3

Information technology systems

Contents

3.1 Hardware

3.1.1 The computer system

In this chapter, we look at the various parts that make up a computer system – the computer hardware. Even though different computers can vary greatly in performance and features, the different systems are similar in that they possess parts that are responsible for the same function; for example, each computer needs a central processing unit and main memory. This topic also addresses the different peripheral devices that can be attached to the core computer system.

What is hardware?

When you purchase a new computer, you will get two things for your money. You get the computer itself, with a range of cables and possibly a monitor, mouse and keyboard. You also get some (more or less useful) programs, such as the operating system, drivers and maybe some utility and application programs.

The hardware comprises all of the 'physical' parts of an IT system; that is, all those parts that you can touch and that take up space. The software consists of programs that are needed to operate the hardware. They are the instructions that the computer uses to perform a certain task. You should not confuse the software with the CD-ROMs or DVDs on which they are stored. They too are considered hardware. Software refers to the programs that are stored on these disks.

Let's use this very ITGS book that you are reading as an analogy. The hardware would be the paper on which it is printed, the ink of the letters, as well as the glue that binds the pages together. The 'software' would be the information written in this book or the ideas stored in the book.

What are some hardware components?

Presented simply, a computer system can be seen as a 'black box' that accepts data from the outside world, processes the data according to a program, and then displays the results. Personal computers, mobile phones, global positioning satellite (GPS) navigation systems, calculators and game consoles all work on the same principle. They take an input, process it and then display a result. IT systems generally possess the components listed below.

Input devices: These are pieces of hardware that send data and control signals to a computer. The keyboard, mouse and microphone are input devices that directly accept user input.

Output devices: These are hardware devices that send processed data from a computer to the outside world. Some output devices convert the digital data into analogue form that can be understood by humans. The monitor and printer are such examples. A robotic arm, such as that used in manufacturing, is another type of output device that is not used for computer–user communication.
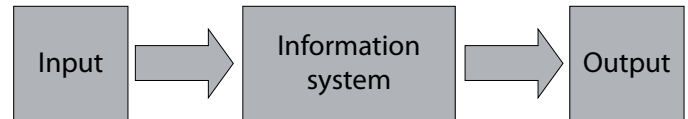
Computer system. A computer takes input, processes it and then displays an output.

What types of computers are there?

Viewed superficially, computers may look very different, possessing different screen sizes, memory capacities, speeds and other features. Mainframes and workstations are powerful computers designed to be used for scientific and financial applications. Netbook computers are extremely small and portable. Still, all of these computers have a sumilar design, even if they are manufactured by different companies and for different purposes. The large choice can be staggering and the consumer may be faced with a difficult choice. The customer must weigh the pros and the cons for each type when buying a new computer.

Mainframe computers: These are used by research institutes and companies. They are large machines that can occupy a whole room. They are used for elaborate and complex calculations, such as for predicting the weather forecast. The energy consumption of these machines is high, even before considering the energy used by air conditioning of the room to prevent the system becoming overheated.
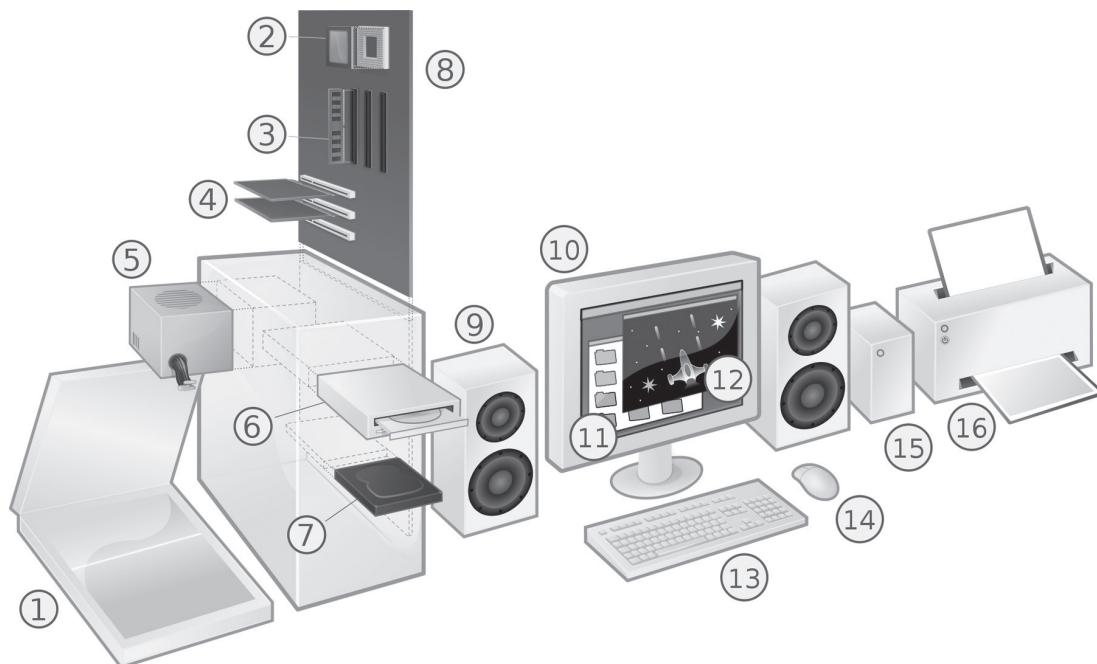
The parts of a computer system. 1: scanner, 2: central processing unit (CPU), 3: random access memory (RAM), 4: expansion cards, 5: power supply, 6: optical drive, 7: hard disk, 8: motherboard, 9: speakers, 10: monitor, 11: system software, 12: application software (e.g. game), 13: keyboard, 14: mouse, 15: external hard disk, 16: printer.

Server computers store large amounts of data and possess high processing power.

Workstations: These are much smaller and can hardly be distinguished externally from desktop computers. They possess powerful CPUs and substantially more main memory. Workstations are also used for time-consuming calculations, such as simulations.

Desktop computers: These machines are small enough to be placed on a table. They are sufficiently powerful for everyday office work. Compared to laptop or notebook computers, desktop computers offer more performance for the same price and can be upgraded more easily than the more compact laptop computers.

Notebook computers: The distinction between laptop computers and notebook computers is somewhat fluent. Laptop computers generally have larger screen sizes (about 17 inches), whereas notebooks have screen sizes of about 15 inches.

Subnotebooks: These have screen sizes of about 13 inches. They offer a compromise between the smaller netbooks and the larger notebooks.

Netbook computers: Netbooks are designed for greatest portability. Netbooks have screen sizes of 9–10 inches. They often do not possess optical drives and are optimized for low power consumption. The performance of these machines is substantially lower than that of laptops or notebooks of the same generation. They are primarily for those people who need a highly portable computer for presentation work or for reading the WWW.

Personal digital assistants (PDAs; e.g. palmtops or organizers): These computers are small enough to be held in the hand. They are about the size of a mobile phone.

Embedded systems: Embedded systems are small computers that can be found in cars, microwave ovens and other electronic devices. They control the operation of the device.
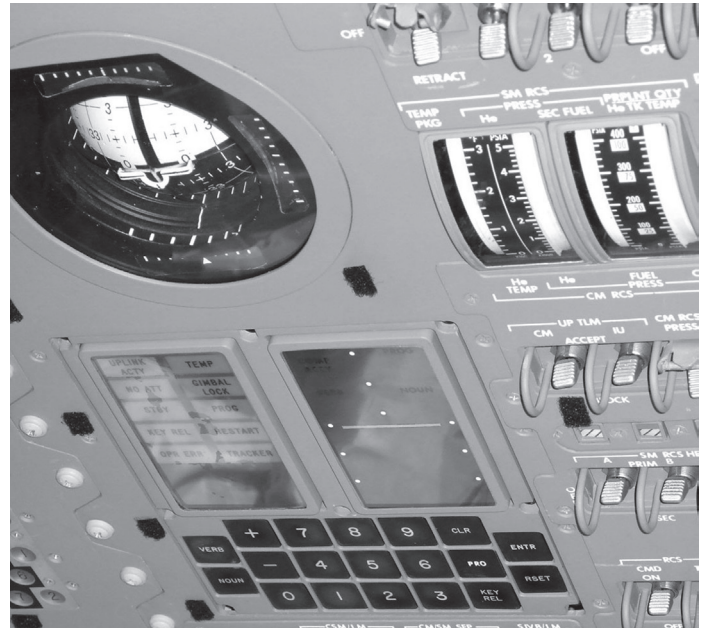
The Apollo guidance computer (AGC) was one of the first embedded systems. It assisted the astronauts in navigation and control of the spacecraft during the trips to the moon.
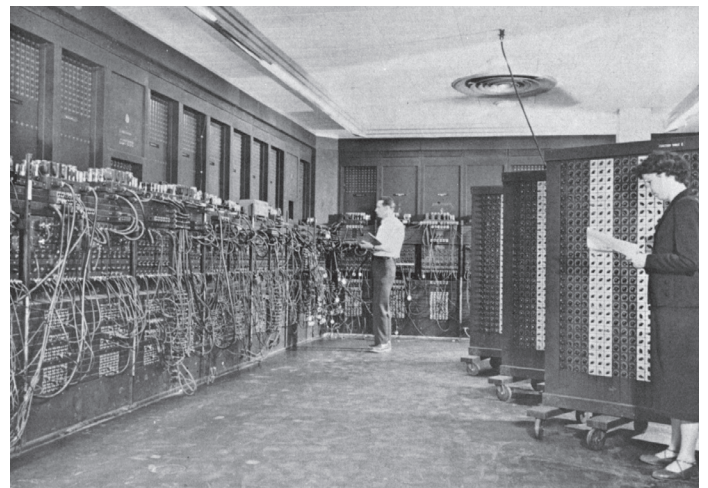
The ENIAC (electronic numeric integrator and calculator). Early computers were large and consumed much electricity.

What does the term platform refer to?

John recently received a new video game console as a present. He visits a shop and buys one of the games on DVD. Back at home he wants to run the game and places the DVD into the drive of the console. The DVD does not work. He discovers that he has accidentally bought a game designed for a personal computer and not for the game console that he owns. He has bought a game for the wrong platform.

In IT, the term *platform* refers to the type of hardware and operating system that is in use. It is not possible to run a

particular software program on a platform for which it was not designed to operate. A program that was designed for a game console will not work on a personal computer and vice versa. It is also not possible to run software designed for a personal digital assistant on a game console or on a super computer. The software must be compatible with its platform.

What are some platform examples?

Some common platform examples include:

Wintel computers: This term is a combination of the two words Windows and Intel. It refers to computers that use the Microsoft Windows operating system and Intel (or compatible) CPU.

Macintosh: The Macintosh (or Mac) is an operating system/hardware combination manufactured by the Apple company.

LINUX: This is an operating system that runs on many different types of hardware. It is free of charge.

Video game consoles: Several different companies manufacture video game consoles. They are not compatible with each other.

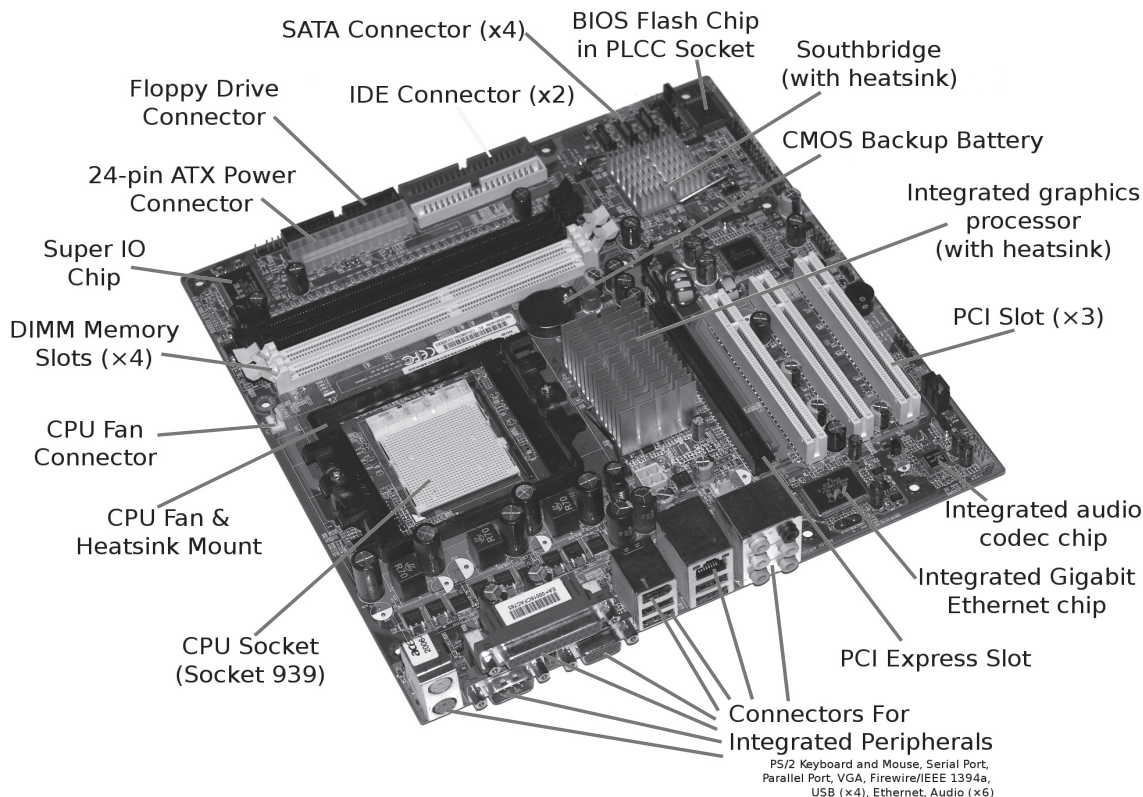**Mobile devices:** Many mobile devices (PDAs, MP3 music players etc.) use the ARM architecture, developed by the British company ARM Holdings. The ARM design presents yet another type of platform, which requires its own software.

