denom() + r2.num() * r1.denom(), r1.denom()
           * r2.denom());
}

inline Rational operator*(Rational r1, Rational r2) {
    return Rational(r1.num() * r2.num(), r1.denom() * r2.denom());
}

inline Rational operator-(Rational r) { //unary -
    return Rational(-r.num(), r.denom());
}

inline Rational operator-(Rational r1, Rational r2) {
    return Rational(r1 + (-r2));
}

inline Rational operator/(Rational r1, Rational r2) {
    return r1 * r2.inverse();
}
```

Rational Example: `rational.h` (3)

```
//overloaded relational operators: only operator< and operator== are really necessary
//the others are automatically derived by the STL using template functions

inline bool operator<(Rational r1, Rational r2) {
    return (r1 - r2).isnegative();
}
inline bool operator==(Rational r1, Rational r2) {
    return (r1 - r2).num() == 0;
}

inline bool operator>(Rational r1, Rational r2) {
    return r2 < r1;
}
inline bool operator!=(Rational r1, Rational r2) {
    return !(r1 == r2);
}
inline bool operator>=(Rational r1, Rational r2) {
    return !(r1 < r2);
}
inline bool operator<=(Rational r1, Rational r2) {
    return !(r1 > r2);
}

//output operator, simplifies first, prints 4 for 4/1
ostream& operator<<(ostream&, Rational);

#endif
```

Rational Example: rational.cpp

```cpp
#include <stdlib.h> // for abs(int)
#include  "rational.h"

ostream& operator<<(ostream& os, Rational r) {
    r.simplify();
    os << (r.isnegative() ? "-" : " ") << abs(r.num());
    if (abs(r.denom()) != 1)
        os << "/" << abs(r.denom());
    return os;
}

istream& operator>>(istream& is, Rational& r) { // reads things like 2/3, 4
    char c;
    if (!is) // return if input stream is not ok (e.g. eof)
        return is;
    is >> r.numerator_;
    r.denominator_ = 1; // default
    if (!is) // end of file after 1 number, just return and r=numerator/1
        return is;
    is.get(c); // get the next char, do not skip white noise (/n/t)
    if (c != '/') { // oops, not a real fraction, just return numerator/1
        cin.putback(c); // but first put back the character, so it will be read again
        return is;
    }
    is >> r.denominator_;
    assert(r.denominator_ != 0);
    return is;
}
```

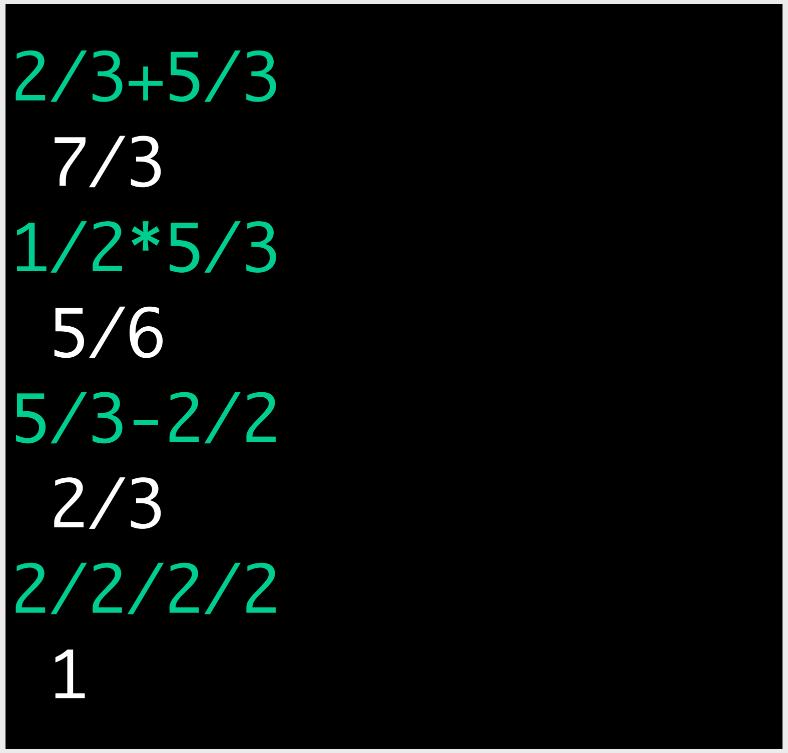
Rational Example: gcd.h gcd.cpp

