Final Examination Programming Project: Exception
Topics: Exceptions, Pre- and Post-conditions
CPSC-298-6 Programming in C++
jbonang@chapman.edu

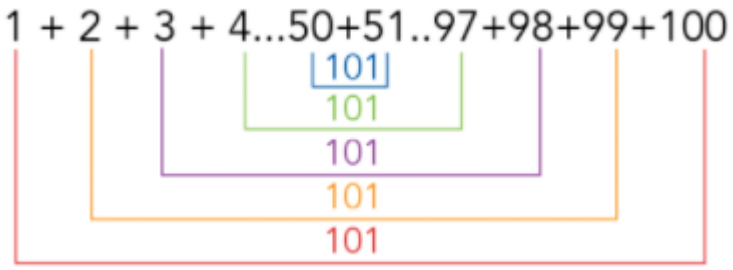
Introduction

According to legend, a very young Carl Friedrich Gauss was asked by his grade school teacher to sum the numbers from 1 to 100, inclusive. In other words, 1 + 2 + 3 + 4 + ... + 100, or, more succinctly:

$$s = \sum_{i=1}^{100} i$$

The teacher assumed this would take the class a while; however, Gauss produced the answer, 5050, almost instantly. How did he do it?

He realized that you could add the pairs of numbers 100 +1, 99 + 2, 98+3, and so on up to 51 + 50. Each pair adds up to 101 and there are 50 pairs so the total is 101 x 50 = 5050.



This can be generalized to:

(number of pairs) x ("last number in the sum" + 1) = 50 (100 + 1) = 5050

For succinctness, we'll call the "last number in the sum" n.

The number of pairs, 50, is equal to n/2, so our formula becomes (n/2)(n+1).

$$\frac{n(n+1)}{2} = \sum_{i=1}^{n} i$$

It works if n is an odd number, too.

Suppose we choose n as 67. The sum of 1 + 2 + 3 + ... + 67 = 2278.

If we substitute n = 67 in to our formula, we have.

67(67 + 1)/2 = 67(68)/2 = 67(34) = 2278

What about n = 0. Nope - not a valid value for n. We're summing the values from 1 to n and constrain the values of n to n ≥ 1. That means that negative integer values are also not allowed.

The Assignment

For this Final Examination programming project, you'll write a function called sigma that accepts n, an unsigned integer, as a parameter and computes the sum of the numbers from 1 to n. The function prototype for sigma is shown in the code listing below.

```
// Sum the integers from 1 to n. For example, if n is 5, then
// sigma returns the sum 1 + 2 + 3 + 4 + 5 == 15.
// @param n integer upper bound of summation
// @pre n >= 1
// @post return value is the sum of the integers from 1 to n.
// @return sum of the integers from 1 to n, where n is
//         specified as an argument or 0 if an error occurred.
unsigned long sigma(unsigned long n)
```

By declaring the argument `n` to be an unsigned long, the negative integers are excluded, but zero isn't. It's possible a user might not read the function preamble comments and pass a zero in as the actual argument to parameter n; that's something you'll need to handle.

You'll compute the sum the hard way, by writing a for loop and summing the numbers from 1 to n.

Function sigma will be similar to the outline provided in the code listing below.

```
// Sum the integers from 1 to n. For example, if n is 5, then
// sigma returns the sum 1 + 2 + 3 + 4 + 5 == 15.
// @param n unsigned integer upper bound of summation
// @pre n >= 1
// @post return value is the sum of the integers from 1 to n.
// @return sum of the integers from 1 to n, where n is
//         specified as an argument or 0 if an error occurred.
unsigned long sigma(unsigned long n)
{
    unsigned long sum = 0;

    try
    {
        // Check preconditions
        //    Raise a std::runtime_error exception if the precondition (n >= 1) is not met.

        // Function body
        //    Implement a for loop to compute sum of integers from 1 to n

        // Check postconditions
        //    Raise a std::runtime_error exception if the postcondition (sum == (n(n+1)/2))
        //    is not met.

    }
    catch (std::runtime_error & ex)
    {
        std::cout << "Exception: " << ex.what() << std::endl;
        std::cout << "Cannot compute sum; returning 0" << std::endl;
        sum = 0; // 0 is returned to indicate an error occurred.
    }

    return sum;
}
```

You'll check that the input argument is valid ($n \geq 1$) and report an error if it isn't by raising a `std::runtime_exception` exception. The exception should be raised in an if block. The conditional expression of the if block should check if the precondition ($n \geq 1$) is **not** true.

When raising the `std::runtime_exception` in the case of a precondition violation, pass the following message string to the `std::runtime_exception` constructor as an argument:

```
std::string strMessage = "Precondition n>=1 violated; invalid value for argument n: " + std::to_string(n) +
                         " (Loc: " + __FILE__ + ", " + std::to_string(__LINE__) + ")";
```

The string uses the `__FILE__` and `__LINE__` macros to report the name of the file and the line number within the file where the exception was raised. It will also print out the erroneous value of `n`.

Use a for statement to compute the sum of the integers from 1 to n, inclusive. Remember that the condition expression of the for loop should use the less-than-or-equal-to operator:

i <= n

For the post-condition, you'll check that the sum computed in your for loop is identical to the sum expected from the formula n(n+1)/2.

If the post-condition is not satisfied, raise a `std::runtime_exception` exception, as you did for the precondition. Pass the following string as the argument to the `std::runtime_exception` constructor:

```
std::string strMessage = "Postcondition sum == (n(n+1))/2 violated: sum: " + std::to_string(sum) + "; n(n+1)/2: " + std::to_string((n * (n + 1)) / 2) +
                         " (Loc: " + __FILE__ + ", " + std::to_string(__LINE__) + ")";;
```

Remember to include the following header files:

```
#include <iostream>
#include <stdexcept>
#include <string>
```

Running the Program

In the main program, call the sigma function twice, once with the actual argument 5 (which is valid) and once with actual argument 0, which is invalid and should trigger the precondition exception.

```
int main()
{
    int sum = sigma(5);
    std::cout << "sigma(5) = " << sum << std::endl;
    sum = sigma(0);
    std::cout << "sigma(0) = " << sum << std::endl;

    return 0;
}
```

The output of the program will appear similar to that shown in the figure below.

```
sigma(5) = 15
Exception: Precondition n>=1 violated; invalid value for argument n: 0 (Loc: C:\Users\Jim\source\repos\PrePostConditions\PrePostConditions\PrePostConditions.cpp, 59)
Cannot compute sum; returning 0
sigma(0) = 0
```

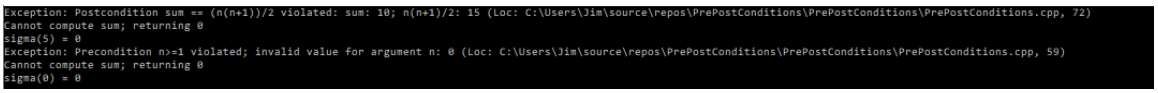
Note that the file and line number where the exception was thrown is printed out when the precondition is violated.

Injecting a Fault and Running the Program Again

Modify your program so that the for loop does not correctly compute the sum. For example, change the for loop condition from i <= n to i < n, a common error.

Build the program again and run it. The post-condition is not satisfied in this case and an exception should be raised.

The output of the program should appear similar to that shown in the figure below.



The post-condition exception should be raised.

Restore the for loop condition to the correct expression, i <= n, and submit the assignment.