Introduction to Computing with Images

CSC 1040 – Algorithms and Data Structures I

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Course website:
www.csc.villanova.edu/~map/1040/

Some slides in this presentation are adapted from the slides accompanying Java Software Solutions by Lewis & Loftus
What is this course about?

- Computer Science
- Problem solving
- Algorithmic thinking
- Data representation
- Images and graphics
- Visual communication
Our textbook

An Interdisciplinary Introduction to Image Processing
Pixels, Numbers, and Programs

Steven L. Tanimoto

The MIT Press
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

• **History:** Started as a United States government project, sponsored by the Advanced Research Projects Agency (ARPA) in late 1970’s
  
  – 1980’s: **ARPANET**
    
    • the wide area network and Protocols for communication, including url’s developed
  
  – 1990’s: **World Wide Web**
    
    • html and web browsers
IP and Internet Addresses

• Each computer on the Internet has a unique *IP address*, such as:

  204.192.116.2

• Most computers also have a unique Internet name, which also is referred to as an *Internet address*:

  hector.vt.edu
  kant.gestalt-llc.com

• The first part indicates a particular computer (*hector*)

• The rest is the *domain name*, indicating the organization (*vt.edu*)
Domain Names

- The last part of a domain name, called a *top-level domain* (TLD), supposedly indicates the type of organization:

  - **edu**: educational institution
  - **com**: commercial entity
  - **org**: non-profit organization
  - **net**: network-based organization

Sometimes the suffix indicates the country:

  - **uk**: United Kingdom
  - **au**: Australia
  - **ca**: Canada
  - **se**: Sweden

Additional TLDs have been added:

  - biz, info, tv, name
The World Wide Web

• The *World Wide Web* allows many different types of information to be accessed using a common interface

• A *browser* is a program which accesses network resources and presents them
  – Popular browsers: Internet Explorer, Safari, Firefox

• Resources presented include:
  – text, graphics, video, sound, audio, executable programs

• A Web document usually contains *links* to other Web documents, creating a *hypermedia* environment

• The term Web comes from the fact that information is not organized in a linear fashion
The World Wide Web

- Web documents are often defined using the HyperText Markup Language (HTML)

- Information on the Web is found using a Uniform Resource Locator (URL):
  
  http://www.cnn.com

  http://www.vt.edu/student_life/index.html

  ftp://java.sun.com/applets/animation.zip

- A URL specifies a protocol (http), a domain, and possibly specific documents
Reverse History of computing

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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
Computer Architecture

Central processing unit

Main memory

Bus

Disk controller

Video controller

Controller

Controller

Other peripheral devices
Main memory is divided into many memory locations (or cells).

Each memory cell has a numeric address, which uniquely identifies it.
Why is main memory called “RAM”???
“Random Access Memory (RAM)”

You don’t have to scan the memory sequentially – go to data directly using the address.
Memory characteristics

• *Direct access* or *Random access* – information can be reached directly (as opposed to sequentially as in the case of magnetic tape)

• *Volatile* - stored information is lost if the electric power is removed

• *Read/Write* – information can be overwritten (as opposed to read-only devices – ROM)
What is “ROM”? is it the opposite of “RAM”????
Read Only Memory

What is “ROM”? is it the opposite of “RAM”??
What is "ROM"?

"RAM"???

is it the opposite of

"ROM"?

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ROM is also random access

NO!
RAM vs. ROM

• **RAM** - Random Access Memory
  - synonymous with main memory:
    • fast
    • read/write
    • volatile
    • random access

• **ROM** - Read-Only Memory
  - ROM typically holds the firmware, eg BIOS
    • fast (except in CD-ROM)
    • read only
    • non-volatile
    • random access

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# Random Access Memory Devices

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<thead>
<tr>
<th></th>
<th><strong>Volatile</strong></th>
<th><strong>Non-volatile</strong></th>
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| **fastest** | CPU registers  
             Cache memory                              | ROM chip              |
| **fast**    | main memory (Also called Random Access Memory --  
                       RAM)                                             | ROM chip              |
| **slow**    |                                                                                   | USB flash drive  
                       Hard disks  
                       CD-ROM  
                       DVD                                                                 |
## Random Access Memory Devices

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<td>CD-ROM</td>
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<td>Hard disks</td>
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<td>CD-ROM DVD</td>
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| **fast**   | main memory  
             (Also called Random Access Memory -- RAM) | ROM chip |
|          |          | **optical**  
             CD-ROM  
             DVD | USB flash drive  
             Hard disks |
Storage Capacity

- Every memory device has a *storage capacity*, indicating the number of bytes it can hold.