```
#ifndef GCD_H_
#define GCD_H_

int gcd(int, int);

#endif /* GCD_H_ */
```

```
#include "gcd.h"

int gcd(int u, int v) { // use Euclid's algorithm to compute
                        // the greatest common divisor of u,v
   if (v == 0)
      return u;
   else
      return gcd(v, u % v);
}
```

Rational Example: `main.cpp` (recap)

```cpp
#include <iostream>
#include "rational.h"

using namespace std;

int main() {
    Rational leftoperand;
    Rational rightoperand;
    char operation;

    while (cin) { // as long as there are data on the standard input stream
        cin >> leftoperand >> operation >> rightoperand;
        switch (operation) {
        case '+':
            cout << leftoperand + rightoperand << "\n";
            break;
        case '*':
            cout << leftoperand * rightoperand << "\n";
            break;
        case '-':
            cout << leftoperand - rightoperand << "\n";
            break;
        case '/':
            cout << leftoperand / rightoperand << "\n";
            break;
        }
    }
}
```



```
2/3+5/3
 7/3
1/2*5/3
 5/6
5/3-2/2
 2/3
2/2/2/2
 1
```

Exceptions

Overview of Concepts

- Exception handling facility
- Exception, exception types,
- Exception throwing, exception re-throwing
- Exception handling, try/catch statement
- Catch-all exception handler

Exceptions: Motivation

```
Rational::Rational(int num = 0, int denom = 0) :
   num_(num), denom_(denom) {
   assert(denom != 0);
}

std::istream&
operator>>(std::istream& is, Rational& r) {
   // reads things like 2/3, 4
   // ... parts omitted: see book p. 78
   is >> r.denom_;
   assert(r.denom_ != 0);
   return is;
}
```

brute error handling if **denom == 0**

brute error handling if **denominator == 0**

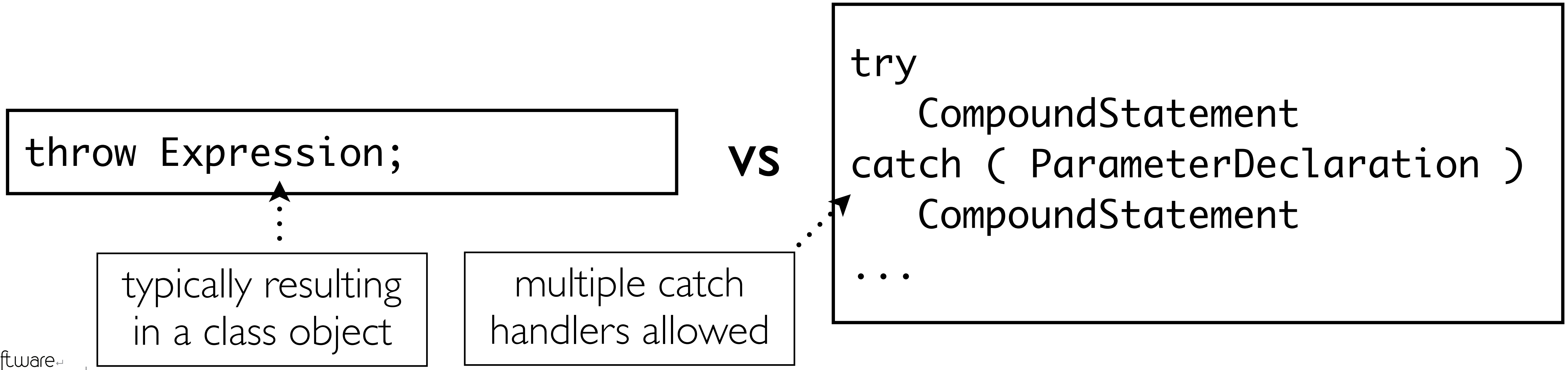
```
1/2+3/0
Assertion failed: (r.denominator_ != 0), function
operator>>, file ../rational.cpp, line 32.
```

Informative for the end-user?

C++ provides a more gentle and cleaner way to handle errors with its **exception handling facility**

C++ Exception Handling Facility

- When an **exceptional situation** is detected:
  - a function can **throw** an object (**exception**)
    - the exception object can contain data pertinent to the situation
    - immediately exits current function without producing a return value
- A calling function can **catch** exception objects of certain **exception types** using a `try` **statement**
  - handles exceptions thrown during the execution of the `try` statement
    - first handler that matches the exception type (*) is passed the exception object
    - exception object data can be analysed to parameterise handling
  - there may be many function calls between the detection and handling level



