Strings and Streams

Representing Text, Working with Streams from Files and Strings

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Have a Question?

sli.do

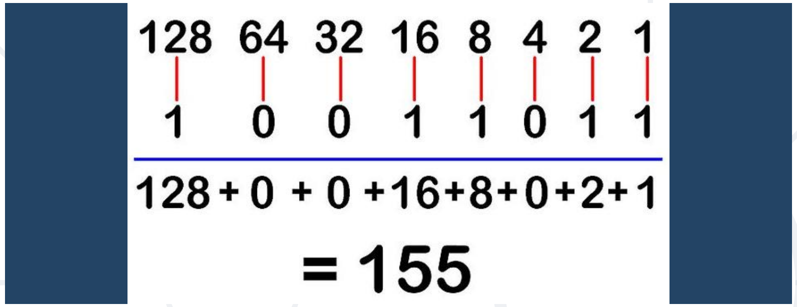
#cpp-fundamentals

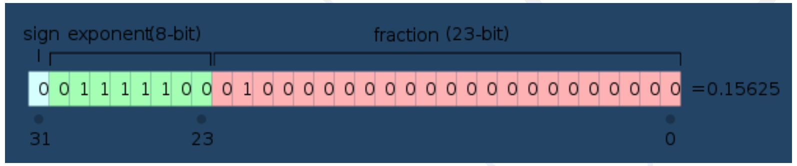
Representing Text in Computers

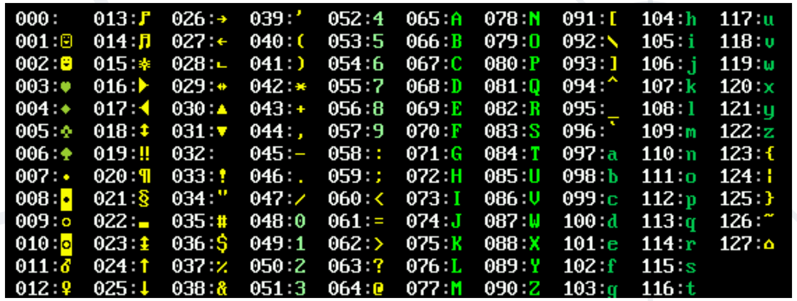
Bytes, Code Points, Encoding

Representing Text in Computers

- Data is bytes of 1s and 0s
  - Interpreted in different ways
  - Interpretation & size = data type
- Ways we interpret bytes:
  - Binary number -> integer types
  - IEEE754 -> floating-point types
  - Binary "code point" -> char types
- Characters (text) is just another interpretation of binary data







```
000:  013:♪ 026:→ 039:' 052:4 065:A 078:N 091:[ 104:h 117:u
001:☺ 014:♫ 027:← 040:( 053:5 066:B 079:O 092:\ 105:i 118:v
002:☻ 015:☼ 028:∟ 041:) 054:6 067:C 080:P 093:] 106:j 119:w
003:♥ 016:► 029:↔ 042:* 055:7 068:D 081:Q 094:^ 107:k 120:x
004:♦ 017:◄ 030:▲ 043:+ 056:8 069:E 082:R 095:_ 108:l 121:y
005:♣ 018:↕ 031:▼ 044:, 057:9 070:F 083:S 096:` 109:m 122:z
006:♠ 019:‼ 032:  045:- 058:: 071:G 084:T 097:a 110:n 123:{
007:• 020:¶ 033:! 046:. 059:; 072:H 085:U 098:b 111:o 124:|
008:◘ 021:§ 034:" 047:/ 060:< 073:I 086:V 099:c 112:p 125:}
009:○ 022:▬ 035:# 048:0 061:= 074:J 087:W 100:d 113:q 126:~
010:◙ 023:↨ 036:$ 049:1 062:> 075:K 088:X 101:e 114:r 127:⌂
011:♂ 024:↑ 037:% 050:2 063:? 076:L 089:Y 102:f 115:s
012:♀ 025:↓ 038:& 051:3 064:@ 077:M 090:Z 103:g 116:t
```

