Chapter 16

Exception Handling

OBJECTIVES

- What exceptions are and when to use them.
- To use try, catch and throw to detect, handle and indicate exceptions, respectively.
- To process uncaught and unexpected exceptions.
- To declare new exception classes.
- How stack unwinding enables exceptions not caught in one scope to be caught in another scope.
- To handle new failures.
- To understand the standard exception hierarchy.

Topics

- ❑ **16.1 Introduction**
- ❑ **16.2 Scenario A: Handle exception thrown by C++ standard lib**
- ❑ **16.3 Scenario B: Define, throw and handle your own exception**
- ❑ **16.4 Stack Unwinding**

16.1 Introduction

- Exception(异常): An exception is an indication of a problem that occurs during a program's execution. 程序执行期间, 可检测到的不正常情况.

- 例子: 0作除数; 数组下标越界; 打开不存在的文件; 内存分配失败

16.1 Introduction

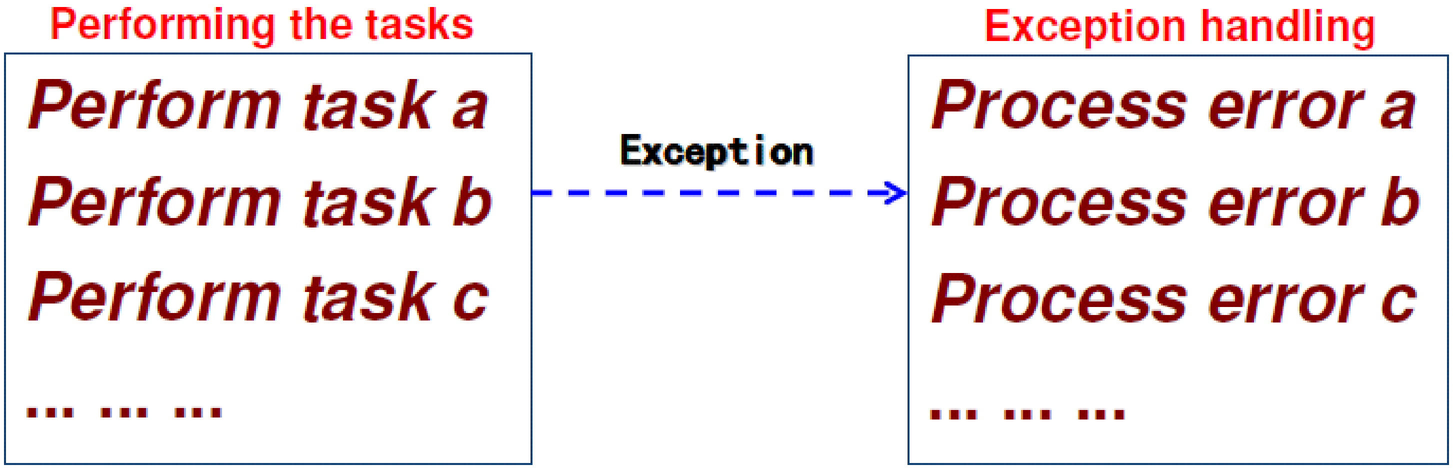
- ❑ Intermixing program logic

```
Perform a task
If the preceding task did not execute correctly
    Perform error processing

Perform next task
If the preceding task did not execute correctly
    Perform error processing


... ... ...
```

- ❑ Difficult to read, modify, maintain and debug especially in large applications
- ❑ Low performance

16.1 Introduction

- **Exception handling(异常处理): In many cases, handling an exception allows a program to continue executing as if no problem had been encountered.**



Performing the tasks

Perform task a

Perform task b

Perform task c

… … …

Exception

Exception handling

Process error a

Process error b

Process error c

… … …

❖ try-catch

robust(健壮性) and fault-tolerant(容错)

16.1 Introduction

□ How to define our own Exception?

□ How to throw Exception?

□ How to catch and handle Exception?

□ Stack Unwinding (栈展开机制)

□ Scenario A: Handle exception thrown by C++ standard lib.

□ Scenario B: Define, throw and handle your own exception.

