Introduction to Algorithms and Data Structures

CSC 1051 – Algorithms and Data Structures I
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Course website:
www.csc.villanova.edu/~map/1051/

What is this course about?

• Computer Science
• Problem solving
• Algorithmic thinking
• Data representation
• Object oriented programming using Java

Course website

www.csc.villanova.edu/~map/1051/s16/

Links to:
• Schedule – topics, slides, projects, labs, code, etc.
• Syllabus – course information
• Piazza – class discussions, announcements
• Blackboard – submit projects, check grades
• Peer Tutors – extra help available for this course
• Exam archive – past exams and quizzes & solutions

Our textbook

Java Software Solutions
Foundations of Program Design
8th Edition
John Lewis
William Loftus

(7th edition is ok, but some exercise numbers may be different)
An old quote

A priest asked: “What is Fate, Master?”
And he answered:
“It is that which gives a beast of burden its reason for existence. It is that which men in former times had to bear upon their backs. It is that which has caused nations to build byways from City to City upon which carts and coaches pass, and alongside which inns have come to be built to stave off Hunger, Thirst and Weariness.”
“And that is Fate?” said the priest.
“Fate... I thought you said Freight,” responded the Master.
“That’s all right,” said the priest. “I wanted to know what Freight was too.”
-Kehlog Albran

Source unknown. This quote appeared as one of the “fortunes” displayed by the fortune cookie program on old unix systems. (“fortune” was a program that ran automatically every time you logged out of a unix session and displayed a random, pithy saying.)

Reverse History of computing

Examine what we already know, travel backwards…

1. What we see now all around us – a connected world of computing
2. Focus on a single “traditional” computer
3. Dig deeper – data and processing

Networks

A network is two or more computers that are connected so that data and resources can be shared

- A Local-Area Network (LAN) covers a small distance and a small number of computers
- A Wide-Area Network (WAN) connects two or more LANs, often over long distances

The Internet and the World Wide Web

- The Internet is a Peer-to-Peer network
- The Internet Protocol (IP) determines how data are routed across network boundaries.
- Devices have unique IP addresses, e.g., 204.192.116.2
- Data are accessed using a Uniform Resource Locator (URL): eg: http://www.cnn.com
- The World Wide Web provides a common interface to data:
  - Text, graphics, video, sound, audio, executable programs
- Web documents often use HyperText Markup Language (HTML)
- A browser is a program which accesses network resources and presents them
  - Popular browsers: Chrome, Internet Explorer, Safari, Firefox
  - My first browser: Mosaic <3
The Internet

History: Started as a United States government project, sponsored by the Advanced Research Projects Agency (ARPA) in late 1960’s

See also: http://www.internethalloffame.org/internet-history/timeline

- 1970’s and 1980’s: ARPANET
  - wide area network
  - protocols for communication
- 1990’s: World Wide Web
  - html and web browsers

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A Computer Specification

- Consider the following specification for a personal computer:
  - 3.07 GHz Intel Core i7 processor
  - 4 GB RAM
  - 750 GB Hard Disk
  - 16x Blu-ray / HD DVD-ROM & 16x DVD+R DVD Burner
  - 17” Flat Screen Video Display with 1280 x 1024 resolution
  - Network Card
Introduction

Computer Architecture

Memory

memory locations (or cells) identified by a unique numeric address

9278
9279
9280
9281 10011010
9282
9283
9284
9285
9286

928
9289
928
92810
92811
92812
92813
92814
92815

Memory = Main Memory = Random Access Memory = RAM
("Random" because you don’t have to scan the memory sequentially – go to data directly using the address)

CPU and Main Memory

CPU and Main Memory

Historical note: Von Neuman architecture

John von Neumann, USA 1945

The Central Processing Unit

• A CPU is on a chip called a *microprocessor*

• It continuously follows the *fetch-decode-execute* cycle:

  - **fetch**: Retrieve an instruction from main memory
  - **decode**: Determine what the instruction is
  - **execute**: Carry out the instruction

  ![Diagram of the fetch-decode-execute cycle](CSC 1051 M.A. Papalaskari, Villanova University

**Historical Note: Automatic control of computation**

A machine that can follow a series of steps - a "program"

• Early efforts:
  – Jacquard loom (France 1801)
  – Babbage's Difference engine and Analytical engine (England 1822)
  – Holerith's census machine (USA 1890)
• Colossus Mark I – first electronic computer to be programmable (*Alan Turing*, England 1944)
• Stored program and the fetch/decode/execute cycle (John von Neumann, USA 1945)
• ENIAC - first fully electronic digital computer (Eckert and Mauchley, University of Pennsylvania, 1946)

![Image](http://www.biography.com/people/alan-turing-9512017)
Introduction

Historical Note: Automatic control of computation

Jacquard Loom

This portrait of Jacquard was woven in silk on a Jacquard loom using 24,000 punched cards (1839).


