

## Chapter 16: Exception Handling

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### Exceptions

- Exceptions are a simple concept, but a powerful one.
- So far, if our program has runtime problem (error), we have no way to handle or correct it.
  - Imagine if every program you ran immediately crashed upon a problem (e.g. the internet was not connect, a hard drive was removed, etc). Very hard to use a computer!
  - You may remember older programs that would crash and say “Program exited with code 47” (or some other code) without providing much detail.
    - \* These were unhandled exceptions, and the program crashing was the way to “fix” the problem by not allowing more problems to occur in a bad program state.
- In the programs we’ve written, you can imagine having issues in a number of ways:
  - A user could pass the wrong parameters to a function
  - Data files that need to be opened for reading or writing could not exist
  - ...just about anything you can imagine could go wrong, may go wrong

### BankAccount Exceptions

- Suppose we want to use the + operator to add two `BankAccounts` together.
- This only makes sense if the accounts are owned by the same person
- But what if the user tries to add two bank accounts together that belong to different people?

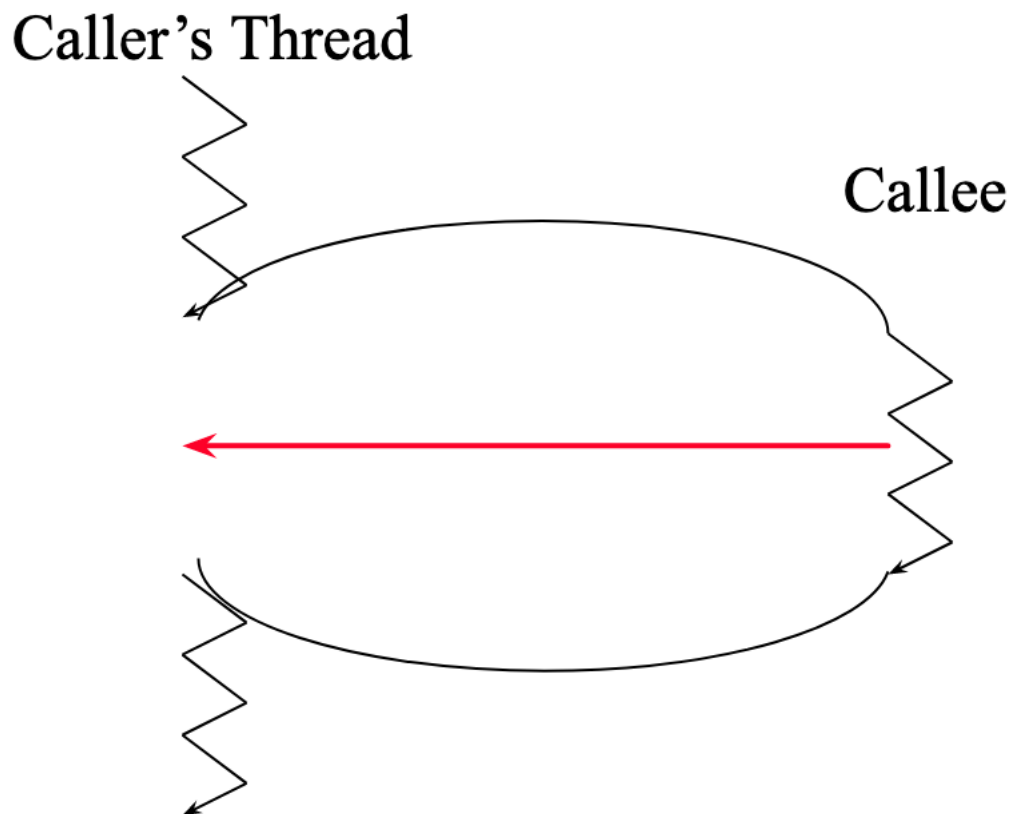
```
1 BankAccount operator+ (const BankAccount& b1, const BankAccount& b2){
2     BankAccount result;
3     if (b1.my_Name == b2.my_Name) {
4         result = BankAccount(b1.my_Name, b1.my_Balance + b2.my_Balance);
5     }
6     return result;
7 }
```

- If the user passes two bank accounts that match as arguments, this works great
- If the user passes two bank accounts that don’t match as arguments, this doesn’t work well
  - We return an uninitialized bank account, but is that the behavior we really want?
  - How can the user tell whether or not the operation (adding two bank accounts) succeeded?
    - \* What if both bank accounts were empty...?

