CMSC 131

Object-Oriented Programming I

Computer Organization

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This material is based on material provided by Ben Bederson, Bonnie Dorr, Fawzi Emad, David Mount, Jan Plane
Computer Organization

- **Hardware:** physical parts of computer
  - Monitor, mouse, keyboard
  - Chips, boards
  - Cables, cards
  - etc.

- **Software:** non-physical ("logical") parts of computer
  - Programs = instructions for computer to perform
Hardware Overview

- **CPU** → central processing unit “brain”
  - Executes the "instructions“ in programs

- **Main memory** → random-access memory = “RAM”
  - Stores data that CPU accesses, including instructions
  - FAST, but temporary; wiped out when computer is shut off!

- **Secondary memory** → Hard disks, CDs, DVDs, flash memory, etc.
  - Stores data that can be loaded into main memory
  - SLOWER, but permanent

- **I/O devices**
  - How you communicate with your machine
  - Keyboard, monitor, mouse, speakers, etc.

- **Networking equipment**
  - How others communicate with your machine
  - Networking “cards”, cables, etc.
Computer data consists of off and on pieces (often written as 0’s and 1’s)

- **bit**: A single cell in main memory that can hold either a 0 or 1

- **byte**: A sequence of 8 bits

- **word**: Unit of memory (often a sequence of 4 bytes)

Main memory: table of bytes indexed by “addresses”

<table>
<thead>
<tr>
<th>Address</th>
<th>Byte value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100111101</td>
</tr>
<tr>
<td>2</td>
<td>00011001</td>
</tr>
<tr>
<td>3</td>
<td>111111101</td>
</tr>
<tr>
<td>4</td>
<td>11000100</td>
</tr>
</tbody>
</table>
How Many Different Values in a...

- Bit?
  2
- Two bits?
  $4 = 2 \times 2$
- Byte?
  $256 = 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 \times 2 = 2^8$
- Word?
  $4,294,967,296 = 2^{32}$
- In general $k$ bits can represent $2^k$ values
Other Standard Terminology

One kilobyte is approximately one kibibyte which is approximately 1000 bytes.

\[ 2^{10} = 1024 \]
\[ 2^{20} = 1024^2 \]
\[ 2^{30} = 1024^3 \]

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<table>
<thead>
<tr>
<th>Prefixes for bit and byte multiples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Decimal</strong></td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Value</td>
</tr>
<tr>
<td>1000</td>
</tr>
<tr>
<td>1000^2</td>
</tr>
<tr>
<td>1000^3</td>
</tr>
<tr>
<td>1000^4</td>
</tr>
<tr>
<td>1000^5</td>
</tr>
<tr>
<td>1000^6</td>
</tr>
<tr>
<td>1000^7</td>
</tr>
<tr>
<td>1000^8</td>
</tr>
</tbody>
</table>
How Are Characters, Etc., Represented?

Via *encoding schemes*

Example: ASCII (American Standard Code for Information Interchange)

- Standard for encoding character values as bytes
- In ASCII:
  - ‘A’ 01000001
  - ‘a’ 01100001
  - ‘,‘ 00101100
  - etc.
Other Character Encodings

- International support?
  - Unicode
- Most common variation: UTF-8
  - Backwards compatible with ASCII
Software Overview

❖ **Two levels** → Operating System and Application

❖ **Operating system** → manages computer's resources; typically runs as soon as computer is turned on. Typical responsibilities:
  ◦ *Process management* → Determines when, how programs will run on CPU time
  ◦ *Memory management*
  ◦ *I/O, window system*
  ◦ *Network control*
  ◦ *Security*

❖ **Applications** → programs users interact directly with; usually are explicitly run. Examples:
  ◦ *Word processors*
  ◦ *Games*
  ◦ *Spreadsheets*
  ◦ *Music software*
  ◦ *Java Programs*
  ◦ *Etc*
How Programs Are Executed

Program “foo” initially stored in secondary storage

Program copied into main memory

CPU executes program instruction-by-instruction
Programming Languages

- Used to write programs that run on computers

- Generations of programming languages
  - 1st (1GL): machine code
  - 2nd (2GL): assembly code
  - 3rd (3GL): procedural languages
  - 4th (4GL): application-specific languages
  - 5th (5GL): constraint languages
1st Generation: Machine Code

- Recall: computer data is 0’s and 1’s
- In machine code, so are programs!
  - Program $\rightarrow$ sequence of instructions
  - Machine code $\rightarrow$ instructions consist of 0’s and 1’s
- Next slide $\rightarrow$ example machine code instruction from MIPS (= “Microprocessor without interlocked pipeline stages”) architecture
  - Popular in mid-, late 90s
  - Instructions are 4 bytes long
Example MIPS Instruction

- “Add data in addresses 1, 2, store result in address 6”:
  00000000001000100011000000100000
- ???
  000000 00001 00010 00110 00000 100000

```
opcode
1st address
2nd address
destination address
shift amount
function specifier
```
Problem with 1GLs: Who can remember those opcodes, addresses, etc., as 0’s, 1’s?

Solution (1950s): assembly language
- Use mnemonics → descriptive character strings for opcodes
- Let programmers give descriptive names to addresses

MIPS example revisited:
add $1, $2, $6
instead of
00000000001000100011000000010000
for “add contents of addresses 1, 2, store result in 6”
Assemblers

- Computers still only work on machine code (1GL)
- Assembly language is not machine code
- *Assemblers* are programs that convert assembly language to machine code ("object code")
Problems with 2GLs

- *Platform dependency*
  - Different kinds (*architectures*) of computers use different instruction formats
    - E.g. x86, Pentium, 68K, MIPS, SPARC, etc.
  - 1GL / 2GL programs written for one kind of machine will not work on another
- *Low level* → programs difficult to understand

Solution (60s → now): *procedural languages*
Procedural languages

Higher-level, “universal” constructs

Examples:

1950's → early 60s: Fortran, Cobol
1958 → Lisp, invented for AI, still used!
late 60's → Algol, first language that "looks" modern
70's → Pascal (like Algol, but simpler), used for teaching
80's → C became popular (although it was "invented" in 70's)
    C++ "C with classes, object oriented"
90's → Java, Fully object oriented
00's → C# (Microsoft's answer to java)

List of computer programming languages

Computers can only execute machine code

*Compilers* are programs for translating 3GL programs ("source code") into assembler / machine code

Diagram:
- Source code → Compiler → Assembly/Object code
Interpreters

- Another way to execute 3GL programs
  - Interpreters take source code as input
  - Interpreters execute source directly
  - Much slower than compiled programs

- *Debuggers* are based on interpreters
  - Debuggers support step-by-step execution of source code
  - Internal behavior of program can be closely inspected

- Common interpreter?
Object-Oriented Terminology

- Procedural-oriented languages
  - Programming centers around “actions” *(verbs)*
- Object Oriented Languages
  - Centered on objects *(nouns)*
- Object
  - Principal entities that are manipulated by the program *(nouns)*
- Class
  - A “blueprint”/recipe that defines the structure for one or more objects
- Method
  - java term for a “function”, a “procedure” or a “subroutine”
  - this is the code that does something *(verbs)*
- Why we prefer the object-oriented approach?
  - One big reason: recycling
- System Example