



Module 36

Partha Pratim
Das

Objective &
Outline

Exception
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Exception Stages

Exceptions in
C

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Non-Local goto
Signals
Shortcomings

Summary

Module 36: Programming C++

Exceptions (Error handling in C): Part 1

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Module Objectives

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Summary

- Understand the Error handling in C



Module Outline

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- Exception Fundamentals
 - Types of Exceptions
 - Exception Stages
- Exceptions in C
 - C Language Features
 - Return value & parameters
 - Local goto
 - C Standard Library Support
 - Global variables
 - Abnormal termination
 - Conditional termination
 - Non-local goto
 - Signal
 - Shortcomings
- Exceptions in C++
 - Exception Scope (try)
 - Exception Arguments (catch)
 - Exception Matching
 - Exception Raise (throw)
 - Advantages



What are Exceptions?

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Summary

- Conditions that arise
 - Infrequently and Unexpectedly
 - Generally betray a Program Error
 - Require a considered Programmatic Response
 - Run-time Anomalies – yes, but not necessarily
- Leading to
 - Crippling the Program
 - May pull the entire System down
 - Defensive Technique
 - Crashing Exceptions verses Tangled Design and Code



Exception Causes

- Unexpected Systems State
 - Exhaustion of Resources
 - Low Free Store Memory
 - Low Disk Space
 - Pushing to a Full Stack
- External Events
 - \hat{C}
 - Socket Event
- Logical Errors
 - Pop from an Empty Stack
 - Resource Errors – like Memory Read/Write
- Run time Errors
 - Arithmetic Overflow / Underflow
 - Out of Range
- Undefined Operation
 - Division by Zero



Exception Handling?

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- Exception Handling is a mechanism that separates the detection and handling of circumstantial **Exceptional Flow** from **Normal Flow**
- Current state saved in a pre-defined location
- Execution switched to a pre-defined handler

Exceptions are C++'s means of separating error reporting from error handling
– Bjarne Stroustrup



Types of Exceptions

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● Asynchronous Exceptions:

- Exceptions that come Unexpectedly
- Example - an Interrupt in a Program
- Takes control away from the Executing Thread context to a context that is different from that which caused the exception

● Synchronous Exceptions:

- Planned Exceptions
- Handled in an organized manner
- The most common type of Synchronous Exception is implemented as a `throw`



Exception Stages

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Summary

1 Error Incidence

- Synchronous (S/W) Logical Error
- Asynchronous (H/W) Interrupt (S/W Interrupt)

2 Create Object & Raise Exception

- An Exception Object can be of any Complete Type
- An int to a full blown C++ class object

3 Detect Exception

- Polling Software Tests
- Notification Control (Stack) Adjustments

4 Handle Exception

- Ignore: hope someone else handles it, that is, Do Not Catch
- Act: but allow others to handle it afterwards, that is, Catch, Handle and Re-Throw
- Own: take complete ownership, that is, Catch and Handle

5 Recover from Exception

- Continue Execution: If handled inside the program
- Abort Execution: If handled outside the program



Exception Stages

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Summary

```
int f() {
    int error;
    /* ... */
    if (error) /* Stage 1: error occurred */
        return -1; /* Stage 2: generate exception object */
    /* ... */
}

int main(void) {
    if (f() != 0) /* Stage 3: detect exception */
    {
        /* Stage 4: handle exception */
    }
    /* Stage 5: recover */
}
```



Support for Exceptions in C

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Return Value & Parameters

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Summary

- Function Return Value Mechanism
 - Created by the Callee as Temporary Objects
 - Passed onto the Caller
 - Caller checks for Error Conditions
 - Return Values can be ignored and lost
 - Return Values are temporary
- Function (output) Parameter Mechanism
 - Outbound Parameters, bound to arguments, offer multiple logical Return Values



Example: Return Value & Parameters

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Summary

```
int Push(int i) {
    if (top_ == size-1) // Incidence
        return 0; // Raise
    else
        stack_[++top_] = i;

    return 1;
}

int main() {
    int x;
    // ...
    if (!Push(x)) // Detect {
        // Handling
    }
    // Recovery
}
```



Local goto

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Summary

- Local goto Mechanism
 - (At Source) Escapes: Gets Control out of a Deep Nested Loop
 - (At Destination) Refactors: Actions from Multiple Points of Error Inception
- A group of C Features
 - goto Label;
 - break; & continue;
 - default switch case