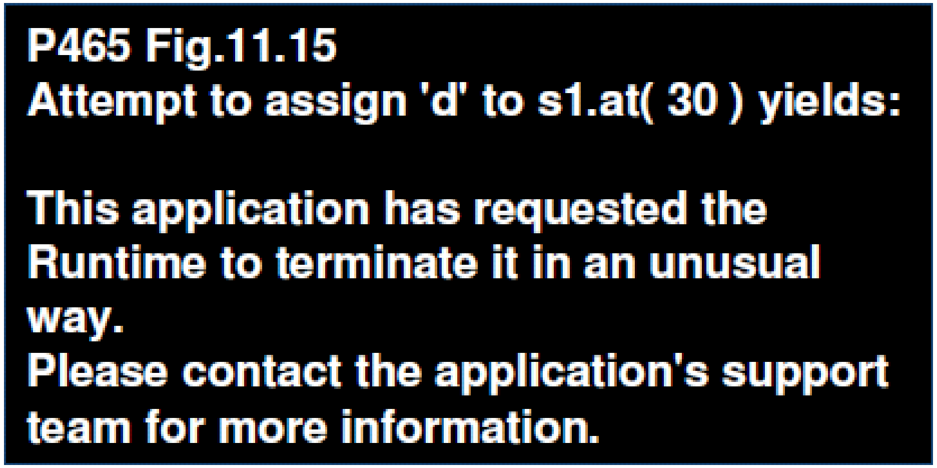
Topics

- □ 16.1 Introduction
- □ **16.2 Scenario A: Handle exception thrown by C++ standard lib**
- □ 16.3 Scenario B: Define, throw and handle your own exception
- □ 16.4 Stack Unwinding

16.2 Scenario A: Handle exception thrown by C++ standard lib

- ❑ 需求: 如何处理C++库调用时抛出的异常?
- ❑ try-catch语句

  Termination Model of Exception Handling



```
P465 Fig.11.15
Attempt to assign 'd' to s1.at( 30 ) yields:

This application has requested the
Runtime to terminate it in an unusual
way.
Please contact the application's support
team for more information.
```

