Object Oriented Programming by C++

Exception Handling

Dealing with Runtime Errors

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Textbook & Copyright

- Textbook: http://python.cs.southern.edu/cppbook/progcpp.pdf
- Sample Codes: https://github.com/halterman/CppBook-SourceCode

Fundamentals of C++ Programming

DRAFT

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Preface

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The source code for all labeled listings is available at

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C++ Exception Handling

- C++'s `exception` handling infrastructure
  - allows programmers to cleanly ***separate the code*** that implements the ***focused algorithm*** from the code that deals with ***exceptional situations*** that the algorithm may face
  - is more modular and encourages the development of code that is ***cleaner and easier to maintain and debug***

- An `exception`
  - is an exceptional event that ***occurs during a program's execution***.
  - always is possible, but it ***should be a relatively rare*** event
  - almost always represents a problem, usually some sort of run-time error
    - example: **`v[i]`** access when '**`i`**' is out-of-range(= bounds)

Let's make some Errors

Listing 22.1: vectorboundscrash.cpp

```
#include <iostream>
#include <vector>

int main() {
    std::vector<double> nums { 1.0, 2.0, 3.0 };
    int input;
    std::cout << "Enter an index: ";
    std::cin >> input;
    std::cout << nums.at(input) << '\n';
}
```

```
Enter an index: 10
libc++abi.dylib: terminating with
uncaught exception of type
std::out_of_range: vector
```

- Program abnormally terminated

Exception Handling Statement

`try` and `catch`

- To ***intercept the problem at run time*** and prevent the program from terminating due to an error
  - we use a ***`try/catch` block***
  - which consists of two parts: a **`try`** block and a **`catch`** block

- To form a try/catch block we
  1. wrap the code that has the ***potential to throw an exception*** in a **`try`** block
  2. provide code to ***execute only in the event of an exception*** in a **`catch`** block
  3. the statements within a **`try`** block and statements within a **`catch`** block ***must appear within curly braces, even if only one statement*** appears in the section.

Enhanced Error Codes

Listing 22.2: vectorboundsexcept.cpp

```
#include <iostream>
#include <vector>

int main() {
    std::vector<double> nums { 1.0, 2.0, 3.0 };
    int input;
    std::cout << "Enter an index: ";
    std::cin >> input;
    try {
        std::cout << nums.at(input) << '\n';
    }
    catch (std::exception& e) {
        std::cout << e.what() << '\n';
    }
}
```

```
Enter an index: 10
vector
Program ended with exit code: 0
```

- Program normally terminated

Exception Handling Statement

`std::exception`

- ***Standard exception class***
- Base class for standard exceptions.
  - All objects thrown by components of the standard library are ***derived from this class***
  - Therefore, ***all standard exceptions can be caught by catching this type by reference***

Member functions

(constructor)	Construct exception (public member function)
operator=	Copy exception (public member function)
what (virtual)	Get string identifying exception (public member function)
(destructor) (virtual)	Destroy exception (public virtual member function)