These two organizers may appear similar from the outside but use two different platforms. Software written for one will not work for the other. The two systems are not compatible with each other.

For discussion

- Which platforms are you familiar with?

- Which ones are you using in school and at home?

Labels:
SATA Connector (x4)
BIOS Flash Chip in PLCC Socket
Southbridge (with heatsink)
Floppy Drive Connector
IDE Connector (x2)
CMOS Backup Battery
24-pin ATX Power Connector
Integrated graphics processor (with heatsink)
Super IO Chip
DIMM Memory Slots (×4)
PCI Slot (×3)
CPU Fan Connector
CPU Fan & Heatsink Mount
Integrated audio codec chip
Integrated Gigabit Ethernet chip
CPU Socket (Socket 939)
PCI Express Slot
Connectors For Integrated Peripherals
PS/2 Keyboard and Mouse, Serial Port, Parallel Port, VGA, Firewire/IEEE 1394a, USB (×4), Ethernet, Audio (×6)

The motherboard (or mainboard) of a computer is the central piece of hardware of a computer. It carries the CPU (grey square on the left), the main memory and sockets for expansion cards (right).

What is the MAC address?

The media access control (MAC) address is a unique number that is used to identify computers on a network. Every computer world wide has a different MAC address. The MAC address is also referred to as Ethernet ID, Airport ID (Apple computer) or physical address (Microsoft). The MAC address should not be confused with the Internet protocol (IP) address of a computer, which is more dynamic and can change frequently.

The MAC address is needed to permit data communication over networks. Network administrators can use MAC address filtering to allow or deny computers to connect to a network. MAC address filtering therefore increases the security of networks.

What does the motherboard do?

The motherboard (also known as the mainboard or system board) of a computer is the main component of a modern computer system. The motherboard contains the CPU of the computer, the memory and a wide range of different connectors and ports to attach peripheral devices. In many cases, it is sufficient to simply exchange the motherboard when the performance of the computer is no longer satisfactory. The computer case, power supply and peripherals (e.g. scanner, printer etc.) can remain the same as they have no effect on the computer's performance.

What does the CPU do?

The central processing unit (CPU) of the computer is also known as the microprocessor. It is a piece of hardware (a chip) that is responsible for two essential operations. First, the CPU controls the flow of data between the input and output devices. The CPU is also responsible for performing mathematical and logical operations. Essentially, the CPU can be considered the 'brain' of the computer.

Some devices (such as video cameras, sound cards and hard disks) deliver so much data that the CPU would be permanently occupied processing this data. The CPU could do nothing else and every time the user opens a file or records a video, the CPU would be blocked until the operation is completed. For this reason, modern computers use direct memory access (DMA), in which the data is written directly to the RAM, without having to use the CPU.
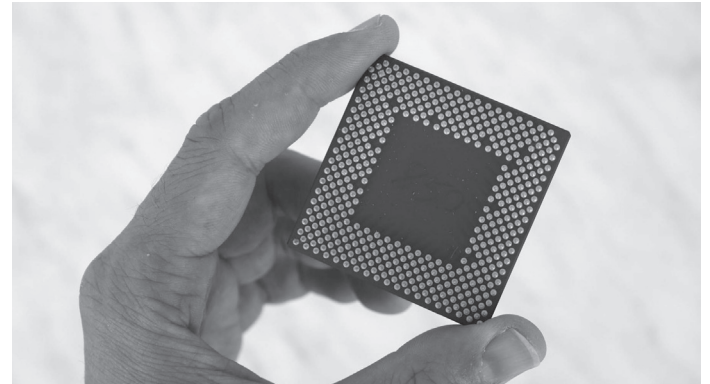
The central processing unit (CPU) of the computer is responsible for calculating and control operations.
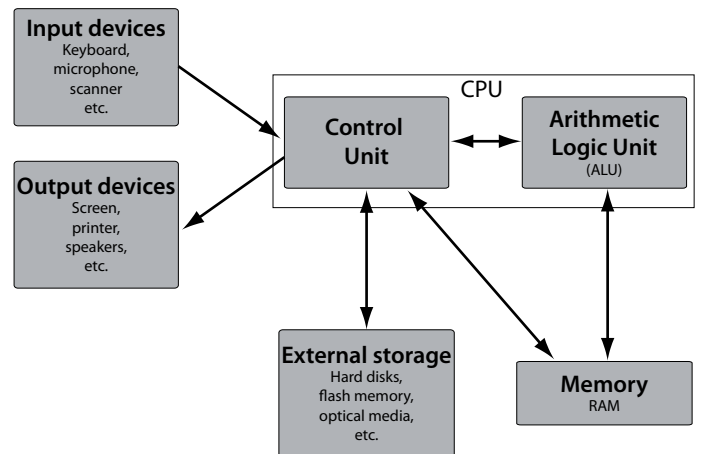
The central processing unit (CPU) contains the control unit (CU) and the arithmetic logic unit (ALU). The CU is responsible for coordinating the flow of data. The ALU performs mathematical and logical operations. The arrows indicate the possible directions of data flow.

A CPU produces much heat. A fan (shown) prevents overheating.

How is the speed of a CPU measured?

The CPU of a computer is the part that is responsible for performing calculations. It can be considered the 'brain' of the computer. The *clock cycle* of a CPU gives an indication of its speed. With all other factors being equal, the higher the clock cycle, the faster the computer. Modern computers possess clock cycles in the Gigahertz (GHz) range. One GHz corresponds to one billion clock cycles per second. The computer's clock ensures that all the operations inside the computer take place in a coordinated manner. Each calculation that the CPU performs requires a certain number of clock cycles. A faster CPU is able to perform more clock cycles per second than a slower one, but clock cycles are not the only factor that determines the computation power of a CPU. Older CPUs need more clock cycles to perform a particular calculation than newer CPUs, for example. The speed of the CPU is one factor that determines the speed of the whole IT system, but it is not the only factor. In many cases, the speed of the hard disk has a much higher effect on the overall performance of a computer system.

Current CPUs operate at around 3 GHz maximum. In the foreseeable future we are unlikely to see CPUs operating in the terahertz (THz) range. Current transistors are not capable of switching at that fast a rate. Additionally, the electrical power required increases rapidly with more clock cycles.

What is the primary storage of a computer?

The primary storage of a computer system is composed of the random access memory (RAM) and read-only memory ROM). The primary storage of a computer can be directly accessed by the CPU.

Random access memory (RAM): The RAM is capable of storing data and software as long as the machine is supplied with electricity. The data disappears when the computer is not supplied with electricity; hence, RAM is referred to as 'volatile' memory. All of the data that the user types or loads into the computer is first stored in RAM. The computer then processes this data according to a program (the software) which itself is also stored in RAM. The results of this processing are then written to the RAM as well. The RAM therefore allows for reading and writing.

Read-only memory (ROM): A computer possesses a type of memory that cannot be erased when the electricity is turned off. This memory also cannot be deliberately (or accidentally) erased by the user. The ROM stores those instructions of the computer that are required as soon as the computer is turned on. The power-on self test (POST) of a computer, for example, is a program that is automatically started when the computer is switched on. This program is stored in ROM.
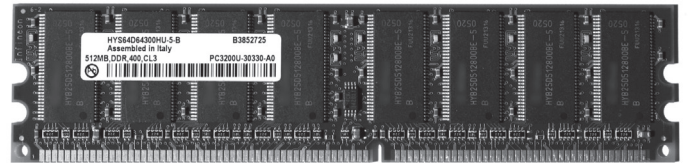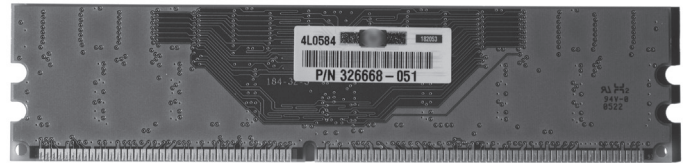
Primary storage. The random access memory (RAM) retains the data as long as the computer is supplied with electricity.

What are some common secondary storage devices?

Secondary storage devices (or external storage devices) store large amounts of data and software even when the device is not supplied with electricity. The external storage of a computer cannot be directly accessed by the CPU. Rather, the CPU communicates with these devices through input and ouptut interfaces. External storage devices are hardware components that are designed to store data and programs even when the computer is not supplied with energy. Hard disk drives (HDD), optical drives (e.g. DVDs, CD-ROMs, Blue ray disks etc.) and Flash memory cards are examples of external storage devices. The stored data or software is loaded into the computer's RAM, the primary storage, when needed. The computer then processes this data and the result can then also be found in the computer's RAM. The result is stored permanently only when the user saves the data to an external storage device.

Hard disks, hard disk drives (HDD): Nearly every personal computer nowadays comes equipped with a hard disk. They are able to store large amounts of data (in magnetic form) on a rapidly rotating aluminium disk. Hard disks are sensitive to bumps and knocks due to their mechanical nature. They are one of the fastest external storage devices and offer the most storage capacity for the money.

Optical disks (e.g. CD-ROMs, DVDs): Compact disk read-only memory (CD-ROMs) and digital versatile disks (DVDs) are external storage media from which the user is allowed to only read. Data cannot be erased from these disks. They are comparatively cheap, but slow. They must be stored properly otherwise they may be damaged by sunlight and the oxygen in the air. They are optical media because they use a laser beam to read the data.

Flash memory sticks: These memory devices are able to store data on microchip semiconductors, which allows for a very compact design. The cost is comparatively high for the amount of data that can be stored compared to other external storage devices available.

What are the advantages and disadvantages of different secondary storage devices?

Secondary storage media store data even when the computer is turned off (in contrast to the computer's memory, the RAM, which loses the data). The table at the bottom of this page summarizes the advantages and disadvantages of different storage media that are currently used.
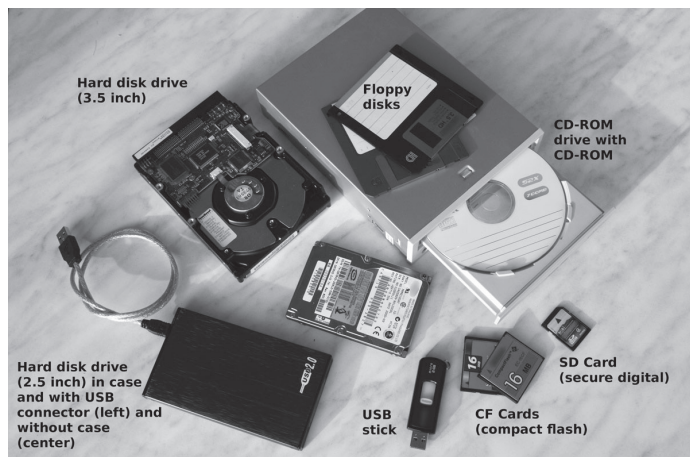
Various secondary storage media are shown.

How do computers store data?

IT systems store data in digital form, both on the internal memory (the RAM), as well on external storage devices (hard disk, CD-ROM, DVD etc.). Binary data can exist in only two states. All types of media, text, images and sound is represented in sequences of 0s and 1s. The lower case letter a, for example, is represented as 01100001. A binary number like this could, however, also represent a specific colour of a pixel in a digital photograph or even a number.

A computer software program is the instructions for the computer. This software is also stored in binary form. In this case, the different sequences of 0s and 1s represent different instructions to the computer. A computer does not differentiate between the storage of programs, text, pictures, music or videos. In the computer's memory all of these are stored in binary form. The binary number 01100001 could therefore also represent a specific instruction for the computer to perform a specific calculation.

But how are these 0s and 1s actually represented inside a computer? A computer contains billions of microscopic switches (so-called *transistors*) controlling the flow of electricity. These transistors can be found in the *integrated circuits* (ICs) of the computer. Each one of these switches can have one of two states: 0 or 1, where a 1 would stand for electricity on and a 0 for off. The computer is able to perform calculations by rapidly switching these transistors on and off.