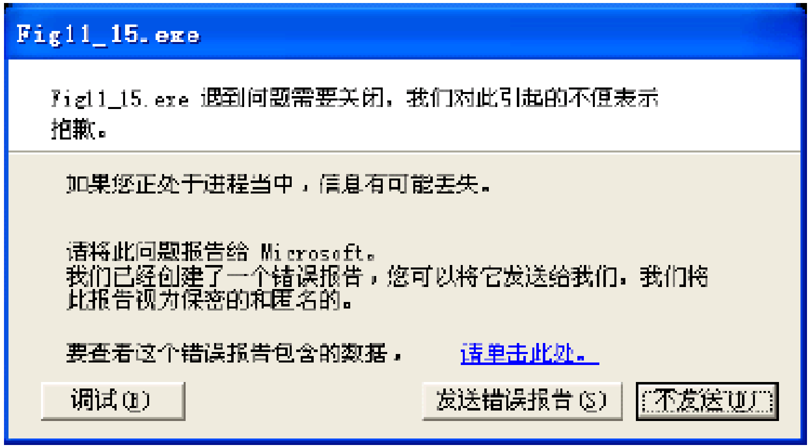


Fig11_15.exe

Fig11_15.exe 遇到问题需要关闭。我们对此引起的不便表示抱歉。

如果您正处于进程当中，信息有可能丢失。

请将此问题报告给 Microsoft。
我们已经创建了一个错误报告，您可以将它发送给我们。我们将此报告视为保密的和匿名的。

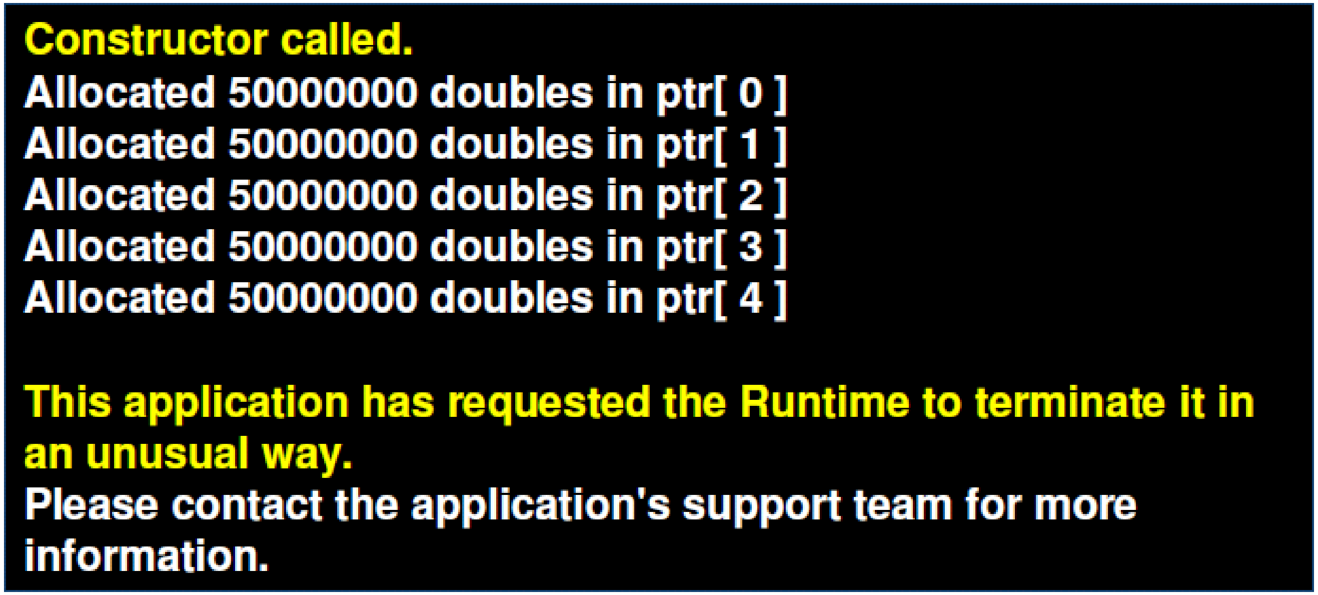
要查看这个错误报告包含的数据， 请单击此处。

16.2 Scenario A: Handle exception thrown by C++ standard lib

```
class Test{
public:
    Test(){ cout << "Constructor called." << endl; }
    ~Test(){ cout << "Destructor ok." << endl; }
};
int main()
{
    Test t;
    double *ptr[ 50 ];

    for ( int i = 0; i < 50; i++ )
    {
        ptr[ i ] = new double[ 50000000 ];
        cout << "Allocated 50000000 doubles in ptr[ " << i << " ]\n";
    }
    return 0;
}
```

16.2 Scenario A: Handle exception thrown by C++ standard lib

- 由于new操作失败, 程序abort
- 危害: 剩余对象全部不调用析构函数等



```
Constructor called.
Allocated 50000000 doubles in ptr[ 0 ]
Allocated 50000000 doubles in ptr[ 1 ]
Allocated 50000000 doubles in ptr[ 2 ]
Allocated 50000000 doubles in ptr[ 3 ]