Reference: http://www.cplusplus.com/reference/exception/exception/

Exception Handling Statement

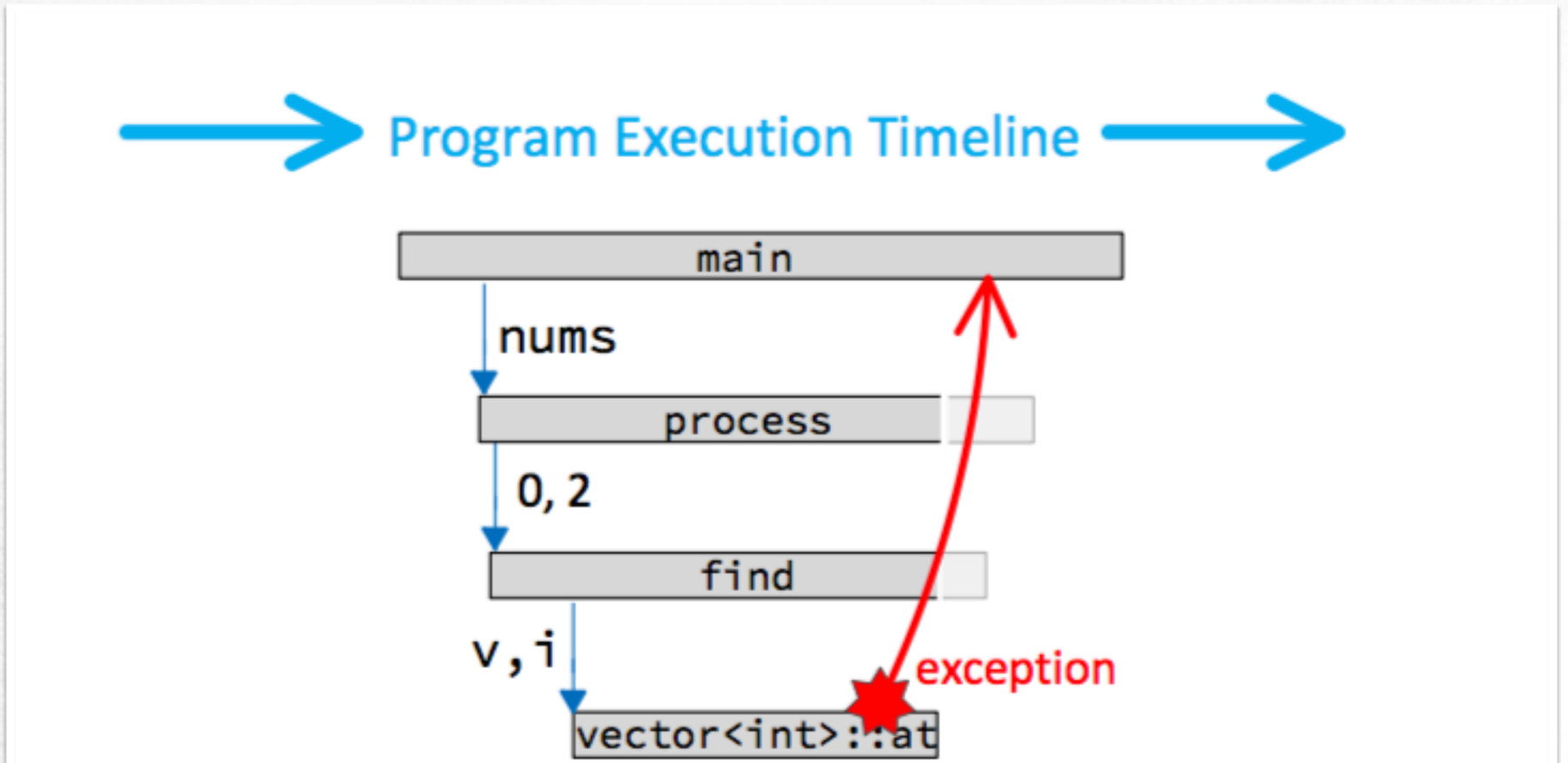
Code Example

```
#include <iostream>
#include <vector>

int main() {
    std::vector<double> nums { 1.0, 2.0, 3.0 };
    int input;
    while (true) {
        std::cout << "Enter an index: ";
        std::cin >> input;
        try {
            std::cout << nums.at(input) << '\n';
            break;  // Printed successfully, so break out of loop
        }
        catch (std::exception&) {
            std::cout << "Index is out of range.  Please try again.\n";
        }
    }
}
```

Finding Nearest `catch` Statement

- Listing 22.4 Case
  - Error in the function may be caught by the catch statement in the function
  - OR, the error traversed to the upper functions (which invoked the error causing function) ***until the first catch statement is encountered***



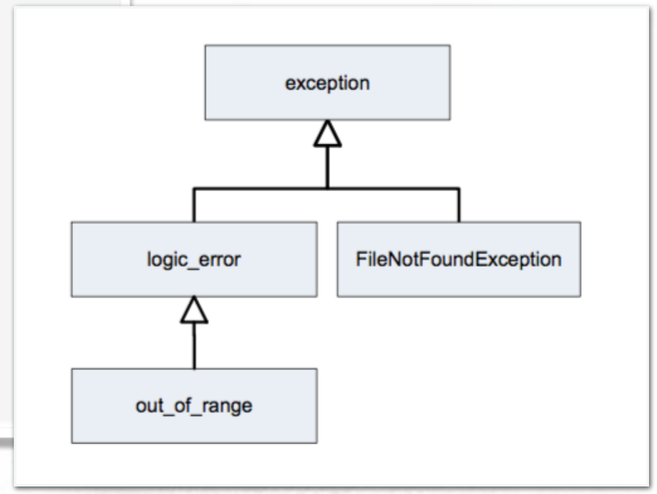
Programmer Defined Exception

Exception Class Inheritance

- ***The standard C++ library has a limited number of standard exceptions***
- ***Programmer can create our own custom exceptions*** for specialized error handling that our applications may require
- Programmer ***creates own constructor(), and override*** required functions

```
// Exception object to thrown when a client attempts to
// open a text file via a name that does correspond to a
// file in the current working directory.
class FileNotFoundException : public std::exception {
    std::string message;  // Identifies the exception and filename
  public:
    // Constructor establishes the exception object's message
    FileNotFoundException(const std::string& fname):
        message("File \"" + fname + "\" not found") {}

    // Reveal message to clients
    const char *what() const {
        return message.c_str();
    }
};
```