Storage medium	Advantages	Disadvantages
Hard disk drive (HDD)	Fast; has large storage capacity; low cost per MB stored	Vulnerable to mechanical defects, loses data when not used for several years therefore not suitable for long-term storage
Floppy disk	Easy transfer of data between computers	Obsolete; has low storage capacity; sensitive to dust
USB stick	Practical; suitable for data transfer	Can be lost; limited number of read/write cycles; data loss possible due to damage; expensive per MB stored
Optical disk (e.g. DVD, CD-ROM)	Cheap; has large capacity	Slow; sensitive to oxygen in the air therefore not suitable for long-term storage
Tape drive	Cheap; has large capacity; is more suitable for long-term storage than other media	Requires a bulky separate tape drive system; slow due to sequential access
Solid state disk (SSD)	Can be used instead of hard disks; robust as it has no moving parts; fast	Currently very expensive and is not capable of storing the same large amounts of data as that by a hard disk
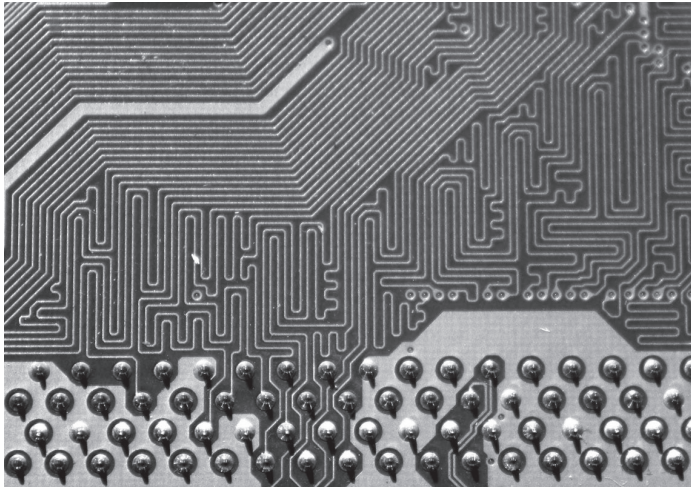
Motherboard. The circuit board tracks conduct electricity. The presence of a voltage represents a '1', its absence represents a '0'.
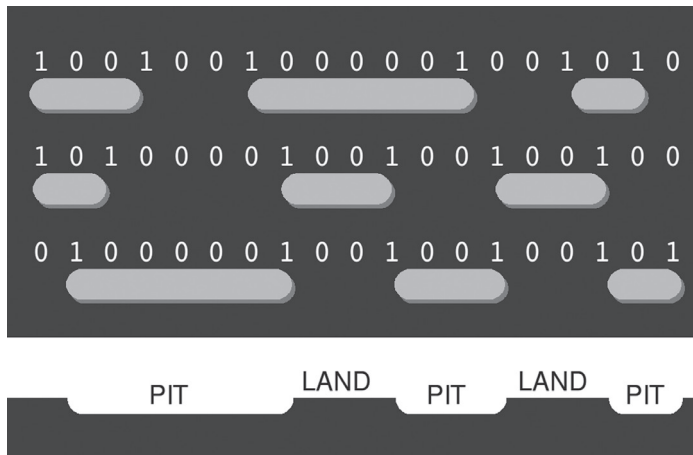
CD-ROM, DVD surface. The data is encoded as a series of 'pits' and 'lands'. Pits are physical depressions in the layer of the disk. The pits reflect the laser light differently than the lands. The pits and lands represent the 0s and 1s.

What are bits and bytes?

The smallest unit of information is a bit, a binary digit. A bit can have two states: it can be either 0 or 1. In IT we rarely talk about the individual bits because the two states are simply not enough to store sufficient information. We need to combine several bits together. Two bits can code for four different states, three bits for eight states. The number of different states doubles with every added bit. Eight bits are able to code for 256 different states. This is enough to store all the letters of the alphabet and a range of special characters. The eight bits are referred to as one byte and is the basic unit of memory storage in the field of IT.

0	0	0	0		4	1	0	0
1	0	0	1		5	1	0	1
2	0	1	0		6	1	1	0
3	0	1	1		7	1	1	1

Three bits are able to hold eight different combinations. One byte (eight bits) is able to hold 256 different combinations.

This is a machine-readable bar code. The sequence of black and white lines represents the sequence of 0s and 1s.

How much is 640 MB of data?

Let us now convert the 640 MB to bytes:
640 MB = 640 × 1024 × 1024 bytes = 671 088 640 bytes Dividing this number by the 6000 bytes per page results in 111 848 sheets of paper – a stack of paper measuring over 11 metres tall!

What are some important units in IT?

Computers use binary numbers for storing data.

Bit: The smallest unit of information is one bit. One bit of data can store two different states: either 0 or 1. The term *bit* is derived from the words *binary digit*.

Byte: One byte is composed of eight bits. There are 256 possible combinations of 0s and 1s that can be encoded in one byte. One byte corresponds to one character in a text document.

Kilobyte (KB): 1 KB = 1024 bytes. Small text files have a size of several kilobytes.

Megabyte (MB): 1 MB = 1024 KB (traditional view) or 1MB = 1000 KB (metric system). Digital photographs are a few megabytes large.

Gigabyte (GB): 1 GB = 1000 MB. Video films are in the area of a few gigabytes.

Terabyte (TB): 1 TB = 1000 GB. This is the capacity of a large hard disk (as of 2009).

Petabyte (PB): 1 PB = 1000 TB. According to one estimate, all text ever written by humans since the beginning of history amounts to about 50 PB of data. The Internet search engine Google processes about 20 PB of data every day.

Exabyte (EB): 1 EB = 1000 PB. The global Internet traffic of one month (in 2008) was estimated to be about 5 to 8 EB. As of 2006, all the computers of the world stored approximately 160 EB. By 2009, the Internet was estimated to contain about 500 EB of data.

Zettabyte (ZB): 1 ZB = 1000 EB. One estimate has stated that all human speech ever spoken, if digitized, could be stored in 42 ZB.

Yottabyte (YB): 1 YB = 1000 ZB.

The floppy disk (left) is capable of storing 1.44 MB of data and the DVD (right) can store 4.7 GB. The storage capacity of 3342 floppy disks would fit on one DVD.
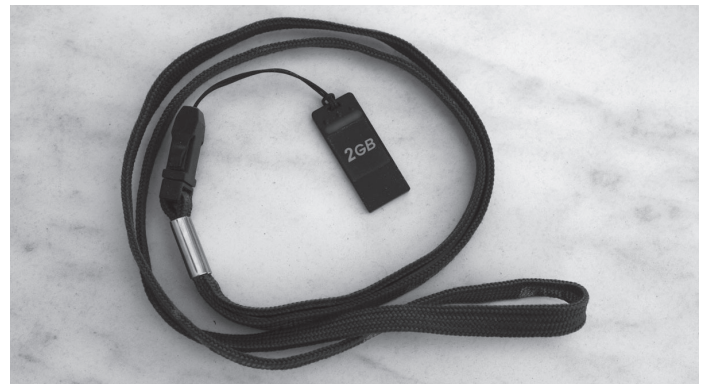
USB flash memory stick. The size of a storage device can usually be found printed on the device.

For discussion

- Obtain an advertising pamphlet for a computer system and write down the specifications of the advertised computer. How much RAM does it have? What is the size of the hard disk? What is the size of the screen? How fast is the CPU?

- Then, towards the end of this course, after about 1.5 years, try to obtain new advertisements of a computer that costs the same amount of money (the same price is important!). Compare the performance of the two computers.

- How much more can the new computer do when compared to the old one?

What is ASCII?

ASCII stands for American Standard Code for Information Interchange. It is a standard that links each letter of the alphabet (including punctuation marks) with a specific number. It is necessary to assign a specific number to each letter of the alphabet because a computer is able to store and process text (and any other media) only in the form of binary numbers.

Standard ASCII can encode only 128 characters (i.e. seven bits). This is not enough to encode the numerous special characters of different languages. For this reason different standards (such as Unicode) were introduced to accommodate these characters.

The words 'Hello world!' in ASCII are represented as follows.

Char	Decimal	Binary
H	72	1001000
e	101	1100101
l	108	1101100
l	108	1101100
o	111	1101111
	32	0100000
W	87	1010111
o	79	1001111
r	114	1110010
l	108	1101100
d	100	1100100
!	33	0100001

ASCII example. Note that the space also occupies one character.

What is Unicode?

Standard ASCII is capable of storing only 128 characters. This is not enough to represent the special characters of many of the world's languages. Unicode overcomes this limitation. Unicode was first introduced in 1987. It currently represents 107 000 different characters in 90 scripts.

π Я 音 æ∞

Unicode is able to represent a large number of different characters, substantially more than standard ASCII.

What are peripherals and ports?

The term *peripheral* refers to any hardware component that can be connected to the computer system, and which is not part of the 'core' design of the computer. A peripheral device extends the capabilities of a computer system. Monitors and keyboards are considered essential to the function of a computer system and are therefore not considered peripheral devices. Common peripheral devices include input and output devices such as microphones, scanners, graphics tablets, printers or cameras.
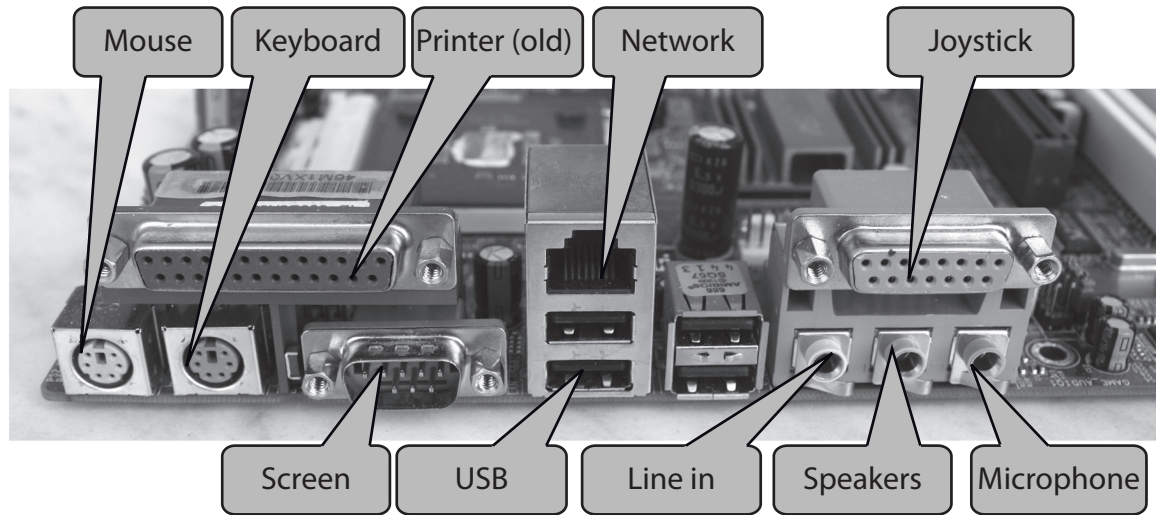
Peripheral devices can be grouped into two categories. Internal peripheral devices are all those input/output interfaces that are built into the computer. A microphone or webcam that is built into a notebook computer, for example, is considered an internal peripheral device. Other peripheral devices are connected over a cable to the core computer unit. Examples include printers, external microphones etc.

All external devices connected to a computer are connected to ports. These are hardware interfaces that supply the device both with electricity and have lines for data communication.

Decimal	Binary	Char	Decimal	Binary	Char	Decimal	Binary	Char	Decimal	Binary	Char
0	0000000	Ctrl @	32	0100000		64	1000000	@	96	1100000	`
1	0000001	Ctrl A	33	0100001	!	65	1000001	A	97	1100001	a
2	0000010	Ctrl B	34	0100010	"	66	1000010	B	98	1100010	b
3	0000011	Ctrl C	35	0100011	#	67	0100001	C	99	1100011	c
4	0000100	Ctrl D	36	0100100	$	68	1000100	D	100	1100100	d
5	0000101	Ctrl E	37	0100101	%	69	1000101	E	101	1100101	e
6	0000110	Ctrl F	38	0100110	&	70	1000110	F	102	1100110	f
7	0000111	Ctrl G	39	0100111	'	71	1000111	G	103	1100111	g
8	0001000	Ctrl H	40	0101000	(	72	1001000	H	104	1101000	h
9	0001001	Ctrl I	41	0101001	)	73	1001001	I	105	1101001	I
10	0001010	Ctrl J	42	0101010	*	74	1001010	J	106	1101010	j
11	0001011	Ctrl K	43	0101011	+	75	1001011	K	107	1101011	k
12	0001100	Ctrl L	44	0101100	,	76	1001100	L	108	1101100	l
13	0001101	Ctrl M	45	0101101	-	77	1001101	M	109	1101101	m
14	0001110	Ctrl N	46	0101110	.	78	1001110	N	110	1101110	n
15	0001111	Ctrl O	47	0101111	/	79	1001111	O	111	1101111	o
16	0010000	Ctrl P	48	0110000	0	80	1010000	P	112	1110000	p
17	0010001	Ctrl Q	49	0110001	1	81	1010001	Q	113	1110001	q
18	0010010	Ctrl R	50	0110010	2	82	1010010	R	114	1110010	r
19	0010011	Ctrl S	51	0110011	3	83	1010011	S	115	1110011	s
20	0010100	Ctrl T	52	0110100	4	84	1010100	T	116	1110100	t
21	0010101	Ctrl U	53	0110101	5	85	1010101	U	117	1110101	u
22	0010110	Ctrl V	54	0110110	6	86	1010110	V	118	1110110	v
23	0010111	Ctrl W	55	0110111	7	87	1010111	W	119	1110111	w
24	0011000	Ctrl X	56	0111000	8	88	1011000	X	120	1111000	x
25	0011001	Ctrl Y	57	0111001	9	89	1011001	Y	121	1111001	y
26	0011010	Ctrl Z	58	0111010	:	90	1011010	Z	122	1111010	z
27	0011011	Ctrl [	59	0111011	;	91	1011011	[	123	1111011	{
28	0011100	Ctrl \	60	0111100	<	92	1011100	\	124	1111100		
29	0011101	Ctrl]	61	0111101	=	93	1011101	]	125	1111101	}
30	0011110	Ctrl ^	62	0111110	>	94	1011110	^	126	1111110	~
31	0011111	Ctrl _	63	0111111	?	95	1011111	_	127	1111111	D

Each character possesses a unique ASCII value. The table shows these values in decimal and binary form.