Allocated 50000000 doubles in ptr[ 4 ]

This application has requested the Runtime to terminate it in
an unusual way.
Please contact the application's support team for more
information.
```

16.2 Scenario A: Handle exception thrown by C++ standard lib

- If new fails to allocate memory and set_new_handler did not register a new -handler function, new throws a bad_alloc exception.
- • Choice 1: Handle bad_alloc exception

16.2 Scenario A: Handle exception thrown by C++ standard lib

```
try {
    // code that may throw exceptions
}
catch (exception-declaration) {
    // code that executes when
    // exception-declaration is thrown
}
catch (exception-declaration) {
    // code that handles another exception type
}
catch (exception-declaration) {

```

关键词try, “包裹”可能出现异常的compound statement

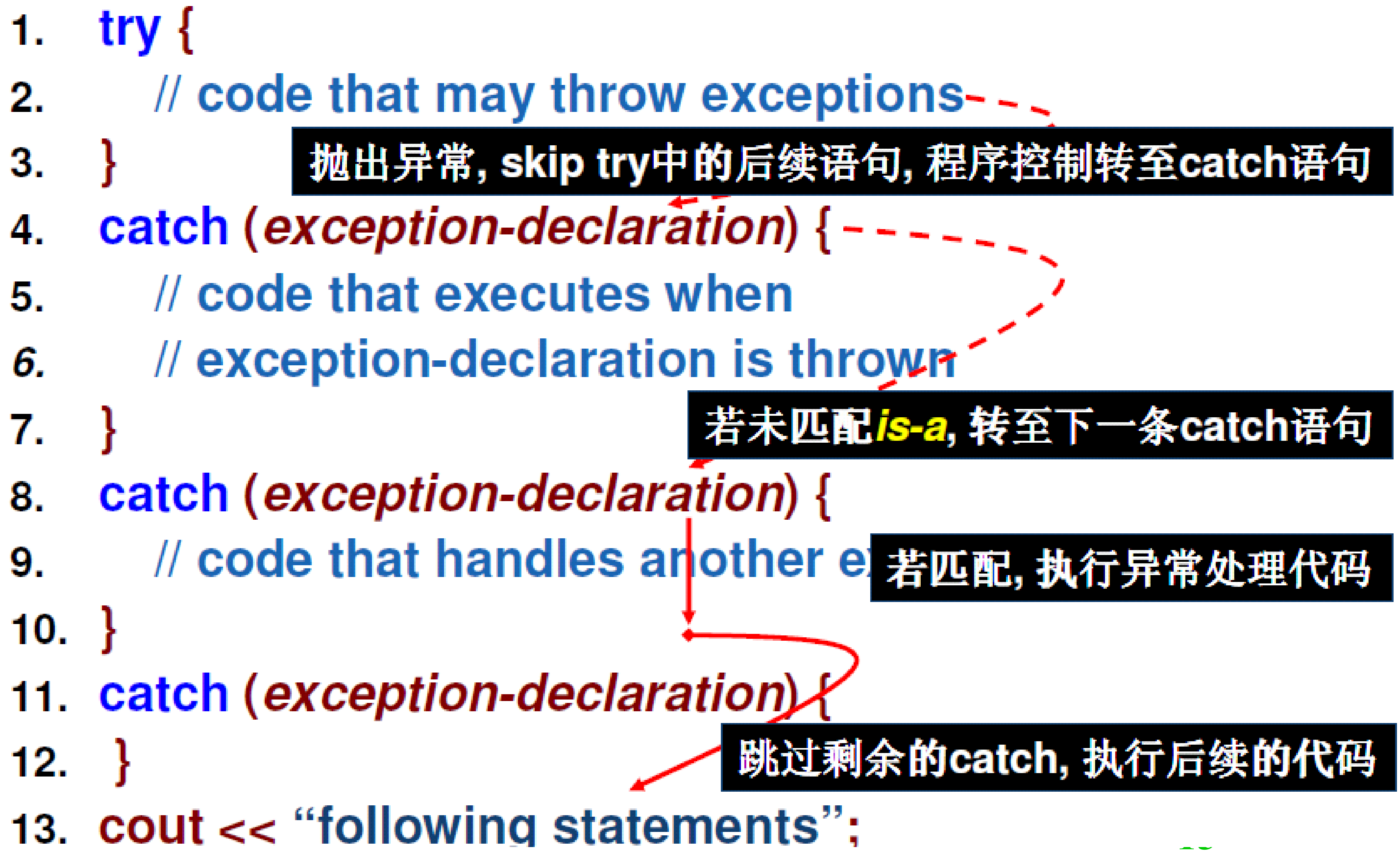
1. 特定异常类型变量的声明，如: catch(*bad_alloc& theexception*)
2. 如要捕捉所有的异常，则: catch(…)