Representing Text in Computers

- Text - a sequence of characters
- A character (letter, symbol, etc.) consists of one or more bytes
  - The binary representation of a **number**
  - Interpreted as a **code point** from a **character set** (**charset**)
- Character set – a group of characters (Latin, Cyrillic, etc.)
- Code point – unique number assigned to a character in a charset
  - ASCII code point **65** (**`0x41`**) is '**`A`**' (English capital letter A)

Character Sets & Unicode

- ASCII is the base charset – code points from `0` to `127`
  - English letters, digits, punctuation, control symbols (e.g. tab)
- "Extended ASCII" – code points from `128` to `255`
  - Different charsets use those codepoints for different characters
  - E.g. Windows: Cyrillic code point `211` (`0xD3`) is **У** У
  - But Windows: Greek code point `211` (`0xD3`) is **Σ** Σ
- Unicode unifies charsets to represent all the world's characters
  - E.g. **У** У is `1059` (`U+0423`) and **Σ** Σ is `931` (`U+03A3`)

rial
# $ % & ' ( ) * + , - . / 0 1 2
6 7 8 9 : ; < = > ? @ A B C D E F G
I J K L M N O P Q R S T U V W X Y Z [\
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¨ © « ¬ ® ² ³ ΄ µ ¶ · Έ Ή Ί » Ό ½
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Representing Text in Computers

LIVE DEMO

C++ Text Representation

C-Strings and `std::string` class

C++ Text Representation

- C++ has good native support for the ASCII charset
  - **`char`** data type (usually) covers code points 0 to 255
  - We'll discuss Unicode later
- Text types (sequences of characters) are called **strings**
- C++ has two standard ways of working with text
  - Character arrays, aka C-Strings (legacy from the C language)
  - The C++ **`std::string`** – a "smart" wrapper of a C-String

C++ Text Representation

LIVE DEMO

char Arrays, aka C-Strings

- An array of char, e. g. `char str[]`, with the following rules:
  - Should be null-terminated, i. e. end with `'\0'`, which is `char(0)`
  - `'\0'` counts as an element – it affects array size
- Null-terminator tells C++ where the string ends
  - C++ arrays don't know their size
- Char arrays with NO null-terminator are NOT used as strings
  - Don't use cin, cout, or C-String functions
  - Can still use like an array of any other data type

C-Strings

- Initialization can happen with array initializer or literal
  - If using normal array initializer, don't forget the `'\0'` at the end

```
char text[16] = { 'C','+','+',' ','P','r','o','g','r','a','m','m','i','n','g','\0' };
char sameText[] = { 'C','+','+',' ','P','r','o','g','r','a','m','m','i','n','g', 0 };
char sameTextAgain[] = "C++ Programming";
char sameTextYetAgain[16] = "C++ Programming";
```

- `cin` & `cout` can directly write to and read from C-Strings
  - `cout` prints until it reaches `'\0'`
  - `cin` works correctly only if array can fit entered data

```
char arr[100];
cin >> arr;
cout << arr << endl;
```

C-Strings

LIVE DEMO

Quick Quiz

- What will the following code print?

```
char line1[4] = {'a', 'b', 'c'};
char line2[] = {'d', 'e', 'f'};
cout << line1 << endl;
cout << line2 << endl;
```

a) It won't – there will be a compile-time error

b) behavior is undefined

c) First line **abc**
Second line **def**

d) First line **abc**, second line is undefined

Some C-String Built-in Functions

- C-String functions are defined in the `<cstring>` header
- `strcat(destination, source)`
  - Appends (concatenates) `source` C-String into `destination` C-String
  - `destination` needs to be long enough for source + null-terminator
- `strlen(str)`
  - Returns length of C-String in `str` (based on the null-terminator)
- `strstr(str, search)`
  - Returns the address (pointer) of `search` in `str`, `NULL` if not found
  - `int index = strstr(str, search) - str;` gets the index

