Assertion

C++ Object Oriented Programming

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Contents

- Errors
- Error handling in procedural programming language
- Error messages vs. error codes
- Modifying interface to help the client
- Assertions - make your code prove that it is correct
- Types of assertions
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  - Postconditions
  - Class invariants
- Conditional compilation and assertions

What is an Error?

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  Most of the above errors occur when the running program and environment do not meet the **program specification**.
- The interface between client codes and server codes is described in the specification. When either side of codes does not follow the specification, some errors occur.

Errors in Procedural Programming

- **Functions being called** (server codes, utility functions, supporting functions, lower level functions)

```
int server() {
    error occurring position 1; // first type of error
    error occurring position 2; // second type of error
    …
}
```

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- Proper error handling depends on the knowledge of both
  - exactly what type of error occurs and
  - in which environment the server function is invoked

Server Handles Errors

```
const int kStackSize = 3;
const int kEmptyStack = -1;
class StackT {
public:
    StackT();




};
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```
const int kStackSize = 3;
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class StackT {
public:
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private:
    int fArray[kStackSize];
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};
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const int kStackSize = 3;
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public:
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    void Push(int element);
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StackT::StackT():fTop(kEmptyStack) {
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StackT::StackT():fTop(kEmptyStack) {
}
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void StackT::Push(int element) {
    if (fTop+1 == kStackSize)
        cout << "Error! Stack full. ("
             << element << ")\n";
    else
        fArray[++fTop] = element;
}
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}
```

```
int StackT::Pop() {
    if (fTop == kEmptyStack) {
        cout << "Error! Stack empty.\n";
        return kEmptyStack; // meaningless
    }
    else
        return fArray[fTop--];
}
```

Server Handles Errors (cont'd)

```
void main() {
    StackT stack;
    stack.Push(1); stack.Push(2); stack.Push(3); stack.Push(4);
```

Server Handles Errors (cont'd)

```
void main() {
    StackT stack;
    stack.Push(1); stack.Push(2); stack.Push(3); stack.Push(4);
    cout << stack.Pop() << '\n'
         << stack.Pop() << '\n'
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}
```

Output:

```
Error! Stack full. (4)
3
2
1
Error! Stack empty.
-1
```

Server Handles Errors (cont'd)

```
void main() {
    StackT stack;
    stack.Push(1); stack.Push(2); stack.Push(3); stack.Push(4);
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Problems:

1. Server does not know the calling environment.

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void main() {
    StackT stack;
    stack.Push(1); stack.Push(2); stack.Push(3); stack.Push(4);
    cout << stack.Pop() << '\n'
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```

Output:

```
Error! Stack full. (4)
3
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Error! Stack empty.
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```

Problems:

1. Server does not know the calling environment.
2. Server often handles errors uniformly and somewhat blindly.

Client Handles Errors

```
bool StackT::Push(int element) {
    if (fTop+1 == kStackSize)
        return true;
    else {
        fArray[++fTop] = element;
        return false;
    }
}
```

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bool StackT::Push(int element) {
    if (fTop+1 == kStackSize)
        return true;
    else {
        fArray[++fTop] = element;
        return false;
    }
}
```

```
int StackT::Pop(bool &error) {
    if (fTop == kEmptyStack) {
        error = true;  // type 1
        return kEmptyStack; // meaningless
    }
    else if (bLocked) {
        error = true;  // type 2
        return kEmptyStack; // meaningless
    }
    else {
        error = false;
        return fArray[fTop--];
    }
}
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bool StackT::Push(int element) {
    if (fTop+1 == kStackSize)
        return true;
    else {
        fArray[++fTop] = element;
        return false;
    }
}
```

```
void main() {
    StackT stack;
    bool error;
    int value;

    error = stack.Push(1);
    if (error)
        cout << "1 is not
     pushed in\n";
```

```
int StackT::Pop(bool &error) {
    if (fTop == kEmptyStack) {
        error = true;  // type 1
        return kEmptyStack; // meaningless
    }
    else if (bLocked) {
        error = true;  // type 2
        return kEmptyStack; // meaningless
    }
    else {
        error = false;
        return fArray[fTop--];
    }
}
```