```
throw Expression;
```

VS

```
try
   CompoundStatement
catch ( ParameterDeclaration )
   CompoundStatement
...
```

typically resulting in a class object

multiple catch handlers allowed

Rational Example: an Exception Class

```
class RationalZeroDenom{ //an exception class
public:
   RationalZeroDenom(int num): num_(num){}

   int num() { return num_; }

private:
   int num_;
};
```

Define a type for the category of errors you want to handle

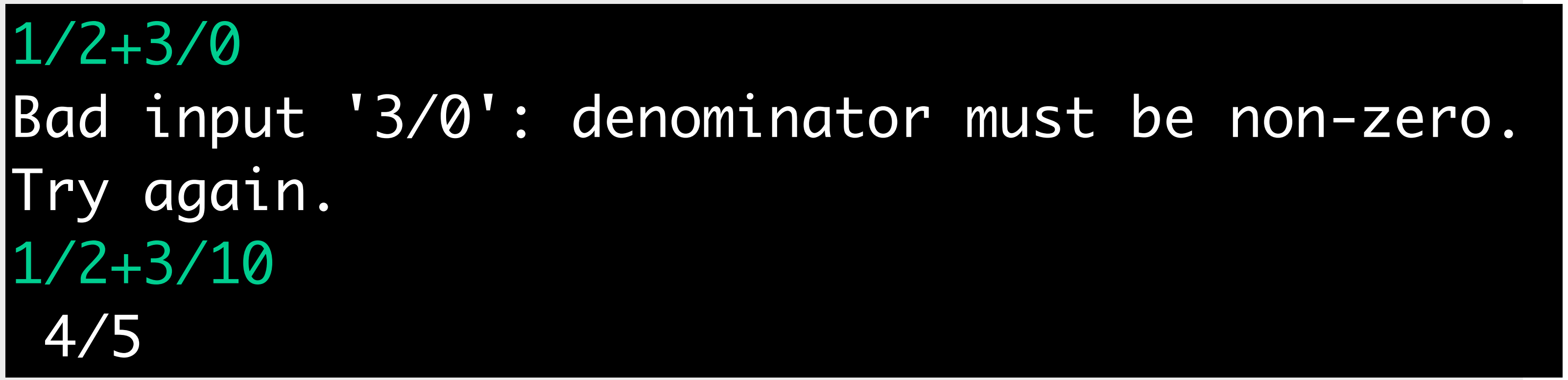
Rational Example: Throwing Exceptions