16.2 Scenario A: Handle exception thrown by C++ standard lib

Termination Model of Exception Handling

- ❑1. 抛出异常时, try block结束执行;
- ❑2. 寻找匹配的catch handler (*is-a*);
- ❑3. 执行catch handler代码;
- ❑4. 程序控制跳至最后一个catch handler后的首条语句. (注意: 不再执行try block中抛出异常点的后续语句)

16.2 Scenario A: Handle exception thrown by C++ standard lib



```
try {
    // code that may throw exceptions
}
catch (exception-declaration) {
    // code that executes when
    // exception-declaration is thrown
}
catch (exception-declaration) {
    // code that handles another e
}
catch (exception-declaration) {
 }
cout << “following statements”;
```

抛出异常, skip try中的后续语句, 程序控制转至catch语句

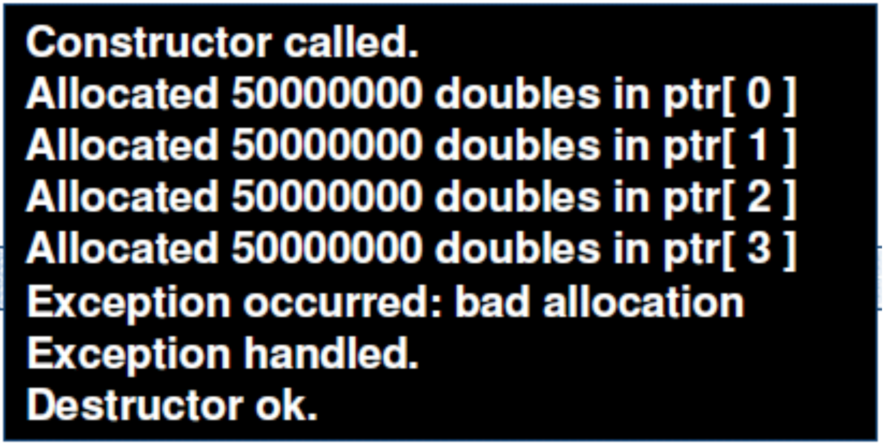
若未匹配*is-a*, 转至下一条catch语句

若匹配, 执行异常处理代码

跳过剩余的catch, 执行后续的代码

16.2 Scenario A: Handle exception thrown by C++ standard lib

```cpp
int main()
{
   Test t;
   double *ptr[ 50 ];
   try
   {
      for ( int i = 0; i < 50; i++ )
      {
         ptr[ i ] = new double[ 50000000 ]; // may throw exception
         cout << "Allocated 50000000 doubles in ptr[ " << i << " ]\n";
      }
   }
   catch ( bad_alloc &memoryAllocationException )// handle exception
   {
      cerr << "Exception occurred: "
           << memoryAllocationException.what() << endl;
   }
   cout << "Exception handled." << endl;
   return 0;
}
```



```
Constructor called.
Allocated 50000000 doubles in ptr[ 0 ]
Allocated 50000000 doubles in ptr[ 1 ]
Allocated 50000000 doubles in ptr[ 2 ]
Allocated 50000000 doubles in ptr[ 3 ]
Exception occurred: bad allocation
Exception handled.
Destructor ok.
```

exception类定义的虚函数, returns error message.