```
error = stack.Push(2);
if (error) cout << “2 is not pushed in\n";
```

Client Handles Errors (cont'd)

```
error = stack.Push(3);
if (error) cout << "3 is not pushed in\n";

error = stack.Push(4);
if (error) cout << "4 is not pushed in\n";

value = stack.Pop(error);
if (!error)
    cout << value << '\n';
else
    cout << "The first pop failed!\n";

value = stack.Pop(error);
if (!error)
    cout << value << '\n';
else
    cout << "The 2nd pop failed!\n";

value = stack.Pop(error);
if (!error)
    cout << value << '\n';
else
    cout << "The 3rd pop failed!\n";

value = stack.Pop(error);
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}
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if (error) cout << "4 is not pushed in\n";

value = stack.Pop(error);
if (!error)
    cout << value << '\n';
else
    cout << "The first pop failed!\n";

value = stack.Pop(error);
if (!error)
    cout << value << '\n';
else
    cout << "The 2nd pop failed!\n";

value = stack.Pop(error);
if (!error)
    cout << value << '\n';
else
    cout << "The 3rd pop failed!\n";

value = stack.Pop(error);
if (!error)
    cout << value << '\n';
else
    cout << "The 4th pop failed!\n";
}
```

Output:

```
4 is not pushed in
3
2
1
The 4th pop failed!
```

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  1. It does not know where and why exactly the error occurs in the server codes.

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- It's possible that the client code passes some environment identifying information in such that the server can handle errors properly.

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- It's possible that the client code passes some environment identifying information in such that the server can handle errors properly.
- Let the **client** handle the error usually makes the client codes longer. Frequently, only client codes know what to do with a particular error.

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  1. It does not know where and why exactly the error occurs in the server codes.
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- Let the **server** handle the error usually can reduce the overall code size. However, it is only possible when the error handling methods for all usages are exactly the same. (perform the factoring operation)
- It's possible that the client code passes some environment identifying information in such that the server can handle errors properly.
- Let the **client** handle the error usually makes the client codes longer. Frequently, only client codes know what to do with a particular error.
- It's possible that the server code passes some exact error types (the **error code**) out such that the client code can handle different errors.

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  - Also, it is preferred that each public method has only **single & simple behavior**, for example, Push(item) puts for sure the specified item onto the stack, instead of various combined behaviors, i.e. nothing happens when stack is full, otherwise item is pushed onto the stack.

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- Usually, we can improve the design by **modifying the interface** - provide client **extra** interface methods such that **the behaviors of Push(item) can be better controlled/predicted**
- In the following example, we add two more interface methods to the StackT class: **IsFull()**, **IsEmpty()** so that the behaviors of Push() and Pop() are simplified.

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    if (!IsEmpty())
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        return kEmptyStack; // meaningless
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```
void main() {
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```
void main() {
    StackT stack;

    if (!stack.IsFull())
        stack.Push(1);
    else
        cout << "Deal with push error\n";




}
```

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        cout << stack.Pop() << '\n';
    else
        cout << "Deal with pop error\n";
}
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  - Used to check / track down programmer's own bugs or negligence
- Exception: try-throw-catch
  - Should be seen by people using the code – the end customers. Not disabled in the final released version.
  - Indicates user errors (e.g. invalid argument errors)
  - Indicates some system errors (e.g. file not found)

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3. Safety-critical programming

The patient will die if the software crashes. / System might be hacked.

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- Three levels:
  - **assert() statements**: those errors that the specification of the program **excludes**. You don't want it to be handled automatically by your program. You don't want your users see them.
  - **if statements**: those **expected** situations that happened normally and quite often, e.g. user enter incorrect data, file not opened, …

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  - **assert() statements**: those errors that the specification of the program **excludes**. You don't want it to be handled automatically by your program. You don't want your users see them.
  - **if statements**: those **expected** situations that happened normally and quite often, e.g. user enter incorrect data, file not opened, …
  - **try-catch-throw exceptions**: those **expected** or **unexpected** situations that happened **rarely** (say 1 out of 100), e.g. disk access errors, … Or, you want to avoid long/ugly error handling codes…

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Sometimes, there are still practices of using a single goto statement to handle all sorts of memory deallocation after program fails. In general, this mechanism can be replaced by exception handling.