- This is problematic, because it expects the user to be able to interpret a default-initialized bank account as an error
  - The function still returns a value when we really encountered an error - probably not the behavior we want
  - What if we could inform the user of an error in a different way, that didn't require a special interpretation of an otherwise "normal" execution during an error?
    - \* This is what exceptions are for!

### Caller-Callee Relationship revisited

- Remember our Caller-Callee relationships for functions:



**Figure 1:** Caller-callee relationship

- The red line indicates that we could return to the Caller function during the Callee's execution if we encounter an error
- An exception is an "alternate" return mechanism to designate an error

- The caller then must handle the exception some way, or the program will crash
- Sending an exception to the caller is called “throwing” an exception
- Receiving and handling the exception in the caller is called “catching” an exception
- So the Callee can throw an exception, and if the Caller doesn’t catch the exception, then the program crashes
  - The analogy is like playing catch with a ball, except if the ball is dropped, the program crashes.

### Throwing Exceptions

- To throw an exception, we’ll use the **throw** statement:

```
1 throw(std::logic_error("Always write a description of the problem as  
the argument to the logic_error constructor"))
```

- This is like a return statement, in the sense we “pass” a value back to the caller
- `std::logic_error` is a class
  - `#include <stdexcept>` to use it
  - We’ll eventually learn how to write our own exceptions, but for now, we can use the ones defined by the Standard Library

### Catching Exceptions

- The caller needs to **try** { } to execute some code that may produce an error and **catch** () { } any errors that occur
  - You can have as many **catch** statements as necessary (meaning you can put multiple, similar to multiple **else if** statements)

```
1 try {  
2     // execute code that could throw an exception inside of a "try" block  
3     some_function_that_may_throw_a_logic_error();  
4 } catch (std::logic_error e) {  
5     // catch the exception, and do some error recovery procedure.  
6     // In this case, we just print out the exception message  
7     cout << e.what() << endl; // e.what() will return the message  
    associated with the exception  
8 }
```

**Example: BankAccount with exceptions**

- This example shows how to throw and use exceptions to process potentially invalid data in a loop.
- To cause an exception to be thrown, do the following:
  1. *Create* an account
  2. *Deposit* or *Withdraw* and use a different name than the name you used when you created the account

**Example: ExceptionBankAccount.h**

```
1 //-----
2 // INTERFACE FILE: baccount.h
3 //
4 // Defines class BankAccount
5 //
6 //-----
7 // SAFEGUARDS AND INCLUDES
8 #ifndef BANKACCOUNT_H // Avoid redeclaring class BankAccount.
9 #define BANKACCOUNT_H // This code is compiled only once
10 #include <string> // for class string
11
12 namespace cs52 {
13
14 ///////////////////////////////////////////////////
15 // class BankAccount definition //
16 ///////////////////////////////////////////////////
17
18 class BankAccount {
19 public: // class member functions
20
21 //--constructors
22     BankAccount();
23
24     BankAccount(std::string initName, double initBalance);
25     // post: A BankAccount with two arguments when called like this:
26     //      BankAccount anAcct("Hall", 100.00);
27
28 //--modifiers
29
30     void deposit(double depositAmount);
31     // post: depositAmount is credited to this object's balance
```

```
32
33     void withdraw(double withdrawalAmount);
34     // post: withdrawalAmount is debited from this object's balance
35
36     //--accessors
37
38     double balance() const;
39     // post: return this account's current balance
40
41     std::string name() const;
42     // post return the account name
43
44     void setName( std::string initName );
45     // post updates the member variable my_name
46
47     // ADDED CODE BEGINS HERE
48     friend std::ostream& operator << ( std::ostream& outs, const
49         BankAccount& b );
50     friend std::istream& operator >> ( std::istream& ins, BankAccount&
51         b );
52     friend BankAccount operator + ( const BankAccount& left, const
53         BankAccount& right );
54     friend BankAccount operator - ( const BankAccount& left, const
55         BankAccount& right );
56     friend bool operator ==( const BankAccount& left, const BankAccount
57         & right );
58     friend bool operator < ( const BankAccount& left, const BankAccount
59         & right );
60     friend bool operator > ( const BankAccount& left, const BankAccount
61         & right );
62
63 private:
64     std::string my_name;    // Uniquely identify an object
65     double my_balance;    // Store the current balance (non-persistent)
66 };
67
68 }
```