The ports are inter-faces. Peripheral devices can be connected to these ports.

Mouse · Keyboard · Printer (old) · Network · Joystick

Screen · USB · Line in · Speakers · Microphone

What is compatibility?

Compatibility refers to the ability of different components of the IT system to work together. Compatibility may either refer to software or hardware compatibility.

Software compatibility refers to the ability of a program to run on different computers. If the memory or disk space is not enough to run the program, then the program is not compatible with this model of the computer.

Hardware compatibility refers to the ability to install different hardware components into the computer. If the connectors do not fit to the ports, then the component is not compatible.

Backward compatible: A component is backward compatible, if it provides all of the functions and features of the older component. For example, modern USB ports (USB v. 2.0) are backward compatible with the slow USB v. 1.1 devices. If you plug in a slow USB stick into a fast USB port, then the USB port will still be able to access the stick. The port will slow down to be able to communicate with the stick.

Forward compatible: A device is forward compatible if it is able to handle input that is designed for a later version.

For discussion

- Is your computer compatible with a particular software product? Try to obtain the cardboard box of a commercial software package. You can find the minimum system requirements written on the box.

- Compare these requirements with your actual hardware. Is the software compatible with your operating system and your hardware?

- Compare the results with other people of your class.
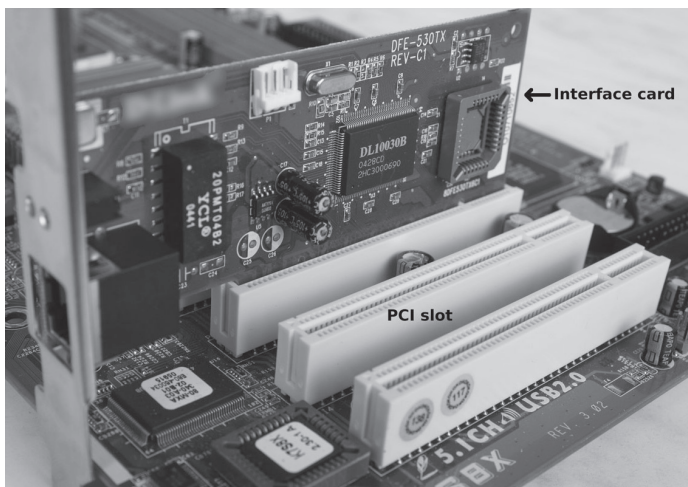
The interface card is compatible with the peripheral component interconnect (PCI) slots.

The fast USB port of the PC is compatible with the slow USB flash memory stick. The port will adjust its transfer speed so that the stick is able to handle the input.

3.1.2 Input and output devices

Introduction

The mouse and keyboard are the most common methods to input data but are not the only ones. The IT industry has developed a variety of specialized input devices and associated software. Some of these are available to consumers and others are directed more towards the commercial customer. This section will give you an outline of optical character recognition (OCR), optical mark recognition, bar codes, digital pens, graphics tablets and touch screens. Not all of them require specialized hardware; for example, OCR operates using conventional scanners but relies extensively on specialized software that may even include artificial intelligence functions.

What are interfaces?

An interface is a piece of hardware or software that allows two different systems to communicate with each other. A computer has a modular design. This means that different parts of the computer are exchangeable. The parts fit together at the interfaces, which must be designed in such a way that they fit together.

Computer–human interfaces: The computer keyboard is an example of an input interface that links the human being with the core computer system. Graphical user interfaces display information on the screen in an easily understandable manner using symbols, icons and buttons. The monitor is an output interface that displays the processing results to be

Braille output. This output device is a computer–human interface that enables blind people to read.

viewed by a person. In short, computer–human interfaces should guarantee a seamless communication between the machine and the person.

Hardware interfaces: Hardware interfaces are standardized to allow different hardware components to be connected to each other. The Ethernet network adapter and the USB port are two examples. Different manufacturers produce different devices which the user should be able to connect to his/her computer. The hardware interfaces are the plugs and sockets that allow these devices to be connected together.

Software interfaces: The ordinary user will probably not be confronted with software interfaces on a regular basis. Software interfaces become relevant only when people want to develop their own computer programs. These interfaces make sure that different program parts work together and that they are able to exchange data with each other.

Graphical user interfaces (GUIs): This is a user interface that allows users to interact with their computer, PDA or mobile phone without having to type commands. GUIs use icons, buttons and menus which allow users to interact with the computer in an intuitive manner.

Virtual reality (VR) interfaces submerge the user in a computer-generated environment. This picture shows VR gloves (input interface), VR goggles (output interface) and a microphone (input interface).

What are input devices?

Input devices are hardware components that are designed to accept data, either directly from the user or from other sources. They are used to feed data into a computer. They

take an external signal and convert it into a form that can be processed by the computer. Common input devices include the keyboard, mouse, touchpads, microphones and webcams.

Keyboard: The keyboard is a computer–human interface. It can be found on nearly all information systems that accept direct user input.

An ergonomic (split) keyboard allows the user to type without bending the wrists outwards.

Mouse: Computer mice are input devices that are commonly used in operating systems using GUIs. The user can point and click to objects on the screen and therefore receive immediate feedback on their actions.

Mouse. In 1984, a computer columnist wrote: 'There is no evidence that people want to use these things.'

Scanner: Scanners are used to digitize images, photographs and text.

Digital camera: Digital photographs are loaded from the camera into the computer. It is possible to also load photographs into the camera (output!), but this is not a common task.

Webcam: These cameras cannot store the images. They have to be connected to the computer during operation.

CD-ROM/DVD: It is not possible to overwrite regular CD-ROMs and DVDs. They can only be used to input data into the computer.

What are output devices?

Output devices communicate the result of the data processing to the outside world, in many cases directly to the user.

Liquid crystal display (LCD) panel: Liquid crystal displays present the result of data processing in visual form to the user.
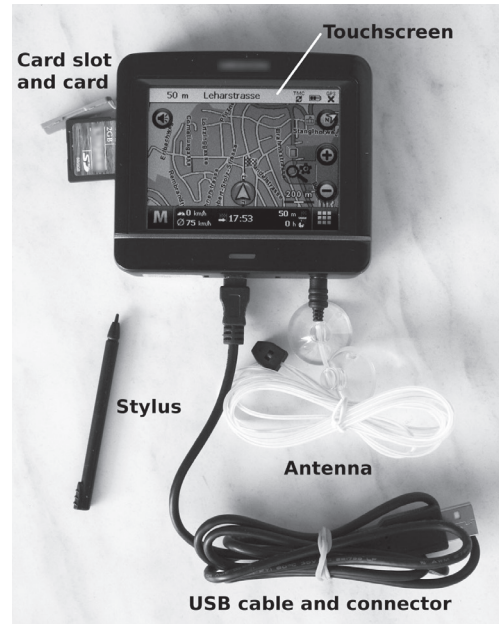
Global positioning satellite (GPS) receivers also possess input and output interfaces. In this particular case, the device possesses a touch screen for human input and an antenna (white) for receiving traffic information. Output interfaces include a speaker for speech and the LCD display. The memory card and the USB cable are for both input and output of data.

Virtual reality (VR) goggles: Virtual reality goggles possess built-in LCD screens and are worn over the eyes of the user. They give the viewer a three-dimensional (3D) vision. There is one separate screen for each eye.
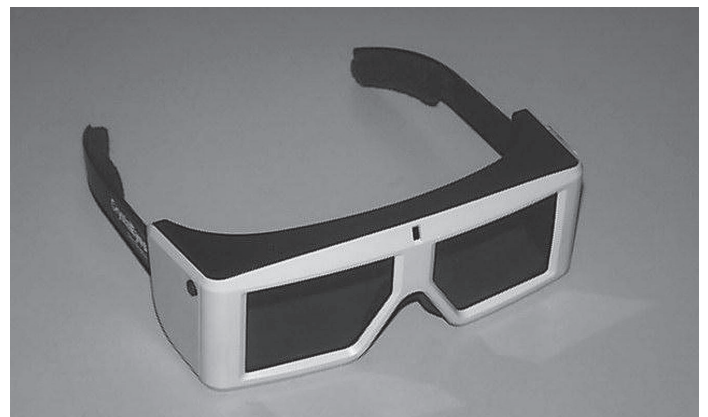
These shutter glasses enable the user to see stereoscopic (3D) images.

Printer: Printers produce 'hard copies' whether by spraying ink on paper (ink jet printers) or by melting a powdered pigment, the toner, into the paper (laser printers).

Speaker: Speakers must be connected to a sound card. Depending on the sound system, the speakers can be optimized for different frequency ranges to give the best sound performance.

Plotters: Plotters are specialized printers that are optimized for line drawings. A pen moves on a piece of paper on two axes.

Robotic arms: Robotic arms are output devices that are used in manufacturing.

What hardware acts as both input and output devices?

Some pieces of hardware serve as both input and output devices, meaning that the flow of data can go into both directions. External storage devices fall into this category. A computer can, for example, take data stored on a hard disk, perform calculations on the data and then write the results back to the hard disk.

Re-writable CD-ROMs/DVDs: It is possible to write and read data from these media.

Flash memory drives: They do not possess moving parts and store the data on a semiconductor microchip. Reading from these drives is often faster than writing to them, but data flow is possible in both directions.
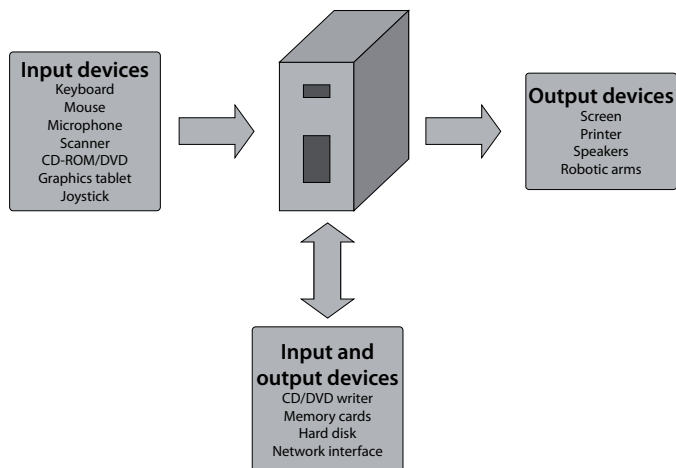
Hard drives: They store data in magnetic form. Hard drives are able to store large amounts of data and are relatively cheap.

Tape drives: These storage media are used for backup purposes. The data is stored magnetically and can therefore be overwritten.

What are digital pens?

Wouldn't it be great if you could write and draw on paper and then have the text and drawings transferred to a computer without having to scan the sheet of paper? Digital pens make this possible. They are used just like any other regular pen. The pen is not connected to a computer but is an independent device, even if it is a bit bulkier and larger than a regular pen. Mounted towards the tip of the pen, right next to the ball delivering the ink, is a small camera that records the movement of the pen on the paper. The pen stores the movement and the user can then transfer the data to the computer. The software will then analyse the stored coordinates and regenerate the text and images.

A problem that the pen designers had to solve was that of actually determining the position of the pen on the paper. How should the camera know where the pen is currently pointing to? This problem was solved by using a special type of paper that contains a fine pattern of small dots. The pattern of dots is different on every part of the paper and so it can be compared to the coordinates of a graph. The most common type of digital paper uses the so-called Anoto pattern of dots. In this pattern, dots are placed 0.3 millimetres apart. To the human eye this is so close that the paper appears in a uniform colour.

The digital pen is capable of digitizing and storing the handwriting of the user. The written text can then be down-loaded to the computer and then displayed on the monitor.

Input and output devices. Input devices receive data from the external world. Many input devices are directly operated by the user. An LCD screen, speaker and printer are common output devices found on nearly all home IT systems. They present the results of the computation to the outside world.

For discussion

- Digital pens store the drawings and writings of the user. Do you see any associated security and privacy issues? What could these be and how could you increase the security and privacy of digital pens?

What is OCR?