Charles Babbage & Ada Lovelace

Designed the Analytical Engine

First “Programmer” for (not yet built) Analytical Engine

Historical Note: Automatic control of computation

1945: The word “computer” changes its meaning

Captain Grace Hopper and other computers

The Electronic Numeric Integrator and Calculator (ENIAC) Programmers Betty Jean Jennings (left) and Fran Bilas (right) operate ENIAC's main control panel at the Moore School of Electrical Engineering. (U.S. Army photo from the archives of the ARL Technical Library)

Historical Note: Automatic control of computation

2014: Benedict Cumberbatch shows the world how cool Alan Turing was

The Imitation Game (2014)

Your rating: 8.1/10 from 332,068 users Metascore: 73/100 Reviews: 555 user · 423 critic · 49 from Metacritic.com

During World War II, mathematician Alan Turing tries to crack the enigma code with help from fellow mathematicians.

Directors: Morten Tyldum Writers: Graham Moore, Andrew Hodges (book)
Stars: Benedict Cumberbatch, Keira Knightley, Matthew Goode · See full cast and crew »

http://www.imdb.com/title/tt2084970/
**Reverse History of computing**

*Examine what we already know, travel backwards…*

1. What we see now all around us – a connected world of computing
2. Focus on a single “traditional” computer
3. Dig deeper – data and processing

**Data Representation**

- Computers store all information **digitally**, using **binary** codes:
  - numbers
  - text
  - images
  - audio
  - video
  - program instructions

**Example: Representing Text**

- Characters, including spaces, digits, and punctuation are represented by numeric codes
  - Hi, Heather.

*Computing devices store use binary codes to represent data of all kinds*
Example: Representing Pixels

- **Color**: \(01110100, 01010110, 10001110\)
- **red** = 116
- **green** = 86
- **blue** = 142

Example: Representing Program Instructions

Intel opcode for the instruction **JZ** (jump if zero):

\[01110100\]

Historical Note: Symbolic Representation & Mechanization of Arithmetic

- Development of number systems & geometry
- The notion of an algorithm
- Creation of special purpose calculators

Historical Note: Symbolic Representation & Mechanization of Arithmetic

Basic human needs: **counting & measuring**

http://ghoststudy.com/new11_galleries/halloweve1067.jpg

Basic human needs: **Symbolism**

- 😊
- 🎵
- π
- 🍏
- ∞
- <3

**Historical Note:**
Symbolic Representation & Mechanization of Arithmetic

- Development of number systems & geometry
  - Abacus (China ~2400 BC)
  - Number systems (Babylonian, Greek, Roman, Arabic 1000 BC - 800 AD)
  - Geometry (Egypt/Greece 300 BC)

**Historical Note:**
The notion of an algorithm

- Euclid (300 BC)
- Muhammad ibn Masu al-Khwārizmī (800 AD)

**Historical Note:**
Creation of special purpose calculators

- Stonehenge (1900-1600 BC)
- Pascal's adder (1642)
- Leibniz's calculator (1670s)

1975 Texas Instruments calculator
Introduction

Historical notes:
Trends that gave rise to the modern computer

• Symbolic representation and the mechanization of arithmetic – the concepts of numbers, symbols, algorithms, and computation

• Automatic control of computation – a "program" to control operations (fetch/decode/execute cycle and the stored program concept)

• Connecting the world – networks and telecommunications

= modern computer

Computer Science
A new paradigm in humanity’s search for understanding of:

• Representation & encoding
• Computation
• Problem solving
• Mechanization

History Epilogue: Just like Physics and other sciences branched off from philosophy during the Renaissance, so CS emerged in the 20th century from the work of philosophers and mathematicians – with the help of dedicated, visionary practitioners, experimental scientists and engineers.

Part 2 – introduction to Java

High-level programming languages

• Programmer writes Source code
• Translation produces the binary equivalent – Object code
• Translation is performed by an assembler, compiler, or interpreter (stay tuned)
Java Translation

Java source code

Java bytecode

Bytecode interpreter

Bytecode compiler

Machine code

Development Environments

- There are many programs that support the development of Java software, including:
  - Sun Java Development Kit (JDK)
  - Sun NetBeans
  - IBM Eclipse
  - IntelliJ IDEA
  - Oracle JDeveloper
  - BlueJ
  - jGRASP

- Though the details of these environments differ, the basic compilation and execution process is essentially the same

Java Program Structure

- In the Java programming language:
  - A program is made up of one or more classes
  - A class contains one or more methods
  - A method contains program statements

- These terms will be explored in detail throughout the course

- A Java application always contains a method called main

- See Lincoln.java

Java Program Example

```java
//********************************************************************
//  Lincoln.java       Author: Lewis/Loftus
//  // Demonstrates the basic structure of a Java application.
//********************************************************************
public class Lincoln
{
    // Prints a presidential quote.
    public static void main (String[] args)
    {
        System.out.println ("A quote by Abraham Lincoln:");
        System.out.println ("Whatever you are, be a good one.");
    }
}
```
Java Program Structure

public class MyProgram
{
    // comments about the class
    class header

    class body

    Comments can be placed almost anywhere
}

Java Program Structure

public class MyProgram
{
    // comments about the method
    public static void main (String[] args)
    {
        // comments about the method
        method header

        method body
    }
}

Comments

- Comments in a program are called inline documentation
- They should be included to explain the purpose of the program and describe processing steps
- They do not affect how a program works
- Alternative ways of making Java comments:

  // This comment runs to the end of the line

  /* This comment runs to the terminating symbol, even across line breaks */

White Space (Spaces, blank lines, and tabs)

- Extra white space is ignored
- Programs should be formatted to enhance readability, using consistent indentation

- See Lincoln2.java, Lincoln3.java
Errors

A program can have three types of errors:

- The compiler will find syntax errors and other basic problems (*compile-time errors*):
  - If compile-time errors exist, an executable version of the program is not created.
- A problem can occur during program execution, such as trying to divide by zero, which causes a program to terminate abnormally (*run-time errors*).
- A program may run, but produce incorrect results, perhaps using an incorrect formula (*logical errors*).