C-String Built-in Functions

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The std::string Class

The std::string Class

- The C++ **string** encapsulates a null-terminated C-String
  - **#include<string>**
- Declare like a normal variable, e.g. **string s;**
  - Empty (**""**, size **0**) if only declared (it gets default-initialized)
  - Can be initialized with C-String or string literal

```
string theFoxPart = "the quick brown fox";
string theActionPart("jumps over");
char dogPartCString[] = "the lazy dog";
string sentence = theFoxPart + string("---") +
                  theActionPart + string(3, '-')
                  + dogPartCString;
```

std::string Basics

- C++ Strings can be used with **cin/cout**

```
string name;
cin >> name; cout << name;
```

- **size()** & **length()** return the number of **char**s

```
string hello = "hello";
for (int i = 0; i < hello.size(); i++)
    cout << hello[i] << endl;
```

- The **[]** operator is supported – similar to **[]** for a char array

```
hello[1] = 'a';
cout << hello << endl; //hallo
```

- The **+** operator concatenates two strings

```
string helloName = hello + string(" ") + name;
cout << helloName << endl; // e.g. "hello George"
```

std::string

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std::string Comparisons and Search

- Two strings can be compared with any comparison operator
  - operators **<**, **<=**, **==**, **>=**, **>** compare the strings lexicographically

```
string s1 = "cat", s2 = "canary";
if (s1 < s2) { cout << s1 << " is before " << s2 << endl; }
else         { cout << s1 << " is after " << s2 << endl; }
```

- **str.find(search)** returns the index of **search** in the **str**
  - If **search** is not found, returns the **string::npos** value (**-1**)

```
cout<<"nar"<<" at index "<<s1.find("nar")<<" in "<<s2;
```

std::string Comparisons and Search

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std::string Find All Occurrences

- The **find(search, index)** overload takes a start index
  - The search starts from that index (ignores results before it)

```
string s = "aha"; cout << s.find("a", 1); // prints 2
```

- We can use this to search all occurrences of a substring
  - Each time search from after the last index where we found it

```
string str = "canary";
int foundIndex = str.find("a");
while (foundIndex != string::npos) {
  cout << foundIndex << endl;
  foundIndex = str.find("a", foundIndex + 1);
}
```

std::string Substring, Erase, Replace

- substr(index, length) returns a new string
  - With length characters, starting from index

```
string s = "abc"; cout << s.substr(1,2); // prints bc
```

- erase(index, length) changes a string by removing chars
  - Removes length characters, starting from index

```
string s = "abc"; s.erase(1,2); cout << s; // prints a
```

- replace(index, length, str) changes a string by replacing
  - Characters in [index, index + length) replaced by str

```
string s = "abc"; s.replace(1,2,"cme"); cout << s; // prints a
```

std::string Substring, Erase, Replace

LIVE DEMO

Supporting Unicode in C++

- **char** supports ASCII, **string** is a **char** array, no Unicode there
- **wchar_t** and **wstring**
  - Variants of **char** & **string** that support system's max code point
  - **wchar_t** on Unicode systems is 32-bit,
  - But on Windows **wchar_t** is 16-bit (UTF-16)
- C++11 adds **char16_t**, **char32_t**, **u16string** & **u32string**
- Built-in support is not very good – storing is ok, operations not
- Best approach: use external libraries – QT, ICU, UTF8-CPP, etc.

Streams, Reading by Line, File I/O

std::stringstream, File Streams

C++ Streams

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- Streams offer an abstraction over incoming/outgoing data
  - `cin` and `cout` are abstractions of the console input/output
- Practically speaking, streams are ways of reading/writing data
- A stream can be constructed for any type of data container
  - Arrays, strings, memory
  - Files, network connections, the keyboard buffer, etc.

The std::stringstream

- A stream that works on a string
- `#include<sstream>`
- Can read data from a string, can write data to a string
  - There are limited `istringstream/ostringstream` versions that only read/write respectively
- Useful for working on a string "word-by-word"
  - Reading in numbers from a string
  - Creating a string with text and numbers

Reading with std::istringstream

- **istringstream** is a limited **stringstream** than only reads
  - If you only want to read, use it instead of **stringstream**
- Initialize **istringstream** by giving it a **string** to read from

```
string str = "3 -2";
istringstream numbersStream(str);
```

- From then on, use the stream just like **cin**

```
int num1, num2;
numbersStream >> num1 >> num2;
int sum = num1 + num2;
```