16.2 Scenario A: Handle exception thrown by C++ standard lib

- ❑ 修改1: bad_alloc → exception
- ❑ 修改2: bad_alloc → logic_error
- ❑ 修改3: bad alloc → …

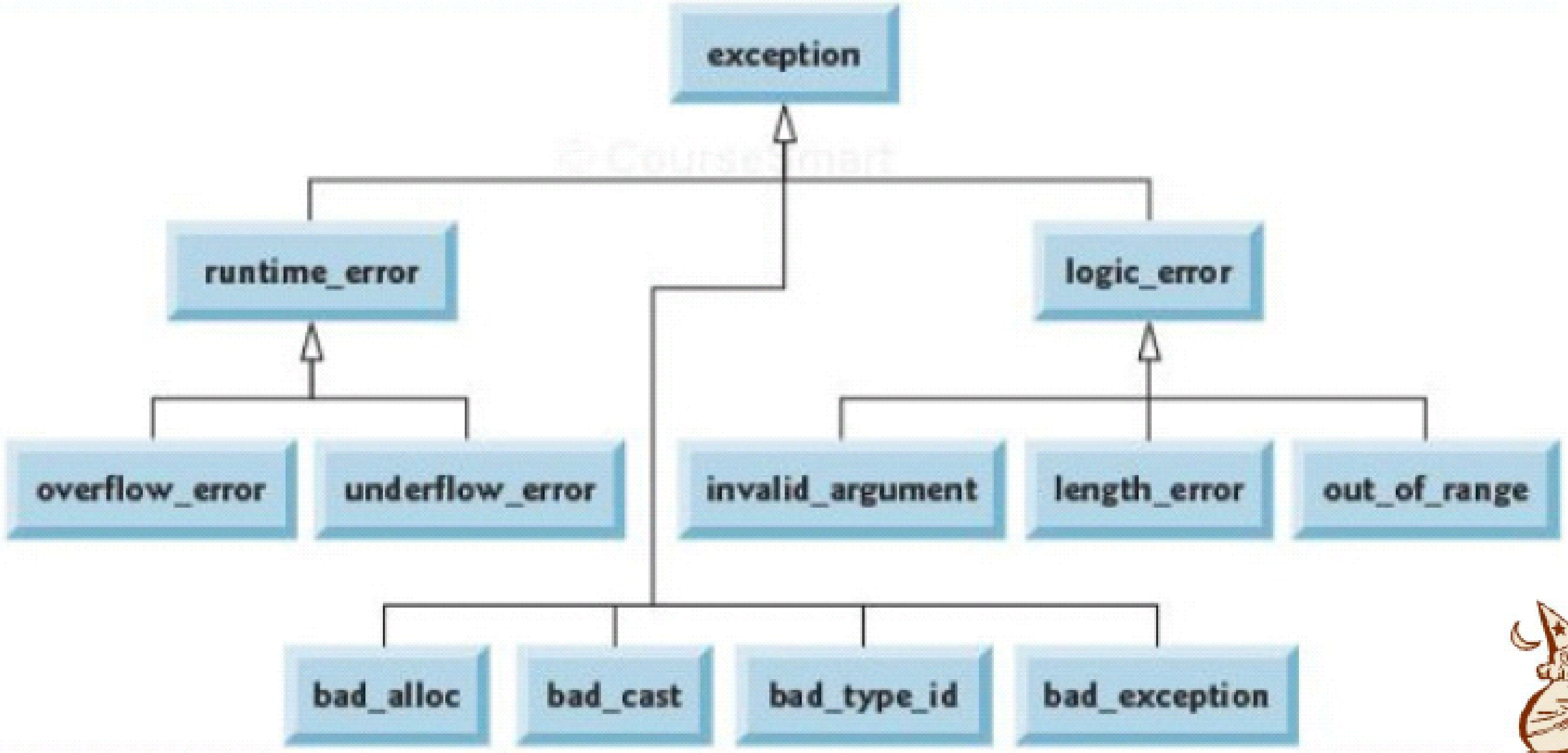


Figure 16.11. Standard Library exception classes

Topics

- 16.1 Introduction
- 16.2 Scenario A: Handle exception thrown by C++ standard lib
- **16.3 Scenario B: Define, throw and handle your own exception**
- 16.4 Stack Unwinding

16.3 Scenario B: Define, throw and handle your own exception

- ❑ 如何在自定义的函数中抛出异常?
- ❑ 需求: 设计quotient函数, 对用户输入的两个数进行除法操作, 希望输入的除数为0时能抛出异常, 由调用函数捕获并处理该异常