Sometimes a text document is available only in printed form. How can this text be entered into a computer? One possibility would be typing it into the computer using a word processor. This, however, is time consuming. It is also possible to scan the text with a scanner. The text is then present in the form of a pixel graphic. The text is then in the computer but can only be modified using a picture editing software program and not with a word processor. It is necessary to convert characters in graphic form to word processable ASCII text.
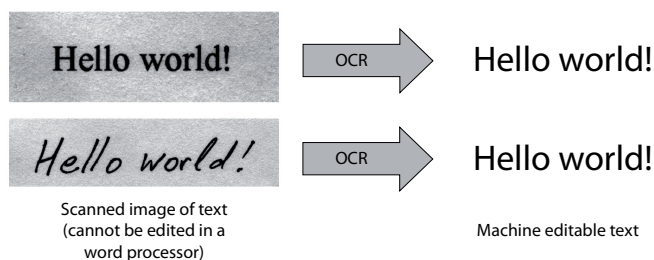
OCR stands for optical character recognition. It is a software program that is capable of converting the scanned text (i.e. a graphic) to ASCII text. OCR software uses a so-called pattern recognition engine that attempts to identify the different characters based on their shape. The pattern recognition engine must be able to recognize different fonts as well as distinguish the letters from dust and dirt from the scan. Initially, the OCR software may not be able to recognize all of the characters and words. The percentage of correctly identified words depends on a range of different factors, including:

Scanning resolution: The higher the scanning resolution, the better the recognition.

Size of printing: If the text is small, then recognition is decreased. The scanning resolution must be increased in this case.

Handwritten marks on the paper: Correction marks and comments on the paper will decrease the recognition quality. The software will attempt to interpret the marks as characters to be processed.

The number of pages processed: The software is able to learn the shape of the printed characters. It will ask the user for feedback (e.g. Is this letter an 'i' or an 'I'?). The more text that is processed, the higher the recognition rate.

Optical character recognition (OCR) converts a scanned image of printed or handwritten text into machine-editable (ASCII) text.

For discussion

- Make a hard copy (print-out) of a paragraph of text using different types of printers (ink jet or laser) and different types of paper (plain white paper and recycled paper).

- Scan these pages and process the page using OCR software. Which paper and printer combination results in the lowest error rate?

- Does scanning resolution or font size play a role? Does colour matter?

- Plan out a systematic investigation to determine the factors that influence the number of OCR errors.

How can OCR save your weekend?

Imagine the following disastrous situation.

You heeded the advice of your ITGS teacher and saved copies of your IB Extended Essay redundantly on different storage media. You saved your data on your notebook computer. Additionally you burned a backup DVD and also saved your essays and portfolios on a USB flash memory stick.

To be extra safe, you also make a backup copy of your whole hard disk once every two weeks on an external hard drive. You now have copies of your data on four different storage media. Certainly your data should be safe now! Unfortunately you are out of luck.

You accidentally bump your notebook computer against the table, causing the hard disk to malfunction. The hard disk starts to make strange clicking sounds and the computer won't start. You get the hard disk exchanged, but your Extended Essay is gone.

You try to recover the data from the DVD that you burned a few days ago, only to realize that the DVD can't be read by the computer. Now you remember that you left the DVD lying in the sun for some time. The sun's rays destroyed the data on the DVD.

But didn't you also save a copy to the external hard disk? You connect the hard disk and search for the stored files. After a few minutes you find them, only to realize that they are too old and that you only have the outline of the Extended Essay saved. Rewriting it would cost you days.

With shaky hands, you reach for your USB flash memory stick. A spark of static electricity jumps from the USB stick to your

fingers (this is mostly a problem in countries with dry air). Congratulations. You just destroyed the data on the stick. Only now you remember that your ITGS teacher told you that you should always touch a metal for discharging yourself before handling computer parts. After all, computer parts are horribly sensitive to static electricity. Unfortunately, you remembered too late…

You talk to your Extended Essay supervisor. He gives you the print-out that you submitted several days ago. You immediately make a photocopy of the essay and take it home. You were looking forward to a relaxing weekend but now have to spend it typing the essay into the computer again.

Suddenly you remember that your scanner came with optical character recognition (OCR) software. Your weekend is saved. You take the print-out and scan it page by page. The OCR software then converts the printed text to a text file.
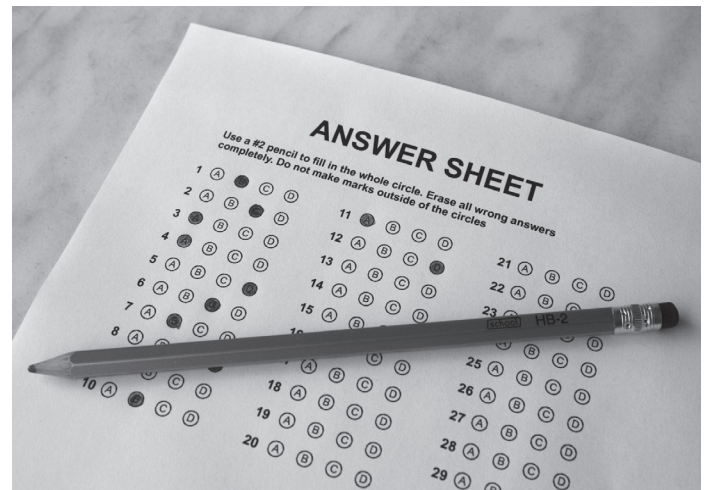
Optical mark recognition (OMR) answer sheet. Multiple-choice answers are often corrected with OMR.

For discussion

- Always make a print-out of important documents. In the case of complete data loss, you can always scan the printed document and convert it back to a word processing file.

For discussion

- Standardized multiple-choice tests (as used by the IB) are corrected using OMR. Give the computer system an easy time and make sure that the marks are clear and strong. Erase all wrong answers completely, otherwise the OMR system may not recognize your answer or will count more than one answer as marked (which is wrong).

What is OMR?

OMR stands for optical mark recognition or optical mark reading. It is the reading of human-made marks from surveys, forms and answer sheets. OMR can also be used for filling in ballots during elections. Multiple-choice exam answers are, for example, often answered by filling in circles or boxes with a no. 2 pencil onto an answer sheet. These answer sheets are automatically processed and a computer reads the marks made by the person. The system reads the marks by shining a narrow beam of light onto the marked paper. A filled-in circle will block the light and the system will thus recognize the mark.

The correct pencil type is critical. If the pencil is too hard, then the mark is too light and the light beam will pass the mark unhindered. The system will not capture the mark. The software will consider the question unanswered (and no point will be given). OMR is otherwise a very reliable input method with a low error rate. No complex pattern recognition software is needed (in comparison to OCR).

What are bar codes?

Bar codes are graphical representations of numbers that can be read by machines. A set of vertical lines represent the data. A bar code reader emits a laser beam. The white and black areas of the bar code reflect the laser light differently, which encodes the data. Bar codes can be found on a large variety of different objects. They serve in the identification of objects, among other uses.

Product code: In a department store, every product possesses a unique UPC (Universal Product Code) bar code. This bar code is scanned when the customer purchases the product at the counter.

ISBN number: Every published book is assigned a unique ISBN number. This number can be found on the back of a book, in combination with a bar code. Even if only the ISBN number is known, then the title of the book, author, publisher and edition of the book can be known as well. All books of the same edition have the same ISBN number.

Library systems: Some libraries place a sticker with a bar code on each book. This greatly speeds up the check-out process of the book. The book's ISBN number would not be enough here because the library may have several identical books. Each book must be uniquely identifiable. For this reason, each book will receive its own number.

Airports: Luggage pieces in airports are labelled with a bar code that indicates the destination of the luggage. The bar code is scanned automatically and the luggage is directed to the correct gate.
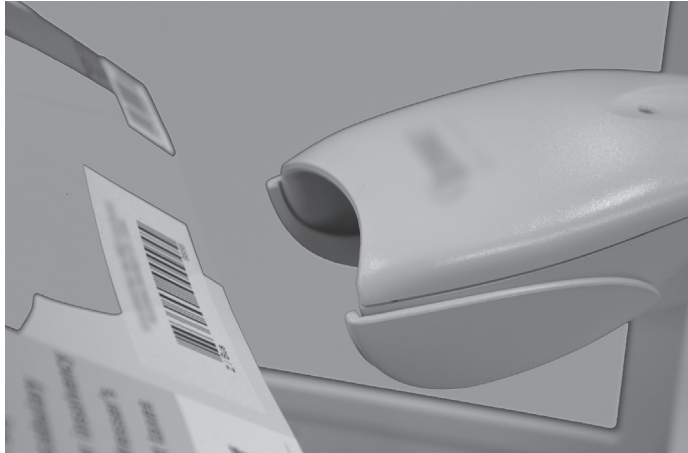
The bar code scanner emits a horizontal laser beam which passes across the bar code.
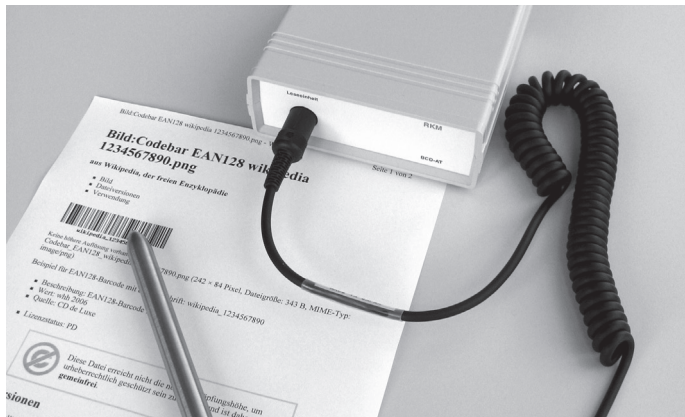
Pen-shaped barcode reader. These readers have to be moved over the bar code.

What is mobile tagging?

A mobile tag can be considered a two-dimensional (2D) bar code. The mobile tag can be photographed with cameras that are built into mobile phones or PDAs. The pattern of dots stores Web addresses or lines of text. A user who would like to quickly access a webpage with the mobile phone does not have to type the Web address into the phone. They can simply take a photograph of the mobile tag. The user is then connected to the webpage.


Mobile tag. Take a picture of this tag using your mobile phone. Are you able to read the text? It should read: 'Hello ITGS student! This text is encoded in the mobile tag.' The three squares help the software to orient the mobile tag for decoding.

What are RFID tags?

A radio frequency identification (RFID) tag is a small chip that can be attached to objects with the purpose of identifying and tracking the object.

An RFID tag is generally made of two parts: a chip and an antenna. The antenna supplies the chip with energy by catching the radio signal from a transmitter and converting this signal to electricity. The chip then uses the electricity to send back its identification code. These types of RFID tags are described as 'passive' because they do not require a battery. In contrast, 'active' RFID tags do require a battery, giving them the advantage of being able to communicate signals over greater distances.
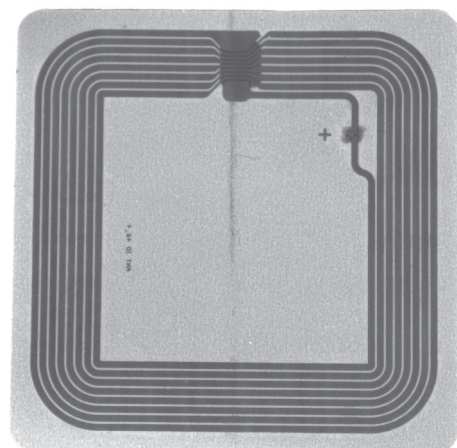
The spiral-shaped antenna converts the radio signal to electrical energy. The integrated circuit chip (top) stores an identification number.
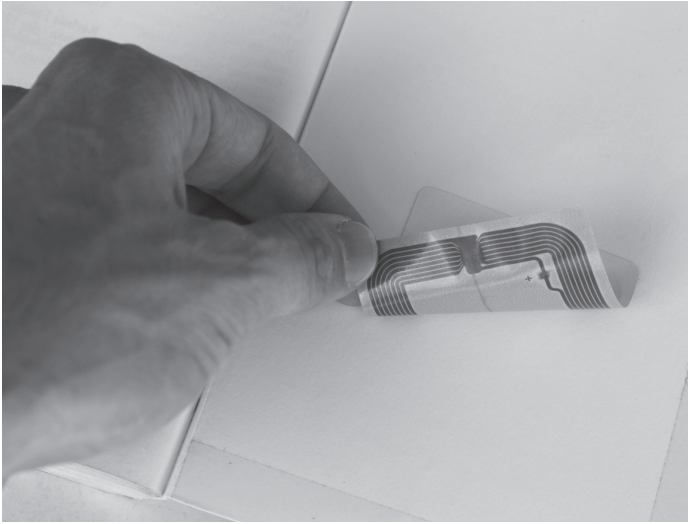
This radio frequency identification (RFID) tag identifies a specific library book.

How can RFID tags be used?

The application areas of RFID are numerous.

Electronic road pricing: Some countries require drivers to pay for the use of highways. RFID chips can automate the payment process. The vehicle simply has to pass beneath a transmitter for the toll to be collected. The RFID tag sends its identification code when requested.

Product tracking: RFID has simplified logistics. It can be used instead of bar codes to track the movement of products and other goods within a factory.

Animal identification: Domestic animals and livestock can be identified using RFID tags. One advantage is that the tags can be read from a distance without having to physically touch the animals. This increases safety.

Inventory systems: Companies can use RFID to label spare parts. The total number of parts available can be determined immediately by sending a radio signal into the spare parts container. Each RFID chip will respond with a unique identifier.

