Computer Science 010
Introduction to Computer Applications
Siena College
Fall 2010

Topic Notes: Computer Structures

We begin the meat of the course by considering the fundamentals of computer structures. We will examine the components of modern computers and learn about how the components work together to allow the computer to perform its tasks.

We will not attempt a formal definition of the term *computer*, but we will consider the major functions of a computer:

1. to *gather* input data from users or devices,
2. to *process* data into information,
3. to *output* data and information, and
4. to *store* data and information.

The terms *data* and *information* are often used interchangeably, but we should be more precise here.

- *Data* (the plural form of "datum") are unorganized facts and figures, without an obvious meaning.
- *Information* is obtained by processing and orgainzing data in a meaningful way.

The text has a good example of this: your personal data such as your name, address, phone number, photograph, and so on are fairly useless on their own, but if you organize them to associate your name with your address and phone number to be able to answer a question like "What is John Smith's phone number?" we have created information.

We will spend much of our time early this semester looking more carefully at how computers gather, process, output, and store data and information.

Representing Data and Information

Before we go any further, it is necessary to think about how we can represent data and information for use by a computer. We think of our computers dealing with numbers, text, pictures, sounds, videos, and more. All of these things must be encoded in a way that a computer can gather, process, output, and store it.

The fundamental idea here is that as a computer is really just a collection of electric circuits. Those circuits transmit and store electrical signals are either off or on. Those signals encode the only two values a computer understands: the values 0 and 1.

Anything more complicated that we wish to use must be encoded using a sequence of these 0's and 1's, which are known as *bit*s, short for **b***inary dig***its**.

The function of any computer can be boiled down to this: it takes a collection of bits, some of which are data and some of which are instructions on what to do to that data, and performs those instructions, producing a new collection of bits.

Units for Measuring Data

While the fundamental unit of information is the bit, the smallest unit of data usually considered is a group of 8 bits, called a *byte*. A byte is enough to store any one of 256 (=2^8) values. Typically, a byte can represent a number or a letter or a special character (like a `!`). We will look more carefully later in the semester at how bytes can be used to represent specific number or characters.

To represent anything beyond the simplest data, we will need to use lots and lots of bytes. A page of text requires a few thousand bytes. So a several hundred-page book requires over a million bytes.

This leads us to some prefixes to indicate numbers, many of which you have likely heard used in this context:

Unit	Abbrv.	Size	
Kilobyte	KB	$2^{10} = 1024$ bytes	2.4% more than 10^3 (thousand)
Megabyte	MB	2^{20} bytes	4.8% more than 10^6 (million)
Gigabyte	GB	2^{30} bytes	7.3% more than 10^9 (billion)
Terabyte	TB	2^{40} bytes	9.9% more than 10^{12} (trillion)
Petabyte	PB	2^{50} bytes	12.5% more than 10^{15} (quadrillion)
Exabyte	EB	2^{60} bytes	15.2% more than 10^{18} (quintillion)
Zettabyte	ZB	2^{70} bytes	18% more than 10^{21} (sextillion)
Yottabyte	YB	2^{80} bytes	21% more than 10^{24} (septillion)

See: `http://www.unc.edu/~rowlett/units/large.html`

Note that each entry in the table is 1000 times larger than the previous. These are some incredibly huge numbers!

These prefixes are used elsewhere in describing sizes in computer technology. A camera's "megapixels" indicates how many millions of pixels are in the images that the camera can capture.

Hardware vs. Software

You have certainly heard the terms *hardware* and *software*. All of the physical components of the computer are considered hardware. The programs that use the hardware to perform specific tasks

make up the software.

We will discuss software in more detail later. For now, note that there are two major categories of software:

- *Application software* consists of the programs you use all the time, like an email client, a web browser, and a word processor.
- *System software* or the *operating system* is the interface between the hardware and software. This is what allows you to use the same (or at least very similar) applications on very different underlying hardware.

Hardware Components

We will break hardware into four categories for now: *input devices*, *output devices*, *processors and memory*, and *persistent storage*.

An additional category of *network devices*, which allow computers to communicate with each other, will be a major topic for us a bit later.

Input Devices

Some input devices are very common, others are more specialized.

- *keyboard*: enter typed data and commands
- *mouse* or *touchpad*: select items on a screen
- *microphone*: input audio
- *scanner*: capture digital images of physical media
- *digital camera* or *webcam*: capture capture digital images or video
- *stylus*: a “pen” to “write” on a screen

Output Devices

There is also a wide variety of output devices that you may or may not be familiar with.

- *monitor*: video output (previously CRTs, now LCDs)
- *printer*: produce physical output
- *speakers*: audio output

- *projectors*: really just another type of monitor

Processors and Memory

The brains of your computer – the part that can perform calculations and store the data used by those calculations – are the processor and memory.

If you open up a desktop or laptop computer, you will find a circuit board which has attached to it many other smaller circuit boards and other devices. This is the *motherboard*. It contains slots to install a *central processing unit* (CPU), *random access memory* (RAM) and expansion devices such as sound, video, modem, or network cards. There will also be external ports, where devices can be connected.