### Example: ExceptionBankAccount.cpp

```
1  //-----
2  // IMPLEMENTATION FILE: baccount.cpp
3  //
4  // Implements 1. class BankAccount member functions
5  //
6  //-----
7  #include "ExceptionBankAccount.h" // allows for separate compilation
   if you want
8  #include <iostream>    // for ostream << and istream >>
9  #include <string>      // for class string
10 #include <stdexcept>   // supports Linux exception classes
11
12 using namespace std;
13
14 namespace cs52 {
15
16   //--constructors
17
18   BankAccount::BankAccount()
19   {
20     my_name = "?name?";
21     my_balance = 0.0;
22   }
23
24   BankAccount::BankAccount(string initName, double initBalance)
25   {
26     my_name = initName;
27     my_balance = initBalance;
28   }
29
30   //--modifiers
31
32   void BankAccount::deposit(double depositAmount)
33   {
34     my_balance = my_balance + depositAmount;
35   }
36
37   void BankAccount::withdraw(double withdrawalAmount)
38   {
39     my_balance = my_balance - withdrawalAmount;
40   }
41
```

```
42  //--accessors
43
44  double BankAccount::balance() const
45  {
46      return my_balance;
47  }
48
49  string BankAccount::name() const
50  {
51      return my_name;
52  }
53
54  void BankAccount::setName( string initName )
55  {
56      my_name = initName;
57  }
58
59
60  // NEW CODE STARTS HERE
61  std::ostream& operator << ( std::ostream& outs, const BankAccount& b )
62  {
63      outs << b.my_name << " " << b.my_balance << endl;
64      return( outs );
65  }
66  std::istream& operator >> ( std::istream& ins, BankAccount& b ) {
67      ins >> b.my_name >> b.my_balance;
68      return( ins );
69  }
70
71  BankAccount operator + ( const BankAccount& left, const BankAccount&
72      right ) {
73      BankAccount newB;
74      if (left.my_name == right.my_name) {
75          newB.deposit( left.my_balance );
76          newB.deposit( right.my_balance );
77      }
78      else {
79          cerr << "YIKES! These two accounts can't be added together
80              since the names differ!" << endl;
81          throw logic_error( "Bad account names" );
82      }
83      return( newB );
```

```
82 }
83
84 BankAccount operator - ( const BankAccount& left, const BankAccount&
    right ) {
85     BankAccount newB;
86     if (left.my_name == right.my_name) {
87         newB.deposit( left.my_balance );
88         newB.withdraw( right.my_balance );
89     }
90     else {
91         cerr << "YIKES! These two accounts can't be subtracted
            together since the names differ!" << endl;
92         throw logic_error( "Bad account names" );
93     }
94     return( newB );
95 }
96
97 bool operator ==( const BankAccount& left, const BankAccount& right ) {
98     return( (left.my_balance == right.my_balance) && (left.my_name ==
        right.my_name) );
99 }
100
101 bool operator < ( const BankAccount& left, const BankAccount& right ) {
102     return( left.my_balance < right.my_balance );
103 }
104
105 bool operator > ( const BankAccount& left, const BankAccount& right ) {
106     return( left.my_balance > right.my_balance );
107 }
108
109 }
```