```
Rational::Rational(int num = 0, int denom = 1) :
   numerator_(num), denominator_(denom) {
   if (denominator_ == 0)
      throw RationalZeroDenom(num);
}

std::istream&
operator>>(std::istream& is, Rational& r)
                  throw (RationalZeroDenom, std::exception) {
   is >> r.denomoninator_; // Stuff omitted: see book p. 78
   if (r.denom_ == 0)
      throw RationalZeroDenom(r.numerator_);
   return is;
}
```

Make a copy of the thrown object and exit the function, its caller, etc. up to a call in a try block with a catch clause matching the type of the exception

Rational Example: Catching Exceptions

```
#include <iostream>
#include "rational.h"
using namespace std;

int main() {
    Rational leftoperand, rightoperand;
    char operation;
    while (cin) { // as long as there are data on the standard input stream
        try { // start try block
            cin >> leftoperand >> operation >> rightoperand;
            switch (operation) {
            case '+':
                cout << leftoperand + rightoperand << "\n"; break;
            case '*':
                cout << leftoperand * rightoperand << "\n"; break;
            case '-':
                cout << leftoperand - rightoperand << "\n"; break;
            case '/':
                cout << leftoperand / rightoperand << "\n"; break;
            }
        } // end try block
        catch (RationalZeroDenom ex) { // catch n/0 exceptions
            cerr << "Bad input \'" << ex.num()
                    << "/0\': denominator must be non-zero." << endl
                    << "Try again." << endl;
        }
        catch (...) { // catch all other exceptions
            cerr << "Unknown exception" << endl;
        }
    }
}
```



```
1/2+3/0
Bad input '3/0': denominator must be non-zero.
Try again.
1/2+3/10
 4/5
```

“catch all” handler

The order of the handlers is important !

Run-time Behaviour: Throwing an Object E

1. **A copy of E is made**, as if E were a call-by-value parameter of a function call (cctor is used)
2. The **current function call exits immediately** (without returning a value)
   - unless the throw statement occurs inside a try block
3. The **call stack is unwound** by popping frames from active function calls (including the call that generated E)
   - Each time a frame is popped: all destructors for local objects in the frame are executed
   - Unwinding stops when the top of the stack contains a frame for an active function call which is executing a statement in a try block
4. **Control is transferred** out of the try block to one of the following **handlers**
   - Each handler can be seen as an overloaded unary function
   - The first handler that is a match for the type of E is executed with E as parameter
     - If no handlers match, the frame is popped and stack unwinding continues
     - If all frames of the stack are popped, the program exits abnormally calling `std::terminate()`
5. After executing the handler, the **try statement is finished** and the execution proceeds as normal
   - You can rethrow an exception using the statement `throw;`

Catching Exceptions: catch(arg) is like a function call

```
while (std::cin) {
   try {                     // catch any exceptions thrown in (functions
                             // called from within) this block
      Rational r;
      std::cout << "input? " << std::endl;
      std::cin >> r;
      // ...
   }
   catch (RationalZeroDenom& e) {     // Complain and continue
      std::cerr << e << ", try again" << std::endl;
   }
   catch (std::exception& e) {        // Complain and throw it again
      std::cerr << e.what() << std::endl;
      throw;                          // Re-throw e.
   }
   catch (...) {                      // Complain and throw it again
      std::cerr << "A weird exception was thrown" << std::endl;
      throw;
   }
}
```

Making Exceptions Compatible with `ostream`

```
class RationalZeroDenom {
public:
   RationalZeroDenom(int n) : num_(n) { }

   friend std::ostream& operator<<(std::ostream& os,
                                   const RationalZeroDenom& e) {
     return os << num_ << "/0 is not a legal Rational";
   }

private:
   int num_;
};
```

```
// ...
catch (RationalZeroDenom ex) { // catch n/0 exceptions
        cerr << ex;
}
// ...
```

More on Exceptions

see book !

- When unwinding the stack, local objects are destructed
  - release resources in destructors
- When throwing an exception from a constructor `C::C(...)`, the destructor `C::~C()` is **not** called (but the destructors of the data members are)
- Exceptions thrown from a destructor: see book p. 212-213
- Exception specifications and unexpected exceptions: see book p. 213-214