Writing with std::ostringstream

- `ostringstream` is a limited `stringstream` than only writes
- Initialize `ostringstream` like a normal variable

```
ostringstream stream;
```

- From then on, use the stream just like `cin`

```
stream << "The sum is " << num1 + num2 << endl;
```

- To get the string when you're done, call `str()`

```
cout << stream.str();
```

Using std::stringstream

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Reading with getline() and Streams

- `getline(stream, targetStr)` reads an entire line of text
  - Or until a delimiter `char` (additional parameter) is reached
  - From the provided `stream` and puts it into `targetStr`
  - Avoid mixing `cin>>` and `getline(cin,…)` http://stackoverflow.com/a/18786719

```
istringstream in("a word");

string line;
getline(in, line);
cout << line << endl; // a word
```

```
istringstream in("a.word");

string line;
getline(in, line, '.');
cout << line << endl; // a
```

Parsing Numbers from a Line

- `getline()` already gives us the line as a string
- Streams allow us to read strings/numbers separated by spaces
- How do we know when to stop?
  - Streams can be used as a `bool` value
  - A stream is `true` if it still has something to read
  - A stream is `false` if the input ended, or if there was an error

Parsing Numbers from a Line

- Read the line from **cin** into a **string** with **getline()**
- Create an **istringstream** over that **string**
- Read numbers from the stream while the stream is **true**
  - Add numbers to a **vector** to use them later

```
string line; getline(cin, line);
istringstream lineStream(line);
vector<int> numbers;
int currentNumber;
while (lineStream >> currentNumber) {
    numbers.push_back(currentNumber);
}
```

Parsing Numbers from a Line

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Streams to and from Files

- We saw that streams work the same way
  - Regardless of whether they are over the console, or a string
  - Same goes for files – you just have to create a file stream
- **`#include<fstream>`**
- **`ifstream`** is for reading, **`ofstream`** is for writing
- Text reading/writing with same operators, functions, concepts
  - **`<<`** for writing, **`>>`** for reading, **`getline()`** reads line, etc.
  - Can be used as **`bool`** just like **`cin`**, **`cout`** and **`stringstream`**

Using Streams to/from Files

- Declare the stream and open the file
  - Input streams expect the file to exist (error state otherwise)

```
ifstream input;
input.open("input.txt");
int a, b;
input >> a >> b;
input.close();
```

  - Output streams create or overwrite the file on opening

```
ofstream output;
output.open("output.txt");
output << a + b << endl; output.close();
```

  - There are parameters to tell the stream to append instead

Using Streams to/from Files

- Declaration and opening can be shortened

```
ifstream input("input.txt");
int a, b;
input >> a >> b;
input.close();
```

```
ofstream output("output.txt");
output << a + b << endl; output.close();
```

- `close()` is automatically called when stream goes out of scope (when the declaring block ends)
  - Still, you should close explicitly if you're not using the stream
- To make an output stream append instead of overwrite:
  - `ofstream output("output.txt", fstream::app);`

Summary

- Text is a sequence of bytes interpreted by special rules
- C++ has two standard ways of working with text
  - `std::string` is the C++ way for working with text
  - Knows size
  - Has special operators and utility functions
  - C-Strings (`char` arrays) are the legacy C approach
- Streams are abstractions for writing/reading data