### Example: ExceptionBanker.cpp

```
1 // This program demonstrates how to make use of existing objects.
2 // This program uses a BankAccount class with the interface described
3 // in class.
4
5 #include <iostream>                // for std::cout
6 #include <string>                  // for string class
7 #include "ExceptionBankAccount.h" // for BankAccount class
8 #include <stdexcept>              // supports Linux exceptions
```



```
9
10 using namespace std;                // supports cout
11 using namespace cs52;                // for BankAccount class
12
13 enum CHOICE { CREATE, DEPOSIT, WITHDRAW, PRINT, QUIT };
14
15 CHOICE menu();
16
17 int main( )
18 {
19     CHOICE choice;
20     BankAccount account, withdrawaccount, depositaccount;
21     string name;
22     double balance;
23
24     cout.setf( ios::fixed );
25     cout.setf( ios::showpoint );
26     cout.precision( 2 );
27
28     cout << endl << endl << "\t\tWelcome to the Bank of SMC!" << endl;
29     do {
30         choice = menu();
31         try {
32             switch (choice) {
33                 case CREATE:
34                     cout << "Please enter your name and opening bank balance: "
35                         ;
36                     cin >> name >> balance;
37                     account.setName(name);
38                     account.deposit(balance);
39                     break;
40                 case DEPOSIT:
41                     cout << "Please enter your name and amount to withdrawl: "
42                         ;
43                     cin >> name >> balance;
44                     depositaccount.setName(name);
45                     depositaccount.deposit(balance);
46                     account = account + depositaccount;
47                     break;
48                 case WITHDRAW:
49                     cout << "Please enter your name and amount to withdrawl: "
50                         ;
51                     cin >> name >> balance;
```

```
49         withdrawaccount.setName(name);
50         withdrawaccount.deposit(balance);
51         account = account - withdrawaccount;
52         break;
53     case PRINT:
54         cout << account;
55         break;
56     case QUIT:
57         break;
58     }
59 } catch (logic_error le) {
60     cout << "Caught logic_error" << endl;
61     cout << "Transaction failed to process" << endl;
62     cout << "Please try again!" << endl;
63 }
64
65 } while (choice != QUIT);
66
67 return 0;
68 }
69
70 CHOICE menu() {
71     CHOICE result;
72     char answer;
73     cout << "(C)reate (D)eposit (W)ithdrawal (P)rint (Q)uit ";
74     cin >> answer;
75     switch (answer) {
76     case 'C':
77     case 'c':
78         result = CREATE;
79         break;
80     case 'D':
81     case 'd':
82         result = DEPOSIT;
83         break;
84     case 'W':
85     case 'w':
86         result = WITHDRAW;
87         break;
88     case 'P':
89     case 'p':
90         result = PRINT;
91         break;
```

```
92     case 'Q':
93     case 'q':
94         result = QUIT;
95         break;
96     }
97     return( result );
98 }
```

- This is a good example because classes typically throw exceptions to indicate failure
- This is sense, the class is typically the callee and the user of the class is the caller

### Auto example

- Exceptions are good because they allow you to greatly simplify your error checking using a consistent system that handles all error checking in one place
- To illustrate this, let's consider the following example
- We'll imagine we have a `Car` class that can fail for a number of reasons, each of which is specific to a reasonable real-world circumstance a car may face

### Example: `auto_if.cpp`

```
1
2
3  WITH A C-MENTALITY AND NO EXCEPTION HANDLING....
4
5
6  ///  Supposing I Have The Class Auto
7  ///  I Am Going To Drive To Work...
8
9  Car c( "Honda", "Prelude" );
10 rv = c.openDoor();
11 if (rv == DOOR_LOCKED || rv == CAR_STOLEN || rv == WRONG_KEYS || rv ==
    WRONG_CAR ) {
12     // something bad happened...
13 }
14 else {
15     rv = c.insertKey();
16     if (rv == WRONG_KEYS || rv == KEY_UPSIDE_DOWN || rv == WRONG_CAR ) {
17         // something bad happened...
18     }
19     else {
```

```
20     rv = c.turnKey();
21     if (rv == DEAD_BATTERY || rv == NO_GAS || rv ==
22         ASTEROID_HITS_ENGINE || rv == SADDAM_IN_ENGINE) {
23         // something bad happened...
24     }
25     else {
26         rv = c.intoReverse();
27         if (rv == CLUTCH_DIED || rv == GEAR_FAILED || rv == FLAT_TIRE
28             || rv == NO_GAS || rv == PARKING_BRAKE_UP) {
29             // something bad happened...
30         }
31     }
32     else {
33         rv = c.drive();
34         if (rv == CLUTCH_DIED || rv == GEAR_FAILED || rv == NO_GAS
35             || rv == NUCLEAR_WAR) {
36             // something bad happened...
37         }
38     }
39     else {
40         rv = c.intoFirst();
41         if (rv == CLUTCH_DIED || rv == GEAR_FAILED || rv == NO_GAS ||
42             rv == SPACE_SHUTTLE_DEBRIS_HITS_WINDSHIELD) {
43             // something bad happened...
44         }
45     }
46     else {
47         // Isn't this approach ridiculous???
48         // I've literally spent so much time checking for errors,
49         // that I can't figure
50         // out what my code was actually supposed to do...
51     }
52 }
53
54
55
56
57
```