We begin with RAM, sometimes called *main memory* or *primary storage*. Modern computers have hundreds of megabytes or up to a few gigabytes of RAM. Data stored in RAM can be accessed quickly for use in computation. However, it is a *volatile* storage, so its contents remain intact only as long as the computer remains on.

The processor is what performs the computations by executing a sequence of *instructions*, which are simple commands like "add these two numbers" or "compare these two numbers". These commands as well as the data on which they operate are stored in RAM. A modern processor is capable of performing billions of these simple operations each second.

Measuring Speed

But.. how fast is fast, when discussing RAM and processors?

The basic unit is a *cycle* – this is how long it takes for one instruction to be executed by the processor, or a value to be stored or retrieved by the memory system.

We want to measure the number of *cycles per second*, and the unit here is *hertz*, abbreviated "Hz".

A speed of 10 Hz would indicate that there are 10 cycles per second, meaning each cycle takes 0.1 seconds.

Even the earliest computers were capable of a few thousand cycles per second. Today's computers do billions.

Our prefixes come into play here again. For many years, processor speeds were measured in *megahertz* (MHz) and today most are measured in *gigahertz* (GHz).

So let's consider a processor that operates at 1 GHz. This means it can perform one billion cycles per second, and hence performs each cycle in one billionth of a second. That is an unimaginably short amount of time. There is a *clock* keeping the operations of the computer synchronized that switches from a 0 value to a 1 value a billion times per second.

Just as we saw the prefixes for large multiples of a value, there are some common prefixes used to represent fractional parts, in this case, of seconds.

Unit	Abbrv.	Length
second	s	10^0 (one)
millisecond	ms	10^{-3} (one thousandth)
microsecond	μs	10^{-6} (one millionth)
nanosecond	ns	10^{-9} (one billionth)
picosecond	ps	10^{-12} (one trillionth)

See: the SI multiples section at `http://en.wikipedia.org/wiki/Second`.

While these infinitesimal time scales are very hard to comprehend, we can think about some things we think are fast and compare them to the speed of a computer.

Consider typing at a keyboard. The world's fastest typists can input around 100 words per minute. Given an average word size of 6 characters (5 letters plus a space), how many characters per second would these typists be producing?

Contrast this with the number of instructions a 1 GHz processor is processing. In the time it takes for a very speedy human to type a character, how many instructions has the processor executed?

The "Hertz" rating for a processor is an important factor in determining how much computational power a computer has. We will consider other factors later in the semester.

Persistent Storage

Since RAM is a volatile storage, any data that needs to be stored when the computer is power off, or any data that is too large to fit in RAM, must be stored in a *persistent storage* device.

There are a number of technologies, varying in size and cost, that provide persisent storage.

- *magnetic disks*: bits of data are stored in densely-packed magnetic particles on a surface
  - *floppy disks*: becoming a legacy technology due to small storage capacity (1 MB)
  - *hard disks*: most common current technology, capacities now exceed 1 TB for both internal and external drives
- *optical discs*: compact discs (CDs), digital video discs (DVDs), Blu-ray disc – capacities from around 700 MB for a CD to 25 GB for a Blu-ray
- *flash storage*: key/thumb drives, memory cards – now can store 64 GB or more

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Device Connection Interfaces

Next, we consider how devices (or, *peripherals*) can be connected to a computer. You have likely seen how many different devices connect. For the novice, this is just a matter of matching the right cord to the connection that fits the cord. But we will spend a bit of time considering the common interfaces on modern computers and which devices typically use them.

A peripheral is (typically) connected via a cord that ends with a *connector*. The connector has a shape that matches with a *port* on the computer. Usually, the connector has some number and configuration of metal pins, and these pins make contact with matching pin slots on the port.

It is through these connections that the peripheral device and the computer communicate using electrical signals. At most one value can be transmitted on each pin at a time, so any meaningful amount of data will need to be transmitted *sequentially*, forming a *bitstream*.

The speed of an interconnect is determined by how quickly this bitstream can be transmitted, its *transfer rate*.

- *data transfer ports*: two-way data communication
  - most common today: *universal serial bus* (USB)
  - legacy: the traditional *serial port* and *parallel port*
  - fast: *FireWire*
- *network ports*
  - *Ethernet port*: local area network connection
  - *modem port*: phone line (also becoming legacy)
- *audio/video ports*
  - *video graphics array* (VGA): connect older monitors
  - *S-video* (super video): PC/TV interconnect
  - *digital video interface* (DVI): digital LCD connection
  - *High-Definition Multimedia Interface* (HDMI): home theater

The transfer rate varies widely among these devices. These are measured in *bits per second* (bps).

Older serial ports operated at 115 Kbps and parallel ports could operate at 500 Kbps. The original USB ports operated at 12 Mbps and USB 2.0 increased that to 480 Mbps. USB 3.0 will operate at 4.8 Gbps.

FireWire devices can operate at 400 Mbps or 800 Mbps.

See: `http://www.coolnerds.com/Newbies/Ports/ports.htm`