Human implants: RFID tags can be implanted under the skin to grant certain people access to high security areas. A night club owner might allow VIPs to voluntarily implant RFID tags to facilitate payment. This has already occurred.

Libraries: Books in libraries can be uniquely identified using these tags. The books can be checked out quickly by placing them on an RFID reader.

What is magnetic ink character recognition (MICR)?

A relatively high error rate is one disadvantage of OCR. The printed text may get overwritten or dirt on the paper may cause characters to be identified incorrectly. In the area of banking, where payment slips have to be processed automatically, this is a particular problem. Magnetic ink character recognition (MICR) overcomes this problem. MICR uses a special kind of ink that can be made magnetic. Each magnetized letter produces a particular electrical wave form as it is passed through the reader. This wave form will stay even if the characters are accidentally overwritten. Therefore, MICR offers the best of both worlds – it is both human readable and has a low error rate.

Magnetic ink character recognition (MICR) uses a standardized font. The characters can be read by humans and machines.

What are smart cards?

Smart cards contain an integrated chip with a non-volatile memory. The chip is therefore capable of storing data even without being supplied with electricity. Smart cards are versatile and can be used for identification and authentication of users and for the storage of data. In business, smart cards make financial transactions automatic, flexible and secure. Unlike RFID tags, smart cards need a direct electrical contact to be read. It is therefore not possible to read the data of the card without the owner being aware. This is an improvement in security.

Smart card. The bottom rectangle shows an enlarged image of the chip. The chip is located behind the contacts on the left.

Chip cards are used when a higher level of security is needed. Only the owner of the chip card is able to access the computer system.

What are different types of microphones?

Microphones are input interfaces that convert sound waves to an electrical signal. The signal is then digitized by the computer hardware. Microphones come in a large range of different shapes and sizes. Despite the apparent differences, microphones can be divided into two distinct types.

Dynamic microphones: These microphones are very rugged and can withstand much rough handling. They do not require an additional power source but are not as sensitive.

Condenser microphones: These microphones deliver an outstanding sound quality but are much more sensitive to loud sounds. Additionally, these microphones require an additional energy source.

Both types of microphones can be connected to the computer for the purpose of recording podcasts and for controlling the computer with voice.

How can webcams be used?

Webcams are low-cost video capture devices that are connected to a computer over a USB port. Some notebook computers have a built-in webcam above the screen. They often have an integrated microphone as well and can therefore be considered composite input devices. Generally, webcams are incapable of storing images and films and therefore must be connected to the computer all the time. Application areas of webcams include:

People who are deaf can use webcams to communicate using sign language.

Video telephony: Webcams are a popular addition to voice communication. Seeing another person's face while talking permits the communication of non-verbal body language. It is also a more natural form of communication than talking into a telephone.

Recording of films: Despite the generally low image quality, people have already used webcams to record short films and clips.

Video surveillance: Webcams can be used as video surveillance cameras. When connected to the Internet, for example, a webcam makes it possible to monitor one's home from a distance.

Webcams are frequently placed on top of a computer monitor.

What are some important characteristics of digital cameras?

Unlike webcams, digital still cameras can store the pictures that are taken. A digital camera can therefore be operated independently from a webcam. Digital cameras possess a significantly higher resolution than webcams. Relevant characteristics of digital cameras are given below.

Image resolution: In many cases, customers consider only a camera's image resolution to determine its quality. In the view of many people, the number of megapixels that the camera can capture is the only criterion. Nevertheless, image resolution is only one of several factors that can determine image quality.

Signal to noise (SNR) ratio: The camera should have a high signal to noise ratio. Cameras with a low SNR will deliver pictures that appear to have random speckles on an evenly coloured surface, such as the blue sky. A low SNR will therefore significantly reduce the image quality.

Shutter lag: This is the time between the pressing of the shutter until the actual taking of the picture. Some digital cameras can have a shutter lag of about 1 second. This is often too long for fast photography requirements, such as photojournalism or sports photography.

Quality of optics: Better cameras have larger objective lenses to catch more light. This way it is possible to reduce exposure time and the images become sharper.

What are camcorders?

Digital video cameras (camcorders) capture moving objects and store the data either on magnetic tape or on a flash memory card. The camera performs an analogue to digital conversion (ADC). The digitized film can be copied directly into the computer for further editing. The films of analogue video cameras cannot be processed directly by computer systems. In this case, a video capture card must first digitize the film.

Camcorders differ from webcams in several ways, such as:
They possess their own storage medium: The recorded movie is either stored on magnetic tape or on a memory chip. They can be operated independently of a computer.

More advanced optics: Camcorders have a larger objective lens to capture more light and to zoom.

Built-in LCD screen: The screen displays a menu and can be used to watch the recordings.

What are some uses of sensors and probes?

Sensors and probes are input devices that measure certain environmental factors, such as temperature, gas concentration, pressure or moisture. The sensors can be connected either directly to a computer's USB port or to a separate data logger. The sensor delivers an analogue signal to the computer. The computer must then digitize the signal before it can be stored for further processing. The environmental data is collected in real time and, often, over longer time periods. The relevancy of the data depends strongly on the time at which the measurement was made. For this reason, the computer will store both the time at which the measurement was taken, together with the measurement data itself.

Application areas of sensors include the examples below.

Scientific applications: Meteorological and other environmental data can be measured and stored for later analyses. Cities may implement sensors to measure the amount of air pollution present.

Safety applications: Sensors for radioactivity monitor radiation levels inside power plants. The computer will sound a warning if critical levels are reached.

Monitoring of engines: Sensors monitor the internal conditions (e.g. temperature, oxygen concentration) of a car engine and send these values to the car's central computer. The computer is then able to fine-tune the fuel–air mixture.

What are composite devices?

Composite devices combine several input interfaces into one single device. Game controllers, for example, combine both buttons and position sensors. Strictly speaking, a computer mouse is also a composite device, possessing buttons, a scroll wheel and a movement sensor.

Wii game controller. This game controller combines a motion sensor with push buttons.

Touch screens combine an LCD display with a pressure-sensitive surface. The user can interact directly with the computer by touching the different regions on the screen.

This game pad possesses input buttons and a track ball.

What are graphics tablets?

Graphics tablets are input devices that allow the user to write and draw using a special stylus. The graphics tablet, which is connected to the computer, tracks the movement of the stylus. Conventional graphics tablets do not display an image, so the user has to rely on the monitor to view the image. More advanced graphics tablets have a built-in screen that gives the user direct feedback. Some tablets are designed in such a way that it is possible to place a sheet of paper between the graphics tablet and the stylus.

What are touch screens?

Touch screens are modified monitors with a pressure-sensitive foil. The user can use either their fingers or a special stylus to point to objects on the screen or to move the mouse cursor. Touch screens enable users to interact intuitively with the computer – they can directly point and click to objects that are visible on the screen.

Touch screens must be calibrated before they can be used. If the foil and the screen information do not match, then the user will not be able to select the right area on the screen.

Graphics tablets can be used as an alternative to mouse input and are commonly used by people who do graphics-intensive work.

Graphics tablets are not only able to record the position of the stylus but also pressure and tilt. This allows for a very natural way of interacting with the computer and may be more comfortable than drawing with the mouse. People who suffer from repetitive strain injury (RSI) may experience an improvement in their symptoms when using a graphics tablet.

Graphics tablets are used by computer artists and in computer-aided design (CAD). It is also possible to combine the graphics tablet with handwriting recognition software. People who feel uncomfortable using a mouse can also use graphics tablets as a replacement for mouse input.

What types of printers are there?

Two common types of computer printers include ink jet and laser.

Ink jet printers: These use liquid ink, which is sprayed onto paper or onto the special overhead foils that have an absorbing surface. Ink jet printers can be relatively cheap to buy but expensive to operate. Replacement ink cartridges and special paper for photographic print-outs can soon surpass the initial cost of the printer.

Laser printers: These are more expensive to buy but have cheaper operation costs. Laser printers use a dry toner. Pages are printed as a whole and not line-by-line, as is the case with ink jet printers. Their speed is therefore substantially higher. Colour laser printers are more expensive in the long run than colour ink jet printers; hence, many people opt for an ink jet printer if colour capabilities are required.

What determines the quality of a monitor?

The quality of a computer screen is determined by several factors.

Viewable image size: Screen size is one of the most evident characteristics of a monitor. It is measured in inches diagonally across the visible area of the screen. Nevertheless, a larger screen is not automatically able to display more information, as it also depends on the resolution (i.e. the number of pixels) of the screen.

Contrast ratio: This value indicates the ratio of the brightest to the darkest colour that the monitor is able to display. Cheaper

LCD screens are unable to produce a completely black image. This reduces the contrast ratio.

Display resolution: This indicates the numbers of pixels horizontally and vertically. The higher the display resolution, the sharper the image.

Luminance: This value indicates the brightness of the screen. A high luminance is needed when the monitor is used close to a window or light source.

Viewing angle: This is the largest angle at which the screen can be viewed without losing too much image quality. The best image is seen when the user is positioned directly in front of the monitor. A large viewing angle will give a good image even when the user looks at the monitor from the side.

Response time: It takes a pixel on the screen a certain amount of time to change colours. The time it takes the pixel to go from black to white and back to black is its response time. People who play fast computer games need monitors with a fast response time otherwise the image quality will be reduced.

Power consumption: This is measured in watts (W). Monitors consume electricity even during standby mode.

Dead and hot pixels: Some pixels may not work and display a different colour or even as black. These pixels are called *dead pixels*. Other pixels may be stuck and display white all the time. Such pixels are labelled *hot pixels*. Nearly every monitor will have at least a few of these dead pixels.

For discussion

- Obtain different makes of monitors and check their quality. Which ones produce the blackest black? Check this by turning off the lights in the room and having the monitors display a black image.

- You can quantify the brightness levels by taking a picture of several screens at the same time and then comparing the colour values with the help of an image editing program.

- Do any monitors produce a significant amount of heat? This could be an indication of low efficiency.

- Do any monitors contain dead or hot pixels?

What are the differences between active and passive speakers?

Users have the choice of connecting either active or passive speakers to their computer system.

Active speakers: These require an additional energy source. Active speakers amplify the sound signal from the computer. They are useful when several people want to listen at the same time. These speakers may also have a volume and tone control.

Passive speakers: Earphones are passive devices. They use the unamplified signal from the computer to generate the sound. The loudness is therefore lower than that by active speakers, but is sufficient for operating the earphones.

What determines the quality of a video projector?

A video projector is an output device that takes a video signal and projects it onto a screen. Video projectors are used in conference rooms, in schools, for entertainment and in any other places where several people must be able to view the output at the same time.

The price of a video projector is determined by several factors: the brightness, the resolution and the ability to correct distortions.

Image correction: Image distortions will result if the projection screen is not located directly in front of the projector. If the projector is located below the screen (i.e. projecting upwards) then the image will be smaller at the bottom and wider at the top. Some parts of the image will also not be in focus. Video projectors can correct these distortions.

Brightness: The brightness of a video projector is measured in ANSI (American National Standards Institute) lumens (lm). The brightness of the image decreases with increasing screen size. More brightness is needed for larger screen sizes and when there is much ambient light in the room. Up to 2500 ANSI lumens is sufficient for small screen sizes. About 4000 lumens is adequate for large screens and for rooms that can't be dimmed.

Resolution: The resolution of a video projector is generally lower than that of a computer monitor. Video projectors may have a resolution of only 1024×786 pixels, whereas computer monitors for home/office commonly have around 1440×900 pixels. The lower resolution is generally not a problem because video projectors are rarely used to read small text. In addition, since video projectors are also viewed from a larger distance, the lower resolution is not distracting.

What are CD-ROMs and DVDs?

CD-ROMs (compact disk read-only memory) and DVDs (digital versatile disk) are optical storage media. A standard CD-ROM can store 640 MB of data and a DVD can store 4.7 GB. Optical media use a laser beam to read the data. The data is stored in the form of little holes (i.e. the *pits*) in the surface of the CD-ROM or DVD and deflect the laser beam into different directions.

There are two ways in which the data can be recorded onto an optical medium. Larger companies will record the data by pressing the disk. A second way is by burning the pits into the surface with a strong laser beam. CD-ROMS/DVDs that are made by burning the data are especially sensitive to sunlight and therefore should be stored in a dark place. The durability of burned optical media is generally not very long, probably only a few years. Some expensive media used specifically for archiving purposes do have a longer lifespan.

What should one do to increase the durability of an optical disk?

Burn the data slowly to the disk: Slower burning results in more clearly defined pits. More optical drives may then recognize the disk.

Choose high-quality media: Some disks contain silver as a recording surface. This silver can oxidize in the air. Disks based on gold are oxidation resistant but more expensive.

Store them properly: Store the disks in a dry dark place. Sunlight degrades the data layer of the disk.

Optical drive. CD-ROMs and DVDs are read by a laser beam.

A damaged CD-ROM. The outer parts of this disk are discoloured, a sign of a chemical reaction with air. The consequence is data loss.

Instead of typing a password, the user pulls his or her thumb over a fingerprint scanner. The scanner reads the patterns on the skin. If the pattern matches, then the user is granted access.