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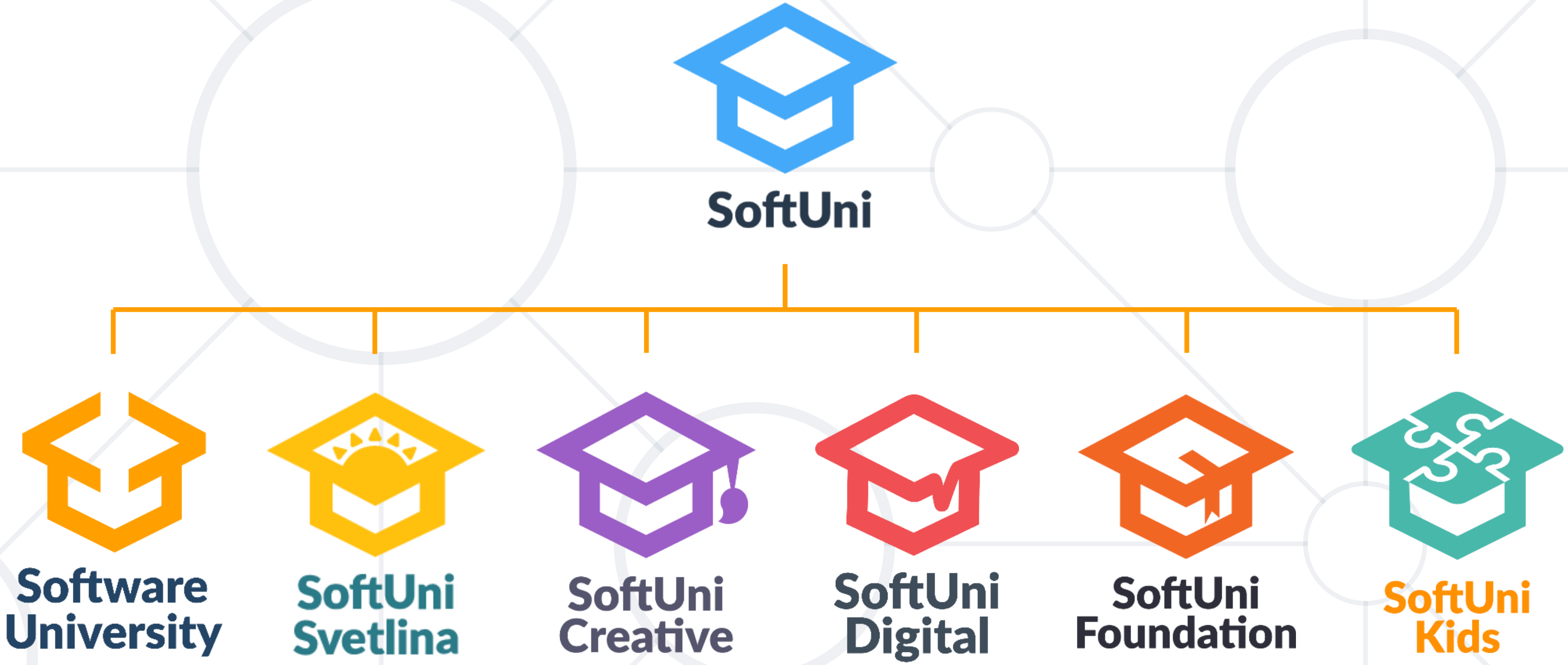
Questions?



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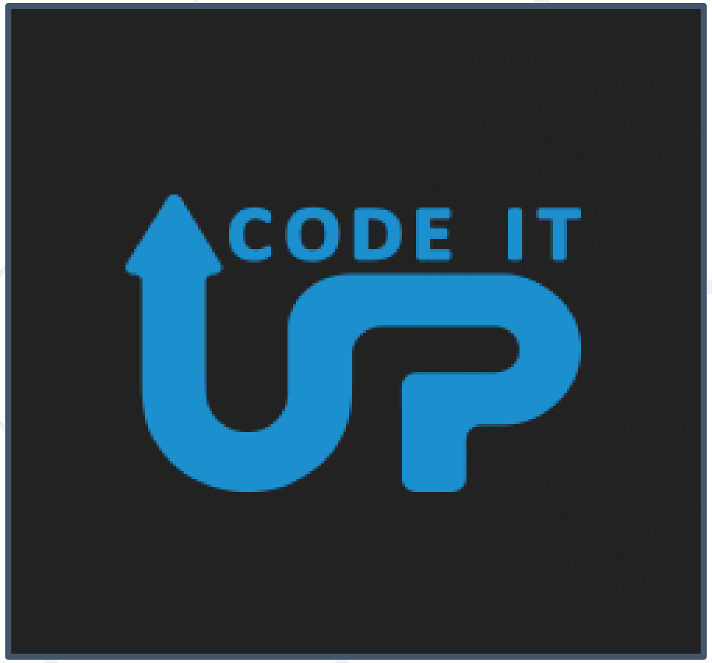

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