COMP2012H

Exception Handling

Terminology

- **Exceptions** are run-time anomalies that a program may detect
  - division by 0,
  - access to an array outside of its bounds,
  - exhaustion of the heap memory.
- An exception is an unusual event, and may require special processing
- The special processing required after detection of an exception is called **exception handling**
- The exception handling code unit is called an **exception handler**

Introduction to Exception Handling

- Traditional approaches in case of exception:
  - Terminate the program: **`exit(), abort()`**
  - Return special values to indicate errors in a function
  - Set global error bits and return normally (leaving the system in an illegal state)
- Error detection and handling code is tedious to write; it clutters the program and is error-prone
- The C++ language provides built-in features to raise and handle exceptions:
  - Separate error-handling code from ordinary code
  - Exception propagation allows a high level of reuse of exception handling code
  - Release local resources automatically

An Example

```
#include <iostream>
using namespace std;

int main () {
   try {
     throw 20;   // throw an exception
   } catch (int e) {
     cout << "Exception No. " << e << endl;
   }
   return 0;
}
```

General Form

```
try {
   -- code that is expected to raise an
   exception
}
// Each catches one type of exception
catch (type1 var1) {                  // var is optional
   -- handler code
}
...
catch (type2 var2) {
   -- handler code
}
```

`try`

- Put statements and function calls that may generate exceptions in a `try` block
- Each try block is associated with a sequence of handlers that follow immediately
- `try` blocks can be *nested*

```
try {
  try {
   f();   // f() may throw an exception
  } catch (int e) {
   cout << "Exception No. " << e << endl;
  }
} catch(double) { cout << "Caught double." <<
  endl; }
```

throw

- An exception is raised using a **throw expression,** composed of `throw` followed by an object whose type is that of the exception thrown
- Any object (built-in or user-defined) can be thrown

```
class to_be_thrown {};
...
throw to_be_thrown;   // error, not an object
throw to_be_thrown(); // correct
throw 2.5;            // correct, double
```

`catch`: The Handler

- `catch` is the name of all **handlers**
  - must immediately follow the try block
  - the formal parameter of each handler must be *unique*
  - <u>no automatic type conversion</u>
- The formal parameter does <u>not</u> have to be a variable
  - Can be simply a type name to distinguish its handler from others
  - A variable transfers information to the handler

`catch`: The Handler

- The formal parameter can be an ellipsis, in which case it handles all exceptions not yet handled

```
catch (...) {   // catches everything
    -- handler code
}
```

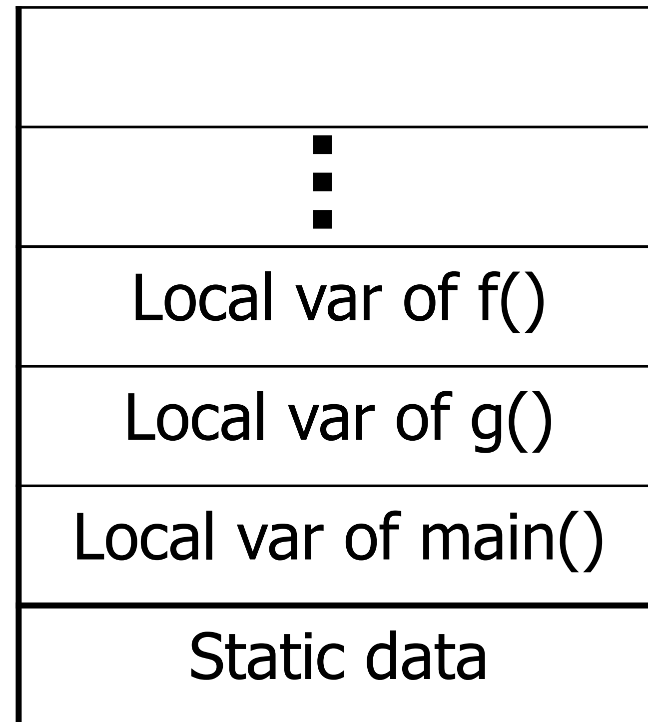
- After a handler completes, control flows to the first statement after the last handler in the sequence
- When no exception occurs, all handlers are neglected (no performance loss)

Propagation/Stack Unwinding

- Exceptions CANNOT be ignored
- If not caught by handlers right after `try` block, exception moves to next-higher level and may be caught there:
  - The next level of try block (if nested)
  - Try block surrounding the function call in which exception occurs
  - If no handler at any level catches the exception, `terminate()` will be called and program will terminate
- Passing an exception while searching for a handler can cause abnormal exit from a function while in middle of executing it (i.e., without any return value)
  - The stack frame corresponding to the exited function's scope is popped – this is called **stack unwinding**
  - So the lifetime of local objects in the exited functions ends
  - C++ still guarantees correct destructors are called

An Example

```
void f() {
  Person p;
  throw 20;
}
void g() {Person g; f();}
void main(){
  try {
    g();
  } catch(int) {
    cout<<"error"<<endl;
  }
}
```



Snapshot of Memory Stack

Release Your Own Resource

- Stack unwinding does not automatically delete pointers or close file handles. These should be handled locally.

```
void func() {
  resource res; res.lock();
  try {
   // use resource
   // some action throws an exception
  } catch (...) {
   res.release();
   throw; // re-throw the exception
  }
  res.release(); // skipped if exception thrown
}
```

Standard Exceptions

- All standard exception classes derive ultimately from the class **exception**, defined in the header **<exception>**.
- **logic_error** and **runtime_error** are derived from **exception** and are defined in **<stdexcept>**
- A handler for base class objects can also catch derived class objects
- Define your own error from standard exception classes

```
class DivideByZeroError : public runtime_error {
public:
   DivideByZeroError(const string& msg = "")
     : runtime_error(msg) {}
};
```

An Example

```
#include <stdexcept>
#include <iostream>
#include "myerror.hpp"
using namespace std;

int divide_int(int numer, int denom) {
   if (denom == 0) throw DivideByZeroError("divide_int");
   return numer/denom;
}
int main() {
   try {
     cout << divide_int(1, 0) << endl;
   } catch (runtime_error &e) {  // pass by ref
      cout << "Error caught in " << e.what() << endl;
   }
   return 0;
}
```

Catch bad_alloc

```
#include <stdexcept>
#include <iostream>
using namespace std;

int main() {
   int* p[9999];
   try {
     for (int i = 0; i < 9999; i++) {
       p[i] = new int[99999999];
     }
   } catch(bad_alloc) {   // don't bother with the thrown object
       cout << "Problem in getting memory" << endl;
   }
   return 0;
}
```

Exception Specification

When declaring functions…

- `void some_function() throw ();`
  - Promises that the function will not throw any exception

- ```
  void some_function() throw(DivideByZero,
                              OtherException);
  ```
  - Promises that the function may only throw the exceptions **`DivideByZero`** and **`OtherException`**

- `void some_function();`
  - No promises – any type of exception might be thrown from this function
  ```