What is biometrics?

The word *biometrics* comprises two parts: 'bio', which stands for life, and 'metrics' which stands for measurement. Biometrics is the measurement of biological features of a human being, such as fingerprints, voice, face or the eye's iris pattern, for the purpose of authenticating a user. The user no longer needs to type in a password but uses a built-in fingerprint scanner, for example, to gain access.

The advantage of biometrics is that it is not possible to pass on a password to another person. It is also not possible to 'guess' a fingerprint or any other biological feature. In this sense, biometrics offers a higher security than passwords. Only the individual is capable of logging into the system, at least in theory.

Biometric authentication requires specialized input devices that are able to pick up the specific features of people.

Fingerprint scanning: The user presses the thumb against a pad that reads the pattern of the fingerprint. The pattern is then compared to the pattern stored in a database.

Voice recognition: Each person's voice is different. The user speaks a word into the microphone. A computer analyses the frequency spectrum of the voice and compares it with the database.

Biometric access control. Fingerprint scanners can also be used to control access to rooms.

This fingerprint scanner can be connected to a computer over a USB port.

computer hardware, software and data from being damaged, modified or deleted by unauthorized people. Security measures also prevent the unauthorized reading or copying of data. Proper security measures are necessary because IT systems often contain sensitive data about different people, whose privacy must be protected. An unauthorized modification of data by computer viruses or hackers can have drastic consequences for the affected individuals, and may even be a threat to life if, for example, medical data is manipulated.

Computer systems and their data need to be protected from people who are not authorized. Who determines the rights that different people should have? Who says that person A has the right to access certain files on the server but not person B? The rights are given to the people by the system administrator, based on the policy of the organization. Authorized access gives users the rights to use (i.e. to access) the computer systems and the data for specific purposes. The process of establishing the identity of a user is called authentication. There are several ways of checking whether a user has access rights.

Passwords: The use of a login/password combination is a common way of authenticating a user. Passwords are generally quite secure, provided that the user has chosen the password wisely and has not written it down somewhere.

Biometrics: Biometric devices measure the physical features of a person, such as fingerprints. If the fingerprint of the person matches the pattern stored in the database, then the user is granted access to the system.

Controlling physical access: Computers with sensitive data should not be accessible to unauthorized people. This can be as simple as locking up a computer.

Chip cards: These cards contain a small chip. The user has to insert the card into a card reader. Only then can the user access the system.

Password protection is a common security measure. Only the authorized person should know the password and have access to the system. Hackers may use special programs to 'crack' a password. There are two possible ways: a brute force attack and a dictionary approach.

A camera takes a picture of the person's iris (i.e. the coloured part of the eye). The iris of each person is unique.

Iris scanning: The person looks into a camera, which records the pattern of the iris in the eye. This pattern is unique for each person.

Retina scanning: Here, the pattern of the blood vessels in the person's eye is used for authentication. The person must look into a camera that magnifies the retina.

Face recognition: A camera takes a picture of the person's face. The distances between the eyes, nose and mouth are different in different people. This information is automatically measured and compared with the data stored in a database.

3.1.3 Social and ethical/ToK

Biometrics may, however, not be as secure as it may appear. In the year 2004, the Chaos Computer Club, a German hacker association, published a method on how to replace one's own fingerprint with that of another person. The procedure is very simple and does not require any specific equipment or even technical know-how.

Some people have to spend many hours each day working behind a computer. Workplaces that are not properly designed can lead to a variety of different health problems and decreased productivity. People may have worries and concerns about the use of biometric authentication and privacy. Finally, is the data stored on computer systems safe and can it be accessed in the future as well? Computer security measures protect the

Brute force attack: A brute force attack tries out all possible combinations of characters and numbers until the correct password is guessed. This requires powerful computers and takes time. The longer the password, the more time it takes to guess it. As a rule, the password should be eight characters or longer. An easy way to prevent such attacks is to automatically lock the account if there have been too many unsuccessful tries. The server may also prevent the user (or, in this case, the cracking software) from logging in immediately after a wrong guess. This will extend the total time required to crack the password.

Dictionary approach: For the dictionary approach, a large number of passwords are either single words or word combinations from a dictionary. The cracking software will try every word in a dictionary and combinations of several words. Often, a password is a single word from a dictionary with a number at the end. These passwords are also easy to guess. As a general rule, a password should look like a random combination of characters and numbers.

What do we learn from this? The passwords that you choose should be long enough and they should be made up of random characters and numbers, and not of meaningful words. The password 'hZ78KiX2' is much better than the password 'solarsystem', which can be guessed much more easily.

Do not give password crackers an easy time! Choose passwords that are:
- long enough;
- composed of characters and numbers;
- contain upper-case and lower-case letters; and
- easily remembered.

Brainstorm a few passwords and discuss whether you consider them to be 'strong' or 'weak'. Check the strength of your password with the online service at http://www.passwordmeter.com/.

Security: What is responsible computer use?

Responsible computer use makes sure that data is stored safely. Responsible computer use increases the reliability of computer systems and prevents data loss.

- Run frequent virus checks of your hard disk.
- Make sure that the antivirus software is frequently updated so that it is able to recognize the newest viruses.
- Do not open e-mail attachments from people you don't know. Many e-mails are generated automatically by viruses.
- Scan e-mail attachments from people you do know before opening them.

- Delete e-mails (and their attachments) that may contain viruses.
- Do not download and install software that you suspect contains spyware.
- Scan USB sticks for viruses before opening files, especially if you used the USB stick on several computers.
- Periodically change your passwords.
- Make regular backups and store them in a safe place.

These measures are often referred to as good housekeeping practices. Some US universities have started taking harsh measures to reduce the spread of computer viruses and to make students aware of the dangers. Some universities impose a fine (a virus 'cleaning fee' of $25 to $30, depending on the university) for accidentally spreading a virus. After all, some IT technicians have to spend weeks removing the viruses from hundreds of computers. In some cases, even the whole university network had to be shut down for days until all the viruses were cleaned off the system.

For discussion

- Did it ever occur to you that you lost data because of irresponsible computer use?

- Does the IT policy of your school require teachers and students to adopt responsible computer use?

- Does the policy of the school impose any sanctions for irresponsible computer use?
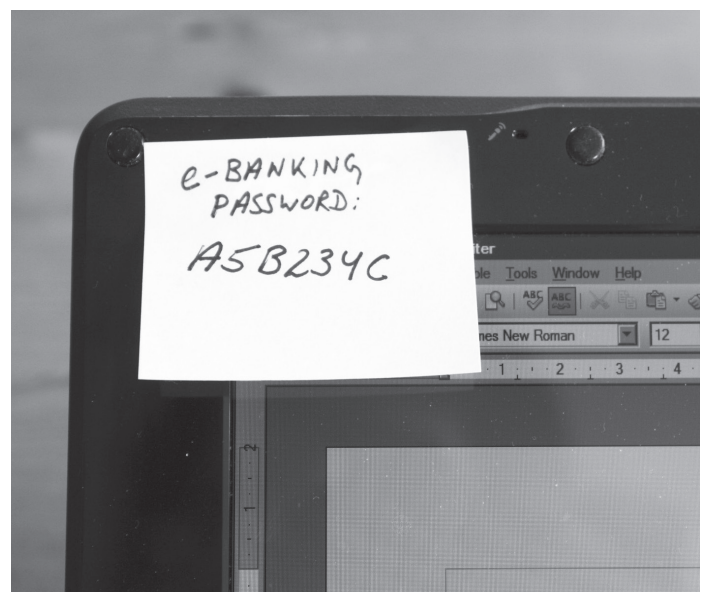
Is this responsible computer use?

Input–output interfaces allow the user to enter and retrieve information from the computer. Disabled people may have problems operating some interfaces. Keyboards, for example, cannot be operated by people who can't move their arms or fingers, or who have no arms in the first place. Computer screens are useless for those who are visually impaired, and people who can't hear will not benefit from the sound system of a computer. Different companies have developed a range of different solutions for people with disabilities. The input–output interfaces designed for those with disabilities are often a combination of both hardware and software.

Speech recognition: People who cannot type can enter commands over a microphone. The computer interprets the speech of the person and performs the appropriate task.

Text-to-speech: Visually impaired individuals can have the text on the screen read out to them. It is possible to adjust the type of voice and the reading speed.

GUIs with large text: The text size can be adjusted. People who have impaired vision can enlarge the size of the characters.

Mouth sticks and head pointers: These devices are mounted on the user's head or held in the mouth. An individual who is unable to use their hands can then use these pointers to type on a keyboard.

Braille output: Some companies manufacture specialized Braille readers. The text is converted to Braille, which can be read by using the fingertips.

Computers are largely non-mechanical devices (with the exception of the drives) and do not wear out when used frequently. This is very much unlike cars or washing machines, which have a limited lifespan. The IT industry is therefore confronted with the problem that it has to motivate computer users to buy new hardware and software. How is this done? Although the power of computers doubles approximately every 18 months (Moore's law), computer prices remain constant. It is impossible, however, to buy computers of the previous generation. They are simply not available. Sometimes it is even difficult to upgrade an old computer because the new memory chips (RAMs) simply don't fit into the old system.

Rapid technological progress results in faster and more powerful computers; however, this increased power is not always directly available to the user. The new installed operating system may consume so much of this computation power that the user may actually sense a decrease in speed; hence, a consumer who installs the latest software may quickly find that the performance of their existing computer is just not good enough. The user must then upgrade the hardware. With the release of the next software version, the cycle repeats. Users may be lured into buying the newest software because of more features or the software's improved optical attractiveness (i.e. eye candy). This planned obsolescence keeps the IT industry actively selling new hardware and software products, at the cost to the environment.

Computer obsolescence can be due to several factors, as described below.

Changing file formats: Old software is often unable to open new file formats. If someone sends you a word processing file written with a software program that is newer than yours, you may not be able to open it. You will then have to obtain a new version of the software program to open the sent file. New software is often able to save files in an older version, but many users do not know how to do this and use the default.

Higher memory requirements: Modern commercial software programs often contain more features and may require more memory. The user must upgrade if they wish to use the new features.

Graphics requirements: Modern operating systems use extensive graphic effects to make the GUI appear more attractive (i.e. 'eye candy'). This requires a faster graphics card. The increased photorealism of games also requires more powerful hardware.

Larger media files: Users increasingly use their computer to store music, films and photographs. The quality and size of the media files have dramatically increased in the past few years. Users therefore have to upgrade both the storage capacity and speed of the hard disks, as well as the CPU and memory to process these files.

For discussion

- Instead of buying a completely new computer, try to upgrade it! Carefully analyse your requirements. In many cases, a memory upgrade will speed up your computer much more than a faster CPU.

Video tapes have been replaced by DVDs. What are some environmental consequences of obsolete electronic equipment and storage media?

People and machines: What are some consequences of IT obsolescence?

The IT industry is interested that consumers frequently exchange their computer systems. They introduce new interface standards and software programs with higher system requirements. The exchange of IT software and hardware can have an impact on customers and service providers.

Psychological consequences: The users may have to face psychological consequences. It takes users a certain amount of time to become familiar with a particular software product. As soon as users are familiar with a software product and able to use it productively, it is time to upgrade to the next version

and they again feel unfamiliar with the product. People who are not as IT-literate may consider this as an unnecessary psychological pressure.

Economic consequences: Consumers and companies are required to upgrade their IT infrastructure every few years. The resale value of obsolete IT equipment is minimal. The cost of obtaining and maintaining the IT infrastructure, as well as the training costs involved may expose the firm to a substantial economic pressure.

Environmental consequences: The environmental consequences of computer obsolescence are dramatic. Millions of computers are discarded every year and recycling is still not common. Consumers should perform partial upgrades and exchange only those parts that have become performance bottlenecks, instead of purchasing a whole new computer.

Obsolete hardware is still functional but it is not used anymore because of its low performance. Consumers want faster and better computer equipment. Obsolete hardware must be recycled or disposed.

Some occupations require that the workers spend many hours in front of a computer screen. Air-traffic controllers must concentrate and focus their attention on uncountable small dots on a computer screen, with each dot representing an aircraft carrying hundreds of people. A slip in concentration can lead to disaster. Secretaries sometimes spend hours typing in offices that are not properly designed for computer work, with sunlight reflected from the screen and with a permanent disturbing sound from the cooling fans of the computers. These adverse working conditions may not be problematic for a short time but, over the years, problems can build up.

Carpal tunnel syndrome (CTS): This is a medical problem that results in pain at the wrist. The median nerve (which runs down the arm and forearm) is compressed at the wrist. There are probably several reasons that contribute to this syndrome. Stress, fractures and dislocations of the joints can result in CTS. There are also work-related causes, such as extensive typing on a computer keyboard.

There are a few precautionary measures you can take to prevent the likelihood of CTS from occurring. The height of the table and chair should be adjusted so that it's unnecessary to bend the hands in an unnatural way. The computer mouse should be held lightly and the mouse buttons should be pressed lightly. Additionally, it is possible to use special computer keyboards that have the keys arranged in such a way that it's not necessary to bend the wrists outwards.

A pad pillow supports the hand and helps to reduce repetitive strain injury.