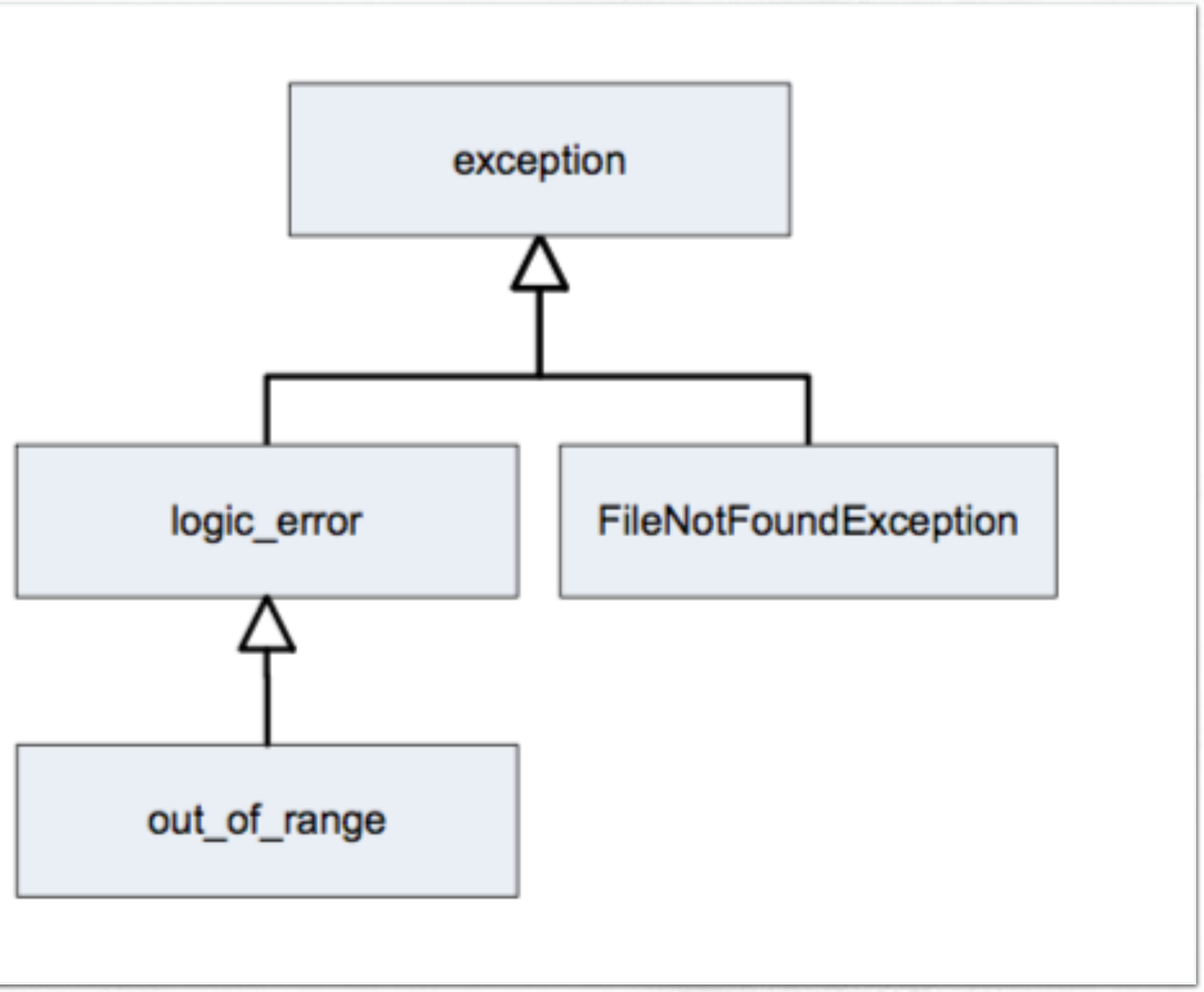


Programmer Defined Exception

Exception Class Inheritance

- The standard C++ library has a limited number of standard exceptions
- Programmer can create our own custom exceptions for specialized error handling that our applications may require
- Programmer creates own constructor(), and override required functions

```
// Exception object to thrown when a cl
// open a text file via a name that does
// file in the current working directory
class FileNotFoundException : public std
    std::string message;  // Identifies
  public:
    // Constructor establishes the excep
    FileNotFoundException(const std::str
        message("File \"" + fname + "\"
    // Reveal message to clients
    const char *what() const {
        return message.c_str();
    }
};
```