- Capacities are expressed in various units:

<table>
<thead>
<tr>
<th>Unit</th>
<th>Symbol</th>
<th>Number of Bytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>kilobyte</td>
<td>KB</td>
<td>$2^{10} = 1024$</td>
</tr>
<tr>
<td>megabyte</td>
<td>MB</td>
<td>$2^{20}$ (over one million)</td>
</tr>
<tr>
<td>gigabyte</td>
<td>GB</td>
<td>$2^{30}$ (over one billion)</td>
</tr>
<tr>
<td>terabyte</td>
<td>TB</td>
<td>$2^{40}$ (over one trillion)</td>
</tr>
<tr>
<td>petabyte</td>
<td>PB</td>
<td>$2^{50}$ (a whole bunch)</td>
</tr>
</tbody>
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CPU and Main Memory

Central Processing Unit

Chip that executes program commands

Primary storage area for programs and data that are in active use

Main Memory

Synonymous with RAM
CPU and Main Memory

Historic note:
Von Neuman architecture

John Von Neuman, USA 1945

Central Processing Unit

Chip that executes program commands

Primary storage area for programs and data that are in active use

Synonymous with RAM

Main Memory
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

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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

  The system clock controls speed, measured in **gigahertz (GHz)**.

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The Central Processing Unit

Arithmetic / Logic Unit

Control Unit

Registers

Performs calculations and makes decisions

Coordinates processing (system clock, decoding, etc)

Small, very fast memory
Historic Note: Automatic control of computation

- The concept of a machine that can follow a series of steps - a “program”
- Some early steps:
  - Jacquard loom (1801)
  - Babbage's Difference engine and Analytical engine (1822)
  - Holerith's census machine (1890)
- Stored program and the fetch/decode/execute cycle (John von Neumann, 1945)
- ENIAC - first fully electronic digital computer (Eckert and Mauchley, 1946)
Reverse History of computing

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Data Representation

• Computers store all information *digitally*, using *binary* codes:
  
  – numbers
  – text
  – images
  – audio
  – video
  – program instructions
Analog vs. Digital Data

• **Analog**
  – continuous, in direct proportion to the data represented
  – music on a record album - a needle rides on ridges in the grooves that are directly proportional to the voltages sent to the speaker

• **Digital**
  – information is broken down into pieces, and each piece is represented separately
  – *sampling* – record discrete values of the analog representation
Binary Numbers

- Number system consisting of 1’s & 0’s
- Simplest way to represent digital information
- modern computers use binary numbers internally

A binary digit is called a **bit** - binary digit
A **byte** is a group of eight bits
Representing and processing bits

• Electronic circuits: high/low voltage

• Magnetic devices (eg hard drive): positive/negative

• Optical devices (eg DVD): light reflected/not reflected due to microscopic grooves
## Bit Permutations

<table>
<thead>
<tr>
<th>1 bit</th>
<th>2 bits</th>
<th>3 bits</th>
<th>4 bits</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>00</td>
<td>000</td>
<td>0000</td>
</tr>
<tr>
<td>1</td>
<td>01</td>
<td>001</td>
<td>0001</td>
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<td></td>
<td>10</td>
<td>010</td>
<td>0010</td>
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<td>101</td>
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<td></td>
<td></td>
<td>110</td>
<td>0110</td>
</tr>
<tr>
<td></td>
<td></td>
<td>111</td>
<td>0111</td>
</tr>
</tbody>
</table>

Each additional bit doubles the number of possible permutations
Bit Permutations

- How many permutations of $N$ bits?
- How many bits are needed to represent 64 items?
- How many bits are needed to represent 100 items?

How many items can be represented by

1 bit ?
2 bits ?
3 bits ?
4 bits ?
5 bits ?
Binary Representation of Information

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

• For example, every character is stored as a number, including spaces, digits, and punctuation

• Corresponding upper and lower case letters are separate characters
Representing Images

Bitmap
1 bit

Grayscale
8 bits

RGB Color
3 colors: red, green, blue
8 bits/color
24 bits
Program instructions are also encoded in binary:

E.g., could be the code that causes input of a symbol from the keyboard.
Memory devices store data of all kinds

- a number? a letter? the red component of a pixel? a program instruction?

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Memory devices store data of all kinds

Each memory cell stores a set number of bits (usually 8 bits, or one byte)

Large values are stored in consecutive memory locations
Historic note: Great human developments that gave rise to the modern computer

• 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)
Historic Note: Mechanization of arithmetic

- Development of number systems
  - Abacus (2400 BC)
  - Number systems (Babylonian, Greek, Roman, Arabic 1000 BC - 800 AD)

- The notion of an algorithm
  - Euclid (300 BC)
  - al-Khwārizmī (780 AD)

- Creation of special purpose calculators
  - Stonehenge (1900-1600 BC)
  - Napier's bones (1600, a precursor of the slide rule)
  - Pascal's adder (1642)
  - Leibniz's calculator (1670s)
  - modern calculators
Mechanization of Arithmetic

+ Automatic Control of Computation

= Modern Computer
Computer Science

Can be viewed as a culmination of humanity’s search for understanding of:

- Problem solving
- Mechanization
- Computation
- Representation & encoding
- Abstraction

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).