VERSUS

```
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```

```
58 Car c( "Honda", "Prelude" );
59 try {
60     c.openDoor();
61     c.insertKey();
62     c.turnKey();
63     c.intoReverse();
64     c.drive();
65     c.intoFirst();
66 } catch( OutOfGasError ooge ) {
67     // something bad happened...
68 } catch( WrongKeysError wke ) {
69     // something bad happened...
70 } catch( ClutchDiedError cde ) {
71     // something bad happened...
72 } catch( GearFailedError gfe ) {
73     // something bad happened...
74 } catch( FlatTireError fte ) {
75     // something bad happened...
76 }
```

### Example: auto\_exception.cpp

- The above is rather hard to read, hard to maintain, and hard to expand
- Consider the following similar approach using exceptions

```
1
2
3 WITH A C-MENTALITY AND NO EXCEPTION HANDLING....
4
5
6 ///  Supposing I Have The Class Auto
7 ///  I Am Going To Drive To Work...
8
9 Car c( "Honda", "Prelude" );
10 rv = c.openDoor();
11 if (rv == DOOR_LOCKED || rv == CAR_STOLEN || rv == WRONG_KEYS || rv ==
    WRONG_CAR ) {
12     // something bad happened...
13 }
14 else {
15     rv = c.insertKey();
16     if (rv == WRONG_KEYS || rv == KEY_UPSIDE_DOWN || rv == WRONG_CAR ) {
```

```
17     // something bad happened...
18 }
19 else {
20     rv = c.turnKey();
21     if (rv == DEAD_BATTERY || rv == NO_GAS || rv ==
22         ASTEROID_HITS_ENGINE || rv == SADDAM_IN_ENGINE) {
23         // something bad happened...
24     }
25     else {
26         rv = c.intoReverse();
27         if (rv == CLUTCH_DIED || rv == GEAR_FAILED || rv == FLAT_TIRE
28             || rv == NO_GAS || rv == PARKING_BRAKE_UP) {
29             // something bad happened...
30         }
31         else {
32             rv = c.drive();
33             if (rv == CLUTCH_DIED || rv == GEAR_FAILED || rv == NO_GAS
34                 || rv == NUCLEAR_WAR) {
35                 // something bad happened...
36             }
37             else {
38                 rv = c.intoFirst();
39                 if (rv == CLUTCH_DIED || rv == GEAR_FAILED || rv == NO_GAS ||
40                     rv == SPACE_SHUTTLE_DEBRIS_HITS_WINDSHIELD) {
41                     // something bad happened...
42                 }
43             }
44         }
45     }
46 }
47 }
48 }
49
50
51
52 VERSUS
53
54
```

```
55  ///  Supposing I Have The Class Auto
56  ///  I Am Going To Drive To Work...
57
58  Car c( "Honda", "Prelude" );
59  try {
60      c.openDoor();
61      c.insertKey();
62      c.turnKey();
63      c.intoReverse();
64      c.drive();
65      c.intoFirst();
66  } catch( OutOfGasError ooge ) {
67      // something bad happened...
68  } catch( WrongKeysError wke ) {
69      // something bad happened...
70  } catch( ClutchDiedError cde ) {
71      // something bad happened...
72  } catch( GearFailedError gfe ) {
73      // something bad happened...
74  } catch( FlatTireError fte ) {
75      // something bad happened...
76  }
```