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UPDATED TO 2021-23 SYLLABUS

CAIE AS LEVEL COMPUTER SCIENCE (9618)

SUMMARIZED NOTES ON THE THEORY SYLLABUS

1. Information Representation

1.1. Data Representation

- The basis of any number system consists of:
  - A base: the number of digits that a number system can use to represent numbers
  - Place value for each digit: digits in certain positions have a specific value
- Denary - Base 10 integer digits
- Binary Systems - Base 2
  - Possible bits (binary digits): 0 and 1
  - All data and characters are represented in binary

128	64	32	16	8	4	2	1
0	0	0	0	0	0	0	0

- E.g. 65 in binary is 0100001
- Denary vs. Binary prefixes:

DenaryPrefix	factor value	BinaryPrefix	factor value
kilo- (k)	×10^3	kibi- (Ki)	×2^10
mega- (M)	×10^6	mebi- (Mi)	×2^20
giga- (G)	×10^9	gebi- (Gi)	×2^30
tera- (T)	×10^12	tebi- (Ti)	×2^40

- Binary Coded Decimal (BCD)
  - Binary representation where each positive denary digit is represented by a sequence of 4 bits (nibble)
  - Only certain digits are converted to BCD, because particular digits represent a digit greater than 9.
  - Ex. 429 in BCD:
- Convert each digit to their binary equivalents
- 4 = 0100 | 2 = 0010 |9 = 1001

Concatenate the 3 nibbles (4-bit group) to produce BCD: 0100 0010 1001

- Practical applications
  - A string of digits on any electronic device displaying numbers (eg. Calculators)
  - Accurately measuring decimal fractions
  - Electronically coding denary numbers
- Two's Complement
  - We can represent a negative number in binary by making the most significant bit (MSB) a sign bit, which indicates whether the number is positive or negative.
  - Converting negative denary into binary (ex. -42)
- Find the binary equivalent of the denary number (ignoring the -ve sign) | 42 = 101010
- Add extra 0 bits before the MSB, to format binary number to 8 bits | 00101010
- Convert binary number to one's complement (flip the bits) | 11010101
- Convert binary number to two's complement (add 1) |1010101 + 1 = 11010110
- Converting binary two's complement into denary (ex. 11010110)
  - Flip all the bits | 00101001
  - Add 1 | 00101010
  - Convert binary to denary and put a –ve sign) | -42
- Maximum positive number in 8 bits: 256
- Maximum negative number in 8 bits: -128
- Hexadecimal Systems - Base 16
  - Possible digits: 0 to 9 and A to F, where A to F represent denary digits 10 to 15
  - Practical applications:
    - Defining colours in HTML
    - Defining Media Access Control (MAC) addresses
    - Assembly languages and machine code
    - Debugging via memory dumps
  - E.g. A5 in Denary = (16×10) + (1×5) = 165
  - E.g. 65 in Hexadecimal = 65÷16=4 Remainder 1∴ = 41
- Character Sets
  - A character set generally includes upper & lower case letters, number digits, punctuation marks and other characters.
  - Character sets use different binary representations for each character via character encoding
  - Character Encoding Standards:

ASCII	Extended ASCII	Unicode
Only English alphabets can be represented	ASCII's extension - Also includes most European languages' alphabets	Superset for ASCII & extended ASCII - recognized by various global languages
Each character encoding takes up 7 bits, hence 128 possible characters	ASCII extended to 8 bits, hence 256 possible characters.	Greater range of characters, as it uses 2 or 4 bytes per character.
Smaller storage space.		2 or 4 times more storage space per character.

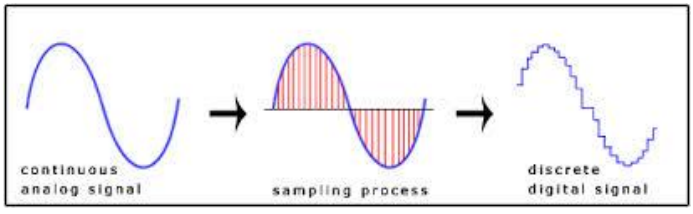
1.2. Multimedia

- Bitmap Images
  - Data for a bitmapped image is encoded by assigning a solid colour to each pixel, i.e., through bit patterns.
  - Bit patterns are generated by considering each row of the grid as a series of binary colour codes which correspond to each pixel's colour.
  - These bit patterns are 'mapped' onto main memory
  - Pixels: smallest picture element whose colour can be accurately represented by binary
    - Bitmap image also contains the File Header which has the metadata contents of the bitmap file, including image size, number of colours, etc.
- Image Resolution