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  - Preconditions: make sure the assumption holds
  - Postconditions: make sure the codes perform the task as promised
  - Class invariants: make sure some properties always hold true for a client

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#include <assert.h>
void StackT::Push(int element) {
    assert(!IsFull());
    fArray[++fTop] = element;
}
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int StackT::Pop() {
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    return fArray[fTop--];
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void main() {
    StackT stack;
    stack.Push(1); stack.Push(2); stack.Push(3); stack.Push(4);
}
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Assertion (!IsFull()) failed in stack.c

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Programmers do not follow the protocol

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```
void StackT::Push(int element) {
    int originalTop = fTop;
    assert(!IsFull());
    fArray[++fTop] = element;
    assert(!IsEmpty() && (fTop == originalTop+1));
}
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void StackT::Push(int element) {
    int originalTop = fTop;
    assert(!IsFull());
    fArray[++fTop] = element;
    assert(!IsEmpty() && (fTop == originalTop+1));
}
int StackT::Pop() {
    int originalTop = fTop;
    assert(!IsEmpty());
    int value = fArray[fTop--];
    assert(!IsFull() && (fTop == originalTop-1));
    return value;
}
```

Example of Postcondition

```
Class DataT {
    friend class StackT;
private:
    int fData;
    DataT(int data);
};
class StackT {
public:
    StackT();
    void Push(int element);
    ….
private:
    DataT *fArray[kStackSize];
    int fTop;
};
```

```
void StackT::Push(int element) {
    assert(!IsFull());
    DataT *temp = new DataT(element);
    fArray[++fTop] = temp;
    assert(temp!=NULL);
}
```

temp might actually be NULL if new operator fails to allocate required memory.

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- When is an invariant exempt from being true?

  inside a private member function

- bool StackT::ClassInvariant() {

  return (fTop>=kEmptyStack) && (fTop<kStackSize);

  }

Class Invariants (cont'd)

- First condition:

```
StackT::StackT() : fTop(kEmptyStack) {
assert(ClassInvariant());
}
```

Class Invariants (cont'd)

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```
StackT::StackT() : fTop(kEmptyStack) {
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}
```

- Second condition:

```
void StackT::Push(int element) {
    assert(ClassInvariant());
    assert(!IsFull());
    fArray[++fTop] = element;
    assert(!IsEmpty());
    assert(ClassInvariant());
}
```

```
void StackT::Pop() {
    int value;
    assert(ClassInvariant());
    assert(!IsEmpty());
    value = fArray[fTop--];
    assert(!IsFull());
    assert(ClassInvariant());
    return value;
}
```

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- Use conditional compilation

  #define _NDEBUG

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- Use conditional compilation

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#define _NDEBUG

StackT::StackT() : fTop(kEmptyStack) {
  #ifndef _NDEBUG
  assert(ClassInvariant());
  #endif
}
```

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void StackT::Push(int element) {
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  assert(!IsFull());
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  fArray[++fTop] = element;
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}
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// module: error message corresponding to errno

GetLastError() in MS Windows

```
LPVOID lpMsgBuf;
FormatMessage( FORMAT_MESSAGE_ALLOCATE_BUFFER |
               FORMAT_MESSAGE_FROM_SYSTEM |
               FORMAT_MESSAGE_IGNORE_INSERTS,
               NULL,
               GetLastError(),
               MAKELANGID(LANG_NEUTRAL,
                          SUBLANG_DEFAULT), // Default language
              (LPTSTR) &lpMsgBuf,
              0,
              NULL ); // Process any inserts in lpMsgBuf.
// ...
MessageBox( NULL, (LPCTSTR)lpMsgBuf, "Error", MB_OK);
```

http://msdn2.microsoft.com/en-us/library/ms681385.aspx