3 Strings and Streams

Objective: to practice using the standard library string and stream classes.

Read:

- Book: strings, streams, function templates.

1 Class string

1.1 Introduction

In C, a string is a null-terminated array of characters. This representation is the cause of many errors: overwriting array bounds, trying to access arrays through uninitialized or incorrect pointers, and leaving dangling pointers after an array has been deallocated. The `<cstring>` library contains operations on C-style strings, such as copying and comparing strings.

C++ strings hide the physical representation of the sequence of characters. The exact implementation of the `string` class is not defined by the C++ standard.

The `string` identifier is not actually a class, but a type alias for a specialized template:

```
using string = std::basic_string<char>;
```

This means that `string` is a string containing characters of type `char`. There are other string specializations for strings containing "wide characters". We will ignore all "internationalization" issues and assume that all characters fit in one byte.

`string::size_type` is a type used for indexing in a string. `string::npos` ("no position") is a value indicating a position beyond the end of the string; it is returned by functions that search for characters when the characters aren't found.

1.2 Operations on Strings

The following class specification shows most of the operations on strings:

```
class string {
public:
    /*** construction ***/
    string();                // creates an empty string
    string(const string& s); // creates a copy, also has move constructor
    string(const char* cs);  // creates a string with the characters from cs
    string(size_type n, char ch); // creates a string with n copies of ch

    /*** information ***/
    size_type size();        // number of characters

    /*** character access ***/
    const char& operator[](size_type pos) const;
    char& operator[](size_type pos);

    /*** substrings */
    string substr(size_type start, size_type n = npos); // the substring starting
                             // at position start containing n characters
```

```
    /*** finding things ***/
    // see below

    /*** inserting, replacing, and removing ***/
    void insert(size_type pos, const string& s); // inserts s at position pos
    void append(const string& s);                // appends s at the end
    void replace(size_type start, size_type n, const string& s); // replaces n
                            // characters starting at pos with s
    void erase(size_type start = 0, size_type n = npos); // removes n
                            // characters starting at pos

    /*** assignment and concatenation ***/
    string& operator=(const string& s);  // also move assignment
    string& operator=(const char* cs);
    string& operator=(char ch);
    string& operator+=(const string& s); // also const char* and char

    /*** access to C-style string representation ***/
    const char* c_str();
}
```

- Note that there is no constructor `string(char)`. Use `string(1, char)` instead.
- The subscript functions `operator[]` do not check for a valid index. There are similar `at()` functions that do check, and that throw `out_of_range` if the index is not valid.
- The `substr()` member function takes a starting position as its first argument and the number of characters as the second argument. This is different from the `substring()` method in `java.lang.String`, where the second argument is the end position of the substring.
- There are overloads of most of the functions. You can use C-style strings or characters as parameters instead of strings.
- Strings have iterators like library vectors.
- There is a bewildering variety of member functions for finding strings, C-style strings or characters. They all return `npos` if the search fails. The functions have the following signature (the `string` parameter may also be a C-style string or a character):

  ```
  size_type FIND_VARIANT(const string& s, size_type pos = 0) const;
  ```

  `s` is the string to search for, `pos` is the starting position. (The default value for `pos` is `npos`, not `0`, in the functions that search backwards).

  The "find variants" are `find` (find a string, forwards), `rfind` (find a string, backwards), `find_first_of` and `find_last_of` (find one of the characters in a string, forwards or backwards), `find_first_not_of` and `find_last_not_of` (find a character that is not one of the characters in a string, forwards or backwards).

  Example:

  ```
  void f() {
      string s = "accdcde";
      auto i1 = s.find("cd");              // i1 = 2 (s[2]=='c' && s[3]=='d')
      auto i2 = s.rfind("cd");             // i2 = 4 (s[4]=='c' && s[5]=='d')
      auto i3 = s.find_first_of("cd");     // i3 = 1 (s[1]=='c')
      auto i4 = s.find_last_of("cd");      // i4 = 5 (s[5]=='d')
      auto i5 = s.find_first_not_of("cd"); // i5 = 0 (s[0]!='c' && s[0]!='d')
      auto i6 = s.find_last_not_of("cd");  // i6 = 6 (s[6]!='c' && s[6]!='d')
  }
  ```

There are global overloaded operator functions for concatenation (`operator+`) and for comparison (`operator==`, `operator<`, etc.). They all have the expected meaning. You cannot use `+` to concatenate a string with a number, only with another string, C-style string or character (this is unlike Java).

In the new standard, there are functions that convert strings to numbers and vice versa: `stod("123.45") => double`, `to_string(123) => "123"`.

A1. Write a class that reads a file and removes HTML tags and translates HTML-encoded special characters. The class should be used like this:

```
int main() {
    TagRemover tr(cin); // read from cin
    tr.print(cout);     // print on cout
}
```

- All tags should be removed from the output. A tag starts with a `<` and ends with a `>`.
- You can assume that there are no nested tags.
- Tags may start on one line and end on another line.
- Line separators should be kept in the output.
- You don't have to handle all special characters, only `<`, `>`, ` `, `&` (corresponding to `< > space &`).
- Assignments like this should be a good fit for regular expressions. Study and use the C++ `regex` library if you're interested.

Copy the makefile from one of the previous labs, modify it, build. Test your program on the file *test.html*.