Example: Local goto

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Summary

```
_PHNDLR _cdecl signal(int signum, _PHNDLR sigact)
{ // Lifted from VC98\CRT\SRC\WINSIG.C
    ...    /* Check for sigact support */
           if ( (sigact == ...) ) goto sigreterror;

           /* Not exceptions in the host OS. */
           if ( (signum == ...) { ... goto sigreterror; }
    else { ... goto sigretok; }

           /* Exceptions in the host OS. */
           if ( (signum ...) ) goto sigreterror;

    ...
sigretok:
    return(oldsigact);

sigreterror:
    errno = EINVAL;
    return(SIG_ERR);
}
```



Example: Local goto

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Example: Local goto

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        /* Exceptions in the host OS. */
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Global Variables

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Summary

- GV Mechanism
 - Use a designated Global Error Variable
 - Set it on Error
 - Poll / Check it for Detection
- Standard Library GV Mechanism
 - `<errno.h>` / `<cerrno>`



Example: Global Variables

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Summary

```
#include <errno.h>
#include <math.h>
#include <stdio.h>

int main() {
    double x, y, result;
    /*... somehow set 'x' and 'y' ...*/
    errno = 0;

    result = pow (x, y);

    if (errno == EDOM)
        printf("Domain error on x/y pair \n");

    else if (errno == ERANGE)
        printf("range error in result \n");

    else
        printf("x to the y = %d \n", (int) result);

    return 0;
}
```



Abnormal Termination

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Summary

- Program Halting Functions provided by
 - `<stdlib.h>` / `<cstdlib>`
- `abort()`
 - Catastrophic Program Failure
- `exit()`
 - Code Clean up via `atexit()` Registrations
- `atexit()`
 - Handlers called in reverse order of their Registrations



Example: Abnormal Termination

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Summary

```
#include<stdio.h>
#include<stdlib.h>
static void atexit_handler_1(void) {
    printf("within 'atexit_handler_1' \n");
}

static void atexit_handler_2(void) {
    printf("within 'atexit_handler_2' \n");
}

int main(){
    atexit(atexit_handler_1);
    atexit(atexit_handler_2);
    exit(EXIT_SUCCESS);

    printf("This line should never appear \n");

    return 0;
}
/* On Execution Output: within 'atexit_handler_2'
                        within 'atexit_handler_1'
   and returns a success code to calling environment */
```



Conditional Termination

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Summary

- Diagnostic ASSERT macro defined in
 - `<assert.h>` / `<cassert>`
- Assertions valid when `NDEBUG` macro is not defined (debug build is done)
- Assert calls internal function, reports the source file details and then Terminates



Example: Conditional Termination

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Summary

```
/* Debug version */
// #define NDEBUG
#include <cassert>
#include <cstdlib>
#include <cstdio>
using namespace std;

int main() {
    int i = 0;
    assert(++i == 0); // Assert 0 here

    printf(" i is %d \n", i);

    return 0;
}

/* When run - Asserts */

void _assert(int test, char const * test_image,
             char const * file, int line) {

    if (!test){
        printf("assertion failed: %s , file %s , line %d\n",
              test_image, file, line);
        abort();
    }
}
```



Example: Conditional Termination

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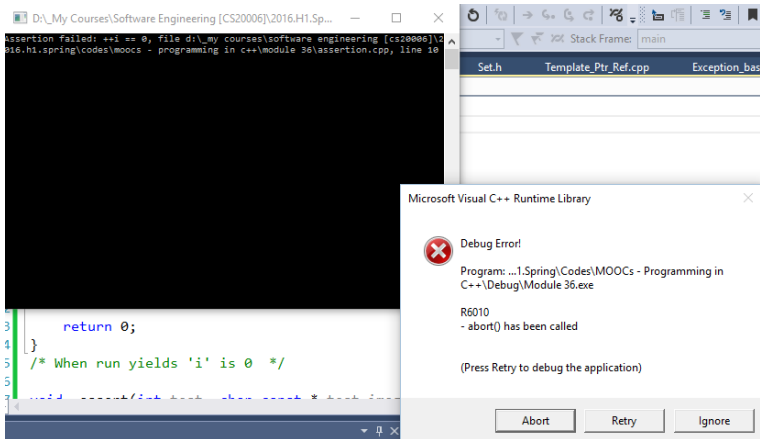
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Example: Conditional Termination

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Summary

```
/* Release version */
#define NDEBUG
#include <cassert>
#include <cstdlib>
#include <cstdio>
using namespace std;

int main(){
    int i = 0;
    assert(++i == 0); // Assert 0 here

    printf(" i is %d \n", i);

    return 0;
}
/* When run yields 'i' is 0 */

void _assert(int test, char const * test_image,
             char const * file, int line) {

    if (!test){
        printf("assertion failed: %s , file %s , line %d\n",
              test_image, file, line);
        abort();
    }
}
```