Eye strain: When looking at a monitor, the eyes must focus at a close distance for many hours. This can result in eye strain. There are several things you can do to remedy the situation. Arrange the screen in such a way that it does not reflect bright light, otherwise use an anti-glare screen. You can also make use of the screen's brightness and contrast adjustments. Relax your eyes by frequently looking out of the window into the distance. This relaxes the ciliary muscles of the eyes, which are responsible for focusing.

Neck and back strain: Sitting in front of a computer for many hours can result in muscle aches of the neck and back. Arrange the monitor and table so that you are able to sit upright. Use chairs that are designed for computer use.

Conjunctivitis: Conjunctivitis is an inflammation of the eye. It results in red eyes, often owing to bacterial infections. A person who works long hours in front of a computer screen tends to blink less frequently. This allows for easier bacterial growth. The user should blink frequently to keep the eyes moist. It is also not a good idea to rub one's eye with the fingers. Many computer keyboards are extremely dirty and rubbing will transfer bacteria into your eyes.

Radiation: Computer components generate low-frequency electrical and magnetic fields. Wireless networks emit high-frequency radiation. Laws regulate the maximum amount of radiation that a device is allowed to emit. The long-term effects of this are being studied.

For discussion

- Collect several mobile phones and put them on a table. As a group, brainstorm a list of ergonomic criteria. Then evaluate each mobile phone against these criteria by giving points. Some of these criteria could be size of the keys, size of the display, contrast of the display etc.

- Try to find more criteria.

Some people may compare the human body to an extremely complex machine. If a person is ill, then he or she has to be 'fixed', much like a machine. The doctors operate on a human patient much like a technician fixes the computer hardware. This is a mechanistic view of the human body. Let's do this again. Let's compare a computer with the human body.

The human central nervous system (i.e. the brain and spinal cord) is the CPU. The input devices are the neurons in your body, which pick up stimuli such as temperature and pressure (skin) or light (eyes). These signals are processed by the CPU (your brain), which sends other signals to the output devices. The output devices of the human body are the muscles. Your memory is the RAM, and your inborn instincts and behaviour patterns are stored in your ROM. You cannot change these inborn characteristics (just like you can't change the ROM). If you have problems remembering something over a long period of time, then you can write it down on paper. This is your external storage. For communication you use your voice to establish networks with other people. When you learn something new, then this new software is loaded into your memory (RAM) and this changes your behaviour.

Indeed, the human seems to be a sophisticated computer. But wait! Why can we not turn around the whole issue? If we can say that a human being is nothing more than a complex computer, then we can also say that a computer is nothing more than a simplified human being. My little notebook computer, which I now use to type this very book, is also like a human! The next time your computer crashes or does not work as you expected, do not feel angry at it. Humans are not perfect, humans make mistakes. And your computer is only human.

For discussion

- Why is it that we seem to have fewer problems comparing a human being to a computer, than comparing a computer to a human being?

- Comparisons like these are called *analogies*. Some common analogies are: 'The CPU is the brain of a computer' or 'The mitochondria are the power houses of cells' etc. Do analogies help or hinder our understanding of the world? Are all analogies equally good? When is an analogy a 'good' analogy and when is it a 'bad' one?

ToK stimulus: On the limits of it all

How many different pictures can a digital photograph show? If you think that the number is infinite, then you are mistaken. Sooner or later (probably more later than sooner…) you will have taken every single picture that the camera is capable of showing and every additional picture is a repetition of a picture that you took before.

Theoretically, how many different pictures can a digital photograph show? The mathematics behind this is surprisingly simple. A digital photograph is composed of individual pixels, with each one possessing a specific colour. A six-megapixel camera has six million pixels; that is, 3000×2000 pixels. Each pixel is able to possess 16 777 216 different colours (for 24-bit true-colour images). Hence, the total number of different images that can be shown is 16 777 216 raised to the power of 6 million; i.e. $16\,777\,216^{6\,000\,000}$.

This is quite a bit more than the estimated total number of atoms in the observable universe, which is 10^{80}.

ToK stimulus: The limits of the human brain

How many bits of data can the human brain store? When is the human brain 'full'? Of course, nobody is able to say this with certainty but some estimates have been proposed. If it is assumed that each nerve cell in the brain represents one bit (i.e. either it fires or does not), then the human brain has a storage capacity from about 500–1000 TB (terabytes).

Think about the value 500–1000 TB. How much is that? 1000 TB equals 1 099 511 627 776 000 bytes. Now, does this number tell us more? Not really. And what happens if we reach this maximum capacity? Do we then have to forget something in order to make space for new information? These numbers are so extremely large that, for all practical purposes, they can be considered irrelevant. We are simply missing a connection with our everyday experience.

For discussion

- Do we need to be able to make analogies with our everyday experience for understanding something?

- Is it possible to understand something that is so abstract that there is no connection to our everyday experience?

Privacy and anonymity: What are some possible concerns by people relating to biometrics?

Not everyone may be in favour of biometric authentication. The following section outlines some possible concerns by people.

Psychological issues: The measurement and recording of biological features is a very personal issue. People may feel uncomfortable knowing that their body features are measured and recorded. Biometric fingerprint scans, for example, may evoke negative associations with the fingerprinting of criminal suspects.

Privacy concerns: What happens with the recorded biometric data? Individuals may feel that they 'own' the biometric data and may be concerned that this data is passed on to other organizations without their consent. Will the fingerprints be passed on to the police?

Health reasons: Individuals may worry that the recording of biometric information may have negative health consequences. Although this may be rather unlikely, individuals do not fully understand how the data is measured and recorded and they may have subjective fears. Individuals may be concerned, for example, that the recording of the blood vessels of the retina may be harmful to their eye sight.

Civil rights: Individuals may be concerned about their basic rights for privacy. How much should the government (and other institutions) know about the individual? This is a very important discussion. What is the next step – that the DNA of individuals is analysed for biometric purposes? Where does this stop?

Reliability concerns: Not every biometric method is reliable. Some systems have a high error rate. For authentication purposes the system must work 100 per cent error free. Even fingerprint systems can't be considered fully reliable anymore. It is possible to fool the system by taking a photograph of a person's fingerprint and making an artificial skin that is then placed over the fingers of another person.

Integrity issues: People may be concerned that the biometric data is not stored safely and may be changed in an unauthorized way.

Privacy and anonymity: What does data reveal about your personal life?

Imagine the unfortunate situation that your notebook computer has been lost or stolen. The data stored on the computer can reveal much about your personal life. For some people, the stored data may provide interesting information about your life.

E-mails: Who do you have contact with? What are your opinions about different issues?

Websites visited (browsing history): What are your interests? Do you visit medical websites? This could tell me something about your health.

Address books: Whom do you have contact with?

Personal calendars: What did you do, when? Where were you?

Office work: What do you do for a living?

Games: What do you like to do in your free time?

Photographs: What do you or your friends look like? What ethnic group do you belong to? How old are you?

For discussion

- Can you think of organisations or individuals who could be interested in personal information like this? Try to look beyond the financial aspect.

Privacy and anonymity: What can you do to protect your data?

It is in the interests of the user to protect this information from unauthorized access. A cautious user applies different methods of protection. Of course, a combination of different methods will result in the highest protection. Here are some recommendations.

Passwords: Protect your files and your whole computer system with passwords. Be aware that passwords can be cracked and that the passwords must be kept a secret and secure. Choose passwords that are sufficiently long but still easy to remember.

Encryption: Encrypt your files so that they are encoded in such a way that they can't be read by unauthorized people. Only the person who is in possession of the decryption key (which, in this case, is comparable to a password) can decrypt and read the file.

Backups: Store your backups in a safe place. Be careful that nobody steals or copies your backups. Keep track of your backups. Where do you store them? Do you leave them lying around openly in your room or office? If you do then they can be accessed by unauthorized people.

Locking: Keep your computer locked up and in a safe place when it is not in use. Lock the doors to prevent theft, even if you leave the room only for a short time. According to analysts, over one million laptops are stolen each year, and along with them trade secrets and private and sensitive data.

Firewalls: Firewalls protect computers that are connected to a network. They prevent other people (and programs) from directly accessing your computer from the outside. Without a firewall there is the possibility that individuals may look at the data stored on your hard disk without you even knowing. It is even possible that your computer could be remote controlled over the network.

Be aware that excessive data protection may backfire as well. If you encrypt data on your work computer, then this may be a sign that you have something to hide from your boss or that you are engaging in unacceptable behaviour. On the other hand, if you do not apply certain security measures, the firm may make you liable for negligence. Carefully study the company's IT policy before employing the different measures.
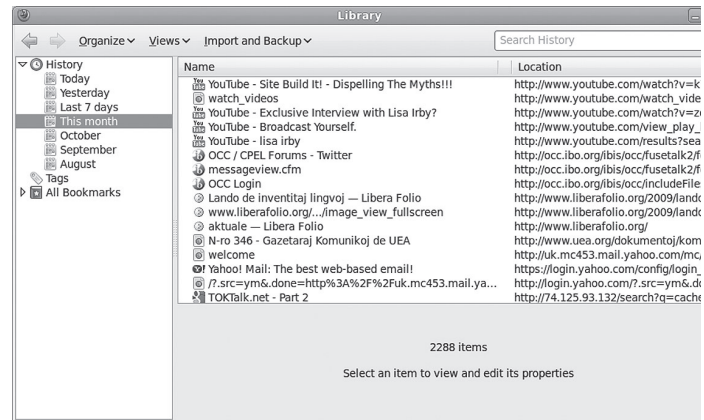
The history feature of web browsers automatically records the websites that the user has visited in the past, including date and time of visit. This history is very useful when the user has forgotten the URL (Internet address) of a website. They then simply have to search the history for the visited website. The Web history also reveals much about the interests and preferences of the user. The Web history may even serve as a proof for the police that the user has visited certain (illegal) websites.

For discussion

- Don't bump the hard disk. This may cause the read/write head to crash. The consequence of a head crash is massive data loss.

- Don't expose CD-ROMs and DVDs to light. The light will destroy the layer carrying the data.

- Don't expose magnetic media (such as hard disks, floppy disks or tape drives) to electrical or magnetic fields. This may erase the data.

- Don't touch the surface of media. Fingerprints and scratches on optical media will cause reading and writing problems.

- Don't smoke. Deposited smoke particles can cause several problems to electronic equipment.

- Store the media in a dust-free environment. Dust particles can cause reading and writing problems. Dust can also cause overheating.

Bumping the hard disk can cause the read/write head to crash into the spinning disk. The hard disk becomes unusable and the data stored on the disk is lost.

Digital citizenship: What are the differences between computer abuse and computer crime?

The terms computer abuse and computer crime are interrelated and it is sometimes difficult to make a clear distinction between them. Generally, computer abuse refers to any use

of a computer for a purpose for which it was not intended. Students who use the school library computers to play network games are abusing the computer. They were not bought for the purpose of entertainment. On a more serious level, computer abuse may also include hacking, computer espionage, data manipulation and so forth. Many of these activities cause substantial financial damage and are regulated by law.

Computer abuse that infringes the laws of a country is considered a computer crime. The programming of viruses, hacking, data manipulation and other illegal activities will result in the person being charged, possibly resulting in imprisonment.

ToK stimulus: Knowledge and wisdom

According to the Greek philosopher Plato, knowledge is justified true belief. In order for you to know something, you have to believe it as well. The ability to believe, so it may seem, is a solely human capability. Computers are technical devices, so certainly they can't believe in anything, can they?

Computers possess billions of microscopic transistors. Each transistor is a switch that either allows electricity to pass or not. A human brain is made of billions of nerve cells. Each nerve cell has the possibility to fire a nerve impulse, or not. The nerve cells in the brain are connected to each other, as are the transistors in a computer microchip. Could it really be that it is only a question of scale and not of principle? Could it be that if a sufficiently large computer was built, it too would start to develop the ability to believe something and to even develop a consciousness?

And since human beings have the ability to believe, is there also (at least theoretically) the ability of such a computer to develop something like wisdom or even empathy? Is it only a question of the number of transistors that engineers are able to pack into a computer or is there more that is needed?

For discussion

- What do you think? Is the comparison of a human brain with a computer a valid comparison? Or is there something else that is needed?

ToK stimulus: The loss of information

The fact that much of the communication nowadays goes over the Internet and is stored digitally and on hard disks and DVDs is a cause of concern for some people. What will future generations know about us, the civilization of the 21st century? Cave paintings, handwritten documents, pieces of art work have endured hundreds, if not thousands, of years. But information stored on the servers and personal computers of people will only last a few years – at best until the next hard disk crash.

We do not even have to look very far into the future. Do you have digital photographs stored on the hard disk of your computer? Think forward a few years. Can these pictures still be accessed by your own grandchildren? Can the file format still be read in several years' time? Have you saved your pictures on DVD or CD-ROM? Well then, you may not even be able to read the data in 5 years from now. What will your grandchildren and great grandchildren know about you and your life?

For discussion

- Many governments store important documents in large archives. These documents should be a resource for future generations. Often, these documents are photographed and stored in analog form on microfilm and not digitally. If stored properly, the microfilm is readable for hundreds of years. Data stored in digital form would be readable maybe for only several decades.