- ❑ Exception Specifications 异常说明

16.3 Scenario B: Define, throw and handle your own exception

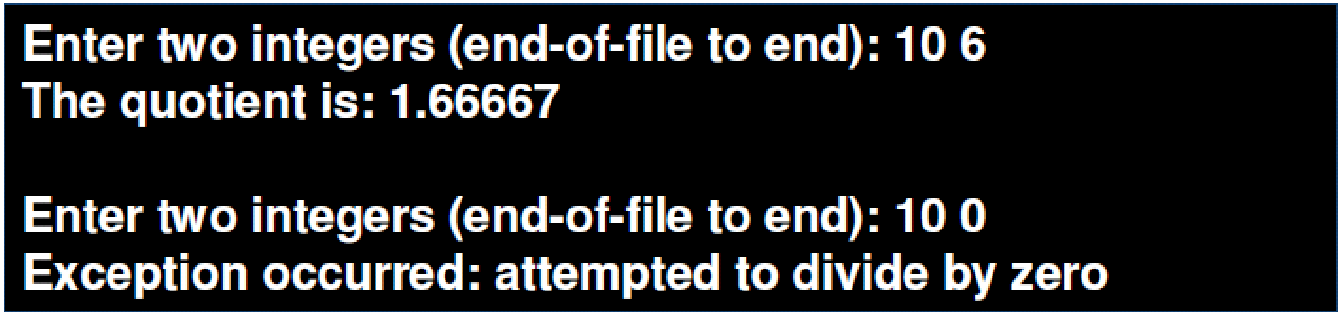
```
// P612. Figure 16.1. Class DivideByZeroException definition
#include <stdexcept>
using std::runtime_error;

class DivideByZeroException : public runtime_error
{
public:
   DivideByZeroException::DivideByZeroException()
      : runtime_error( "attempted to divide by zero" ) {}
};
```

```
// P612. Figure 16.2. throws  and handle exceptions
double quotient( int numerator, int denominator )
{
   if ( denominator == 0 )
      throw DivideByZeroException(); // terminate function
   return static_cast< double >( numerator ) / denominator;
}
```

what()输出的信息

16.3 Scenario B: Define, throw and handle your own exception

```
try
{
    result = quotient( number1, number2 );
    cout << "The quotient is: " << result << endl;
} // end try
catch ( DivideByZeroException &divideByZeroException )
{
    cout << "Exception occurred: "
            << divideByZeroException.what() << endl;
} // end catch

cout << "\nEnter two integers (end-of-file to end): ";
```



```
Enter two integers (end-of-file to end): 10 6
The quotient is: 1.66667

Enter two integers (end-of-file to end): 10 0
Exception occurred: attempted to divide by zero
```

Topics

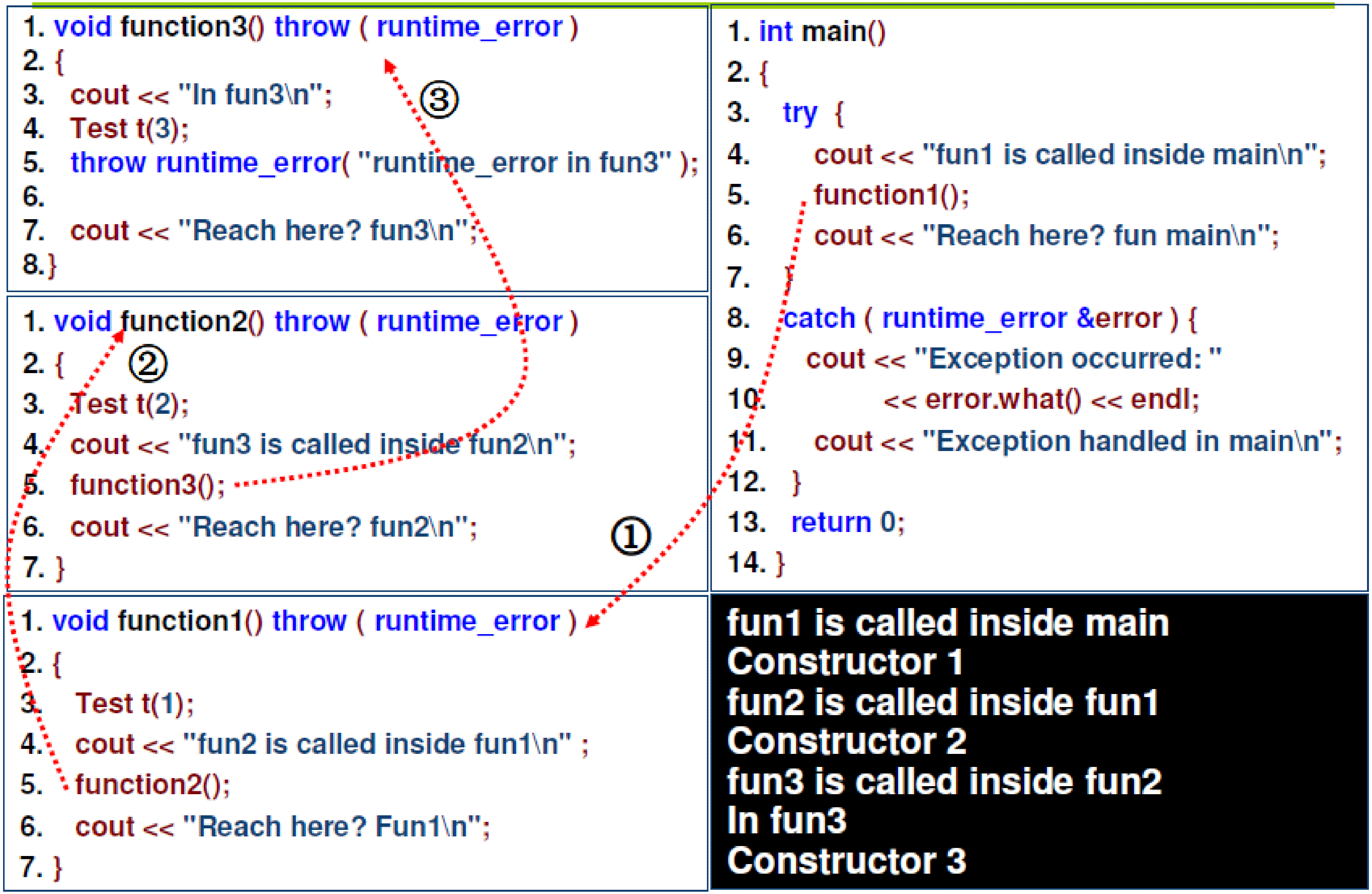
- ❑ 16.1 Introduction
- ❑ 16.2 Scenario A: Handle exception thrown by C++ standard lib
- ❑ 16.3 Scenario B: Define, throw and handle your own exception
- ❑ **16.4 Stack Unwinding**