Lab 1:

- Learn about jGrasp - the programming environment (IDE) that we will be using.
- Compile and run a java program.
- Understand the relationship between a Java class name and file names.
- Practice using basic Java output statements and adding comments.
- Learn the basics of sequential execution, variables, and the assignment statement:

```
System.out.println("Howdy " + name);
System.out.println("The answer is " + x);
System.out.print("Counting... up: " + (count + 1));
System.out.println("... and down: " + (count - 1));
```
- Experience some errors!
Identifiers

- Identifiers are used for naming variables, classes, and other components of a program.
- An identifier can be made up of:
  - letters (upper or lower case – case sensitive!)
  - digits (but cannot begin with a digit)
  - underscore character ( _ )
  - the dollar sign ($)
  - NOTHING ELSE!
- Example: Total, total, and TOTAL are different identifiers
- Conventions: use case to indicate whether it is a class or a variable etc.

Reserved Words

These identifiers have a special meaning in Java and cannot be used in any other way:

- abstract
- assert
- boolean
- break
- byte
- case
- catch
- char
- class
- const
- continue
- default
- do
- double
- else
- enum
- extends
- false
- final
- finally
- float
- for
- goto
- if
- implements
- import
- instanceof
- int
- interface
- long
- native
- new
- null
- package
- private
- protected
- public
- return
- short
- static
- strictfp
- super
- switch
- synchronized
- this
- throw
- throws
- transient
- true
- try
- void
- volatile
- while
- with

Character Strings

- A string literal is represented by putting double quotes around the text
- Examples:
  "This is a string literal."
  "123 Main Street"
  "X"
The println Method
- In the Lincoln program we invoked the `println` method to print a character string.
- The `System.out` object represents a destination (the monitor screen) to which we can send output.

```java
System.out.println("Whatever you are, be a good one.");
```

String Concatenation
- The `string concatenation operator` (+) is used to append one string to the end of another.

```java
"And one more " + "thing"
```

The print Method
- In the Lincoln program we invoked the `println` method to print a character string.
- The `System.out` object represents a destination (the monitor screen) to which we can send output.
- `print` is similar to `println` except that it does not advance to the next line.

```java
System.out.print("Whatever you are, be a good one.");
```

Hands on:
- Use MyQuote.java as a starting point (program from Lab 1), focus on this part of the code:

```java
System.out.println("Howdy " + name);
System.out.println("The answer is " + x);
System.out.print("Counting... up: "+(count + 1));
System.out.println("... and down: "+(count - 1));
```

- Try the following:
  1. What if you remove the parentheses around `(count + 1)`?
  2. What happens if we try this way of breaking a line:

```java
System.out.print("Counting...
up: "+(count + 1));
```

  3. How can we get all this output to print all in one line?
- Other examples (textbook): `Countdown.java`, `Facts.java`
Escape Sequences

- What if we wanted to print the quote character? e.g.,
  `System.out.println("I said "Hello" to you.");` // wrong!
- An escape sequence is a series of characters that represents a special character.

- Example:
  `System.out.println ("I said \"Hello\" to you.");`
- Some Java escape sequences:

<table>
<thead>
<tr>
<th>Escape Sequence</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>\t</td>
<td>tab</td>
</tr>
<tr>
<td>\n</td>
<td>newline</td>
</tr>
<tr>
<td>&quot;</td>
<td>double quote</td>
</tr>
<tr>
<td>'</td>
<td>single quote</td>
</tr>
<tr>
<td>\</td>
<td>backslash</td>
</tr>
</tbody>
</table>

Example from textbook: Roses.java

```java
//********************************************************************
// Roses.java  Author: Lewis/Loftus
// Demonstrates the use of escape sequences.
//********************************************************************
public class Roses {
    public static void main(String[] args)
    {
        System.out.println ("Roses are red,\nViolets are blue,\nSugar is sweet,\nBut I have "commitment issues",\nSo I'd rather just be friends\nAt this point in our relationship.");
    }
}
```

Output

```
Roses are red,
Violets are blue,
Sugar is sweet,
But I have "commitment issues",
So I'd rather just be friends
At this point in our relationship.
```

Quick Check

Write a single `println` statement that produces the following output:

"Thank you all for coming to my home tonight," he said mysteriously.

Summary

- History of computing
- Computer hardware and software overview
- An introduction to Java:
  - Identifiers
  - Comments
  - Errors
  - Strings and printing