Non-Local goto

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Summary

- `setjmp()` and `longjmp()` functions provided in `<setjmp.h>` Header along with collateral type `jmp_buf`
- `setjmp(jmp_buf)`
 - Sets the Jump point filling up the `jmp_buf` object with the current program context
- `longjmp(jmp_buf, int)`
 - Effects a Jump to the context of the `jmp_buf` object
 - Control return to `setjmp` call last called on `jmp_buf`



Example: Non-Local goto: The Dynamics

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Summary

Caller

```
void f() {  
    A a;  
    if (setjmp(jbuf) == 0)  
    {  
        B b;  
        g();  
        h();  
    }  
    else {  
        cout << ex.what();  
    }  
    return ;  
}
```

Callee

```
jmp_buf jbuf ;  
  
void g(){  
    A a;  
    UsrExcp ex ("From g()");  
  
    longjmp(jbuf, 1);  
  
    return ;  
}
```



Example: Non-Local goto

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```
void f() {  
    A a;  
    if (setjmp(jbuf) == 0)  
    {  
        B b;  
        g();  
        h();  
    }  
    else {  
        cout <<  
        ex.what();  
    }  
    return;  
}  
  
jmp_buf jbuf;  
  
void g()  
{  
    A a;  
    UsrExcp ex("From g()");  
  
    longjmp(jbuf, 1);  
  
    return;  
}
```

- g() called



Example: Non-Local goto

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```
void f() {  
    A a;  
    if (setjmp(jbuf) == 0)  
    {  
        B b;  
        g();  
        h();  
    }  
    else {  
        cout <<  
        ex.what();  
    }  
    return;  
}  
  
jmp_buf jbuf;  
  
void g()  
{  
    A a;  
    UsrExcp ex("From g()");  
  
    longjmp(jbuf, 1);  
  
    return;  
}
```

- g() successfully returns



Example: Non-Local goto

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```
void f() {  
    A a;  
    if (setjmp(jbuf) == 0)  
    {  
        B b;  
        g();  
        h();  
    }  
    else {  
        cout <<  
        ex.what();  
    }  
    return;  
}  
  
jmp_buf jbuf;  
  
void g()  
{  
    A a;  
    UsrExcp ex("From g()");  
    longjmp(jbuf, 1);  
    return;  
}
```

- g() called and longjmp() executed
- setjmp() takes to exception part



Example: Non-Local goto

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```
#include<setjmp.h>
#include<stdio.h>
jmp_buf j ;
void raise_exception(){
    printf("Exception raised \n");
    longjmp(j, 1) ; /* Jump to exception handler */
    printf("This line should never appear \n");
}
int main(){
    if (setjmp == 0) {
        printf(" 'setjmp' is initializing j \n ");
        raise_exception();
        printf("This line should never appear \n");
    }
    else
        printf(" 'setjmp' was just jumped into \n")
        /* This code is the exception handler */
        return 0 ;
}
/* On execution : 'setjmp' is initializing j ,
   exception raised and 'setjmp' was just jumped into */
```



Signals

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Summary

- Header `<signal.h>`
- `raise()`
 - Sends a signal to the executing program
- `signal()`
 - Registers interrupt signal handler
 - Returns the previous handler associated with the given signal
- Converts h/w interrupts to s/w interrupts



Example: Signals

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```
// Use signal to attach a signal
// handler to the abort routine
#include <stdio.h>
#include <stdlib.h>
#include <signal.h>
#include <tchar.h>
void SignalHandler(int signal) {
    printf("Application aborting...\n");
}

int main() {
    typedef void (*SignalHandlerPointer)(int);

    SignalHandlerPointer previousHandler;

    previousHandler = signal(SIGABRT, SignalHandler);

    abort();

    return 0;
}
```



Shortcomings

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Summary

- **Destructor-ignorant:**
 - Cannot release Local Objects i.e. Resources Leak
- **Obtrusive:**
 - Interrogating RV or GV results in Code Clutter
- **Inflexible:**
 - Spoils Normal Function Semantics
- **Non-native:**
 - Require Library Support outside Core Language



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Summary

- Introduced the concept of exceptions
- Discussed exception (error) handling in C
- Illustrated various language features and library support in C for handling errors
- Demonstrated with examples



Instructor and TAs

Module 36

Partha Pratim Das

Objective & Outline

Exception Fundamentals

Types of Exceptions
Exception Stages

Exceptions in C

C Language Features
RV & Params
Local goto
C Standard
Library Support
Global Variables
Abnormal Termination
Conditional Termination
Non-Local goto
Signals
Shortcomings

Summary

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