- Pixel density which is measured by no. of pixels/cm
- If image resolution increases, then image is sharper/more detailed
- Screen Resolution
  - Number of pixels which can be viewed horizontally & vertically on the device's screen
  - Number of pixels = width × height
  - E.g. 1680 × 1080 pixels
- Colour depth: number of bits used to represent the colour of a single pixel
  - An image with n bits has 2n colours per pixel
  - E.g. 16-colour bitmap has 4 bits per pixel ∵ $2^4 = 16$
  - Colour depth↑: colour quality↑ but file size↑
  - File Size = Number of Pixels × colour depth
  - Convert bits to bytes by dividing by 8 if necessary.
- Applications: scanned images and general computer usage ∵ small file size and can be easily manipulated.
- Vector Graphics
  - Made up of drawing objects
  - Drawing objects: a mathematically defined construct (of shapes like rectangle, line, circle, etc.)
  - Drawing list: set of commands defining the vector
  - Properties of each object are the basic geometric data which determine the shape and appearance.
  - Data is encoded using mathematical formulas to generate properties in order to draw lines & curves to create the image
  - If object is resized, properties are recalculated.

∴ Scalable without losing quality unlike bitmaps

- Applications: company logos
- Sound
  - Analogue data is continuous electrical signals whereas digital data is discrete electrical signals.
  - Sound signals are vibrations through a medium. Hence are analogue in nature as there can be an infinite amount of detail for sound.
  - Analogue signals converted (encoded) to digital signals by sampling:
    - Sound wave's amplitude (height) sampled at set time intervals
    - These samples (amplitudes) are encoded as a binary number sequence
    - This sequence provides a digital representation of the sound wave



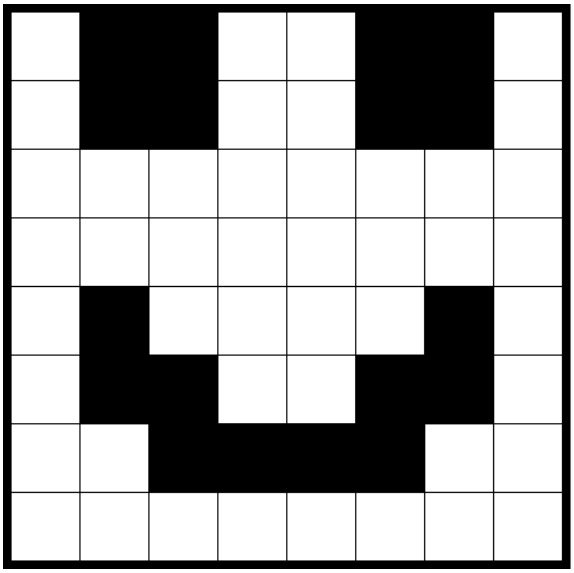
- Sampling Rate
  - Number of samples taken per unit time
  - Increasing the sampling rate increases accuracy of digitized sound wave representation but increases the file size
- Sampling Resolution
  - Number of bits used to encode each sample
  - Increasing sampling resolution increases accuracy of digitized sound wave but increases the file size
- Bit Rate: no. of bits for storing 1 second of sound

$$Bit\ Rate = Sampling\ Rate \times Sampling\ Resolution$$

File Size=Bit Rate * Length of Sound

1.3. Compression

- Compression is the process of reducing file size without a significant loss in quality which results in
  - Reducing the time needed to search for data.
  - Faster transfer of compressed files, which uses less bandwidth than uncompressed files.
- Lossless Compression
  - Type of compression that allows original data to perfectly reconstructed from compressed file when the file is opened by utilizing some form of replacement.
  - E.g. bitmap (.bmp), vector graphic (.svg) and .png images, text file compression, database records
  - Run-length Encoding (RLE)
    - Form of lossless compression which is used for compressing text files and bitmap images.
    - Reduces file size of a sequence of elements which has adjacent, identical elements (characters in text file and pixels in bitmap images).
    - Repeating sequence of elements encoded in two values: run count and run value.
  - E.g. RLE of bitmap image:
    - We can represent the first row as a sequence of pixels: "W B B W W B B W" | W: white and B: black



    - After applying RLE: "W 2B 2W 2B W".
    - In '2B' 2 is the run count and B is the run value, which represents a run of two adjacent black pixels
    - Process is repeated for other rows.
- Lossy Compression

- Type of compression which irreversibly eliminates unnecessary data
- File accuracy/quality lower than that of lossless but file size is lower (~10% of lossless).
- E.g. Sound files (.mp3), .jpeg images
- Sound files compression (.mp3) utilizes Perceptual Coding to remove certain parts of sound that are less audible/discernible to human hearing.