Creating Programmer Defined Exception

- `throw` Statement
  - Signals an erroneous condition and executes an error handler
  - In general, an exception is thrown by using the throw keyword from inside the try block, or explicit throwing operation
  - A throw expression accepts one parameter, which is passed as an argument to the exception handler
  - ***Multiple handlers (i.e., catch expressions) can be chained***; each one with a different parameter type. Only the handler whose argument type matches the type of the exception specified in the throw statement is executed
  - After an exception has been handled the program, ***execution resumes after the try-catch block, not after the throw statement!***

Programmer Defined Exception

Code Review (Listing 22.8) (1/2)

```
#include <iostream>
#include <fstream>
#include <vector>
#include <string>

// Exception object to thrown when a client attempts to
// open a text file via a name that does correspond to a
// file in the current working directory.
class FileNotFoundException : public std::exception {
    std::string message;  // Identifies the exception and filename
public:
    // Constructor establishes the exception object's message
    FileNotFoundException(const std::string& fname):
    message("File \"" + fname + "\" not found") {}

    // Reveal message to clients

//  ORIGINAL CODE (BELOW) Causes error and we modified:
//  const char *what() const {
    virtual const char* what() const throw () {
        return message.c_str();
    }
};
```

- Inherited from std:exception class

Programmer Defined Exception

Code Review (Listing 22.8) (2/2)

```
// Creates and returns a vector of integers from data stored
// in a text file.
// filename: the name of the text file containing the data
// Returns a vector containing the data in the file, if possible
std::vector<int> load_vector(const std::string& filename) {
    std::ifstream fin(filename);      // Open the text file for reading
    if (fin.good()) {                 // Did the file open successfully?
        std::vector<int> result;      // Initially empty vector
        int n;
        fin >> n;                     // Size of data set
        for (int i = 0; i < n; i++ ) {
            int value;
            fin >> value;             // Read in a data value
            result.push_back(value); // Append it to the vector
        }
        return result;                // Return the populated vector
    }
    else   // Could not open the text file
        throw FileNotFoundException(filename);

}

int main() {
    try {
        std::vector<int> numbers = load_vector("values.data");
        for (int value : numbers)
            std::cout << value << ' ';
        std::cout << '\n';
    }
    catch (std::exception& e) {
        std::cout << e.what() << '\n';
    }
}
```

```
File "values.data" not found
Program ended with exit code: 0
```

Catching Multiple Exceptions

- Multiple catch Statement after try Statement can solve problems
  - As we already saw in slide 13
  - ***only the handler whose argument type matches*** the type of the exception specified in the throw statement ***is executed***

Code Example (Listing 22.10) (main() only)

```
int main() {
    try {
        std::vector<int> numbers = load_vector("1.dat");
        for (int value : numbers)
            std::cout << value << ' ';
        std::cout << '\n';
    }
    catch (std::out_of_range& e) {
        std::cout << "Error: vector bounds exceeded\n";
        std::cout << e.what() << '\n';
    }
    catch (FileNotFoundException& e) {
        std::cout << "Error: cannot open file\n";
        std::cout << e.what() << '\n';
    }
}
```

- Protection from possible bound error
- Same with Listing 22.8

Exception Re-trhrowing

- An exception handler within a catch block may take a few steps to handle the exception and then ***re-throw the exception or throw a completely different exception***.

Code Example

```
#include <iostream>
#include <fstream>
#include <vector>

void filter(std::vector<int>& v, int i) {
    v.at(i)++;
}

void compute(std::vector<int>& a) {
    for (int i = 0; i < 6; i++) {
        try {
            filter(a, i);
        }
        catch (std::exception& ex) {
            std::cout << "*********************************\n";
            std::cout << "* For loop terminated prematurely\n";
            std::cout << "* when i = " << i << '\n';
            std::cout << "*********************************\n";
            throw ex;  // Rethrow the same exception
        }
    }
}

int main() {
    std::vector<int> list { 10, 20, 30, 40, 50 };
    try {
        compute(list);
    }
    catch (std::exception& e) {
        std::cout << "Caught an exception: " << e.what() << '\n';
    }
    std::cout << "Program finished\n";
}
```

- Exception caused when ‘i’ is ‘5’
- First catcher

```
*********************************
* For loop terminated prematurely
* when i = 5
*********************************
Caught an exception: std::exception
Program finished
Program ended with exit code: 0
```

- Second catcher

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