A2. The Sieve of Eratosthenes is an ancient method for finding all prime numbers less than some fixed number M. It starts by enumerating all numbers in the interval $[0, M]$ and assuming they are all primes. The first two numbers, 0 and 1 are marked, as they are not primes. The algorithm then starts with the number 2, marks all subsequent multiples of 2 as composites, finds the next prime, marks all multiples, ... When the initial sequence is exhausted, the numbers not marked as composites are the primes in $[0, M]$.

In this assignment you shall use a string for the enumeration. Initialize a string of appropriate length to `PPPPP...PPP`. The characters at positions that are not prime numbers should be changed to `C`. Write a program that prints the prime numbers between 1 and 200 and also the largest prime that is less than 100,000.

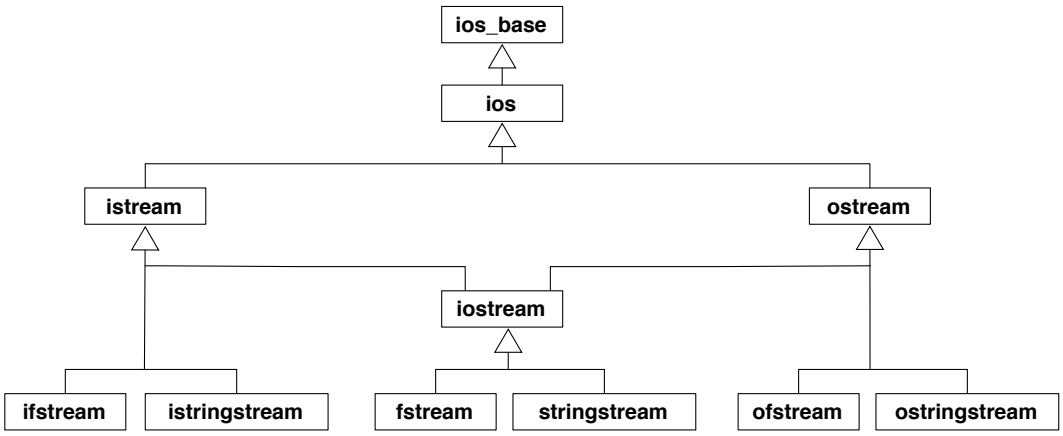
Example with the numbers 0–35:

```
                                  1         2         3
                        01234567890123456789012345678901234
Initial:                CCPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPPP
Find 2, mark 4,6,8,...: CCPPCPCPCPCPCPCPCPCPCPCPCPCPCPCPCPCP
Find 3, mark 6,9,12,...: CCPPCPCPCCCPCPCCCPCPCCCPCPCCCPCPCCCP
Find 5, mark 10,15,20,...: CCPPCPCPCCCPCPCCCPCPCCCPCCCCCPCPCCCC
Find 7, mark 14,21,28,35: CCPPCPCPCCCPCPCCCPCPCCCPCCCCCPCPCCCC
Find 11, mark 22,33:    CCPPCPCPCCCPCPCCCPCPCCCPCCCCCPCPCCCC
...
```

2 The iostream Library

2.1 Input/Output of User-Defined Objects

In addition to the stream classes for input or output there are `iostream`'s that allow both reading and writing. The stream classes are organized in the following (simplified) hierarchy:



The classes `ios_base` and `ios` contain, among other things, information about the stream state. There are, for example, functions `bool good()` (the state is ok) and `bool eof()` (end-of-file has been reached). There is also a conversion operator `operator bool()` that returns true if the state is good, and a `bool operator!()` that returns true if the state is not good. We have used these operators with input files, writing for example `while (infile >> ch)` and `if (!infile)`.

To read and print objects of user-defined classes `operator>>` and `operator<<` must be overladed.

A3. The files *date.h*, *date.cc*, and *date_test.cc* describe a simple date class. Implement the class and add operators for input and output of dates (`operator>>` and `operator<<`). Dates should be output in the form `2015-01-10`. The input operator should accept dates in the same format. (You may consider dates written like `2015-1-10` and `2015 -001 - 10` as legal, if you wish.)

The input operator should set the stream state appropriately, for example `is.setstate (ios_base::failbit)` when a format error is encountered.

2.2 String Streams

The string stream classes (`istringstream` and `ostringstream`) function as their "file" counterparts (`ifstream` and `ofstream`). The only difference is that characters are read from/written to a string instead of a file. In the following assignments you will use string streams to convert objects to and from a string representation (in the new standard, this can be performed with functions like `to_string` and `stod`, but only for numbers).

A4. In Java, the class `Object` defines a method `toString()` that is supposed to produce a "readable representation" of an object. This method can be overridden in subclasses.

Write a template function `toString` for the same purpose. Also write a test program. Example:

```
double d = 1.234;
Date today;
std::string sd = toString(d);
std::string st = toString(today);
```

You may assume that the argument object can be output with <<.

A5. Type casting in C++ can be performed with, for example, the `static_cast` operator. Casting from a `string` to a numeric value is not supported, since this involves executing code that converts a sequence of characters to a number.

Write a function `string_cast` that can be used to cast a string to an object of another type. Examples of usage:

```
try {
    int i = string_cast<int>("123");
    double d = string_cast<double>("12.34");
    Date date = string_cast<Date>("2015-01-10");
} catch (std::invalid_argument& e) {
    cout << "Error: " << e.what() << endl;
}
```

You may assume that the argument object can be input with `>>`. The function should throw `std::invalid_argument` (defined in header `<stdexcept>`) if the string could not be converted.