16.4 Stack Unwinding

Stack Unwinding(栈展开机制)

- 1. 当某个函数(异常源)抛出异常, 将立即结束该函数的执行, 根据函数调用链回溯(可以是本函数)寻找可以catch该异常的Handler;
- 2. 如果找到了匹配的Handler, 则执行Stack Unwinding, 即依次释放从异常源Handler所在函数的所有局部对象;
- 3. 如果在main函数中仍没有找到匹配的Handler,则调用terminate函数(该函数缺省调用abort, 不执行栈展开), 结束程序.

16.4 Stack Unwinding



```
void function3() throw ( runtime_error )
{
   cout << "In fun3\n";
   Test t(3);
   throw runtime_error( "runtime_error in fun3" );

   cout << "Reach here? fun3\n";
}
```

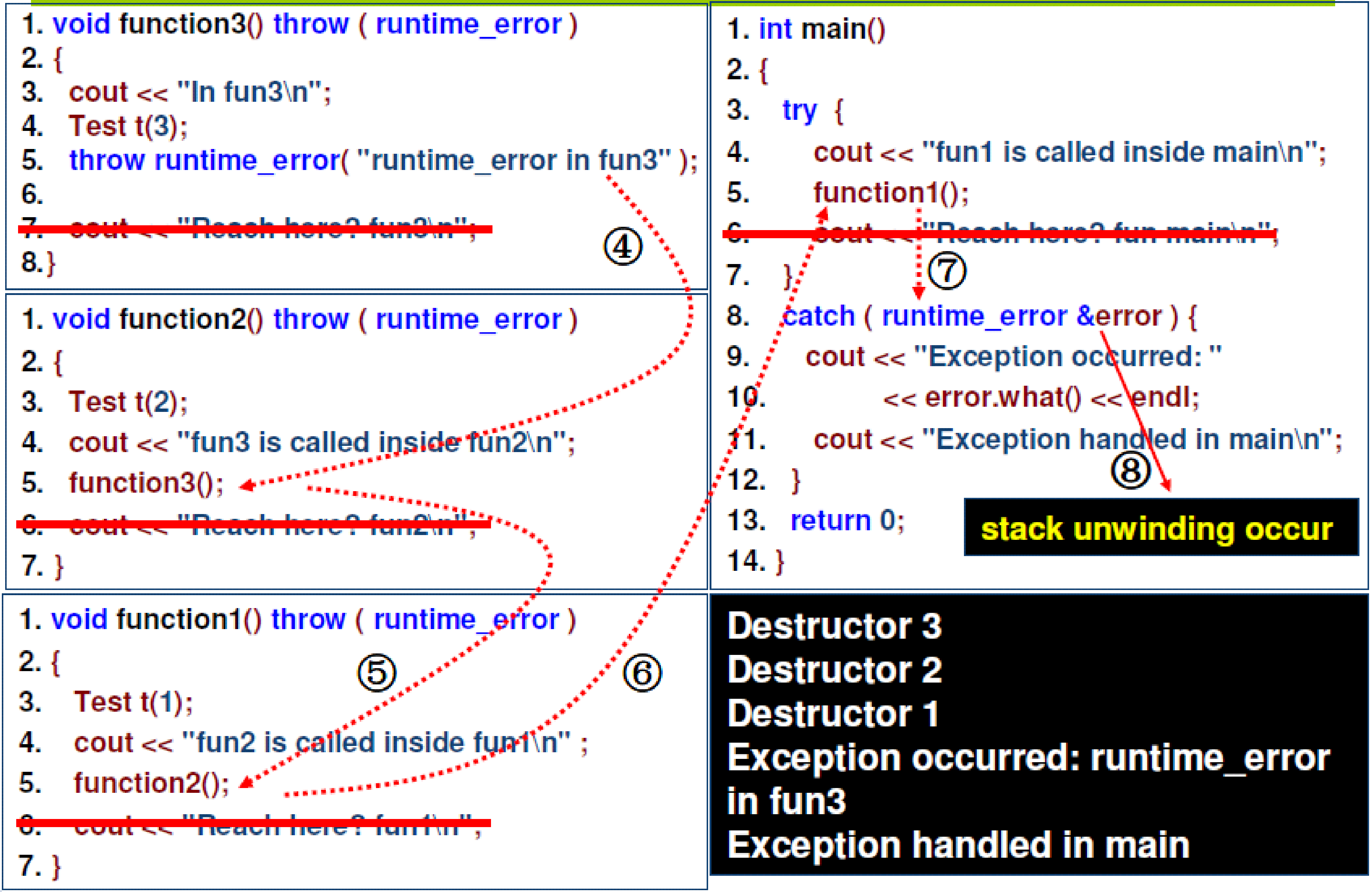
```
void function2() throw ( runtime_error )
{
   Test t(2);
   cout << "fun3 is called inside fun2\n";
   function3();
   cout << "Reach here? fun2\n";
}
```

```
void function1() throw ( runtime_error )
{
   Test t(1);
   cout << "fun2 is called inside fun1\n" ;
   function2();
   cout << "Reach here? Fun1\n";
}
```

```
int main()
{
  try  {
      cout << "fun1 is called inside main\n";
      function1();
      cout << "Reach here? fun main\n";
  }
  catch ( runtime_error &error ) {
     cout << "Exception occurred: "
               << error.what() << endl;
      cout << "Exception handled in main\n";
  }
  return 0;
}
```

```
fun1 is called inside main
Constructor 1
fun2 is called inside fun1
Constructor 2
fun3 is called inside fun2
In fun3
Constructor 3
```

16.4 Stack Unwinding



```
void function3() throw ( runtime_error )
{
  cout << "In fun3\n";
  Test t(3);
  throw runtime_error( "runtime_error in fun3" );

  ~~cout << "Reach here? fun3\n";~~
}
```

```
void function2() throw ( runtime_error )
{
  Test t(2);
  cout << "fun3 is called inside fun2\n";
  function3();
  ~~cout << "Reach here? fun2\n";~~
}
```

```
void function1() throw ( runtime_error )
{
  Test t(1);
  cout << "fun2 is called inside fun1\n" ;
  function2();
  ~~cout << "Reach here? fun1\n";~~
}
```

```
int main()
{
  try  {
      cout << "fun1 is called inside main\n";
      function1();
      ~~cout << "Reach here? fun main\n";~~
  }
  catch ( runtime_error &error ) {
     cout << "Exception occurred: "
              << error.what() << endl;
      cout << "Exception handled in main\n";
  }
  return 0;
}
```

stack unwinding occur

```
Destructor 3
Destructor 2
Destructor 1
Exception occurred: runtime_error
in fun3
Exception handled in main
```

16.4 Stack Unwinding

- □ As control passes from a throwexpression to a handler, destructors are invoked for all automatic objects constructed since the try block was entered. The automatic objects are destroyed in the reverse order of the completion of their construction.
- □ The process of calling destructors for automatic objects constructed on the path from a try block to a throw expression is called "*stack unwinding*".

16.4 Stack Unwinding

- 如果Exception Handler无法处理捕获的异常，可以re-throw重新抛出异常：

  throw;

- 根据栈展开机制，解读Fig 16.3

程序解读（P494）

Summary

- □异常的概念
- □try-throw-catch模块的语法和处理流程
- □栈展开过程（与构造和析构的关系）
- □new异常的处理

Homework

- 实验必选题目：

  16.23

- 实验任选题目：

- 作业题目：