2. Communication

2.1. Networks including the Internet

- Networking devices are interconnected devices that allow a fast means of data transmission within the network.
- Networking benefits:
  - File sharing - you can easily share data between different interconnected devices
  - Resource sharing - using network-connected output devices like printers, or can share the same software within the network
  - Higher storage - can store files in network-connected storage mediums.
- LAN(Local Area Network) vs. WAN(Wide Area Network)

LAN	WAN
Network that connects devices within a small geographical area	Network that connects devices within a larger geographical area
Only private ownership	Private or public ownership
Transmission medium: twisted pair cable, coaxial cable or Wi-Fi	Transmission medium: PSTN or satellite link
Higher data transfer rate	Lower data transfer rate
Lesser congestion	Higher congestion

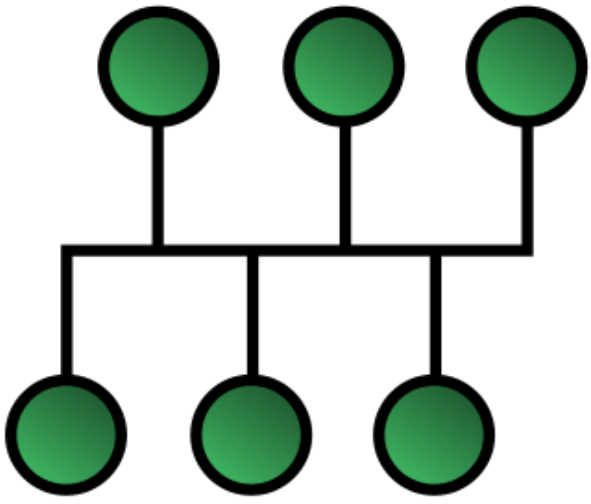
- Client-server Model
  - Server based network: dedicated server provides an application (administration of users, security and resources) for the client computer to utilize
- Client-server Applications
  - Printer: manages print jobs from client computers
  - File Sharing: the client accesses software and user's data files stored on the server
  - Proxy server
  - Email server: for sending, receiving & storing emails
  - Database server: manages DBMS
  - Domain controller server
    - Management of user accounts (IDs & passwords)
    - Client sends login request to server which processes and grants request if user ID & password recognized
- Thin Clients vs. Thick Clients

Thin Clients	Thick Clients
A client that solely runs on the resources provided by the server and has no local storage	An independent client that does not require the server to run
Only provides input and receives output; processing done by server	Thick client processes most of the application
Smaller purchase cost: expensive, demanding hardware is not required	Can function even if no server is connected (works offline)
Improved security: cannot run unauthorized, harmful software	No lag related to network problems

- Peer-to-peer network model (P2P)
  - Decentralised network where each connected computer stores data and operates independently as a 'peer', and can act as both a client & server.
  - Applications: Internet and Ad hoc networks
- Client-server vs. Peer-to-peer models

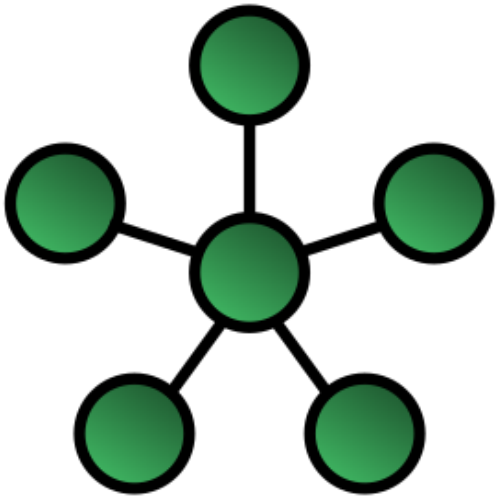
Client-server	Peer-to-peer
Centralized backup	Lesser initial setup cost
Files & resources centralized in server: prevents illegal resource usage	Lesser network traffic: each peer can simultaneously receive data from different sources
Improved security: files are stored on central server which would be regularly scanned for malware	Can work even if a device goes down, but Client-server model can't work if server goes down

- Network Topologies
  - Bus

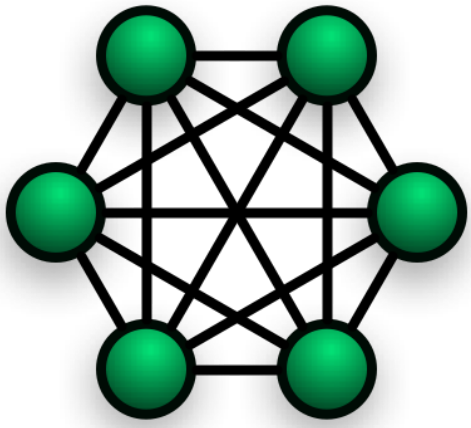


- Single line (bus) connecting all devices with terminators at each end.
- Other computers can read the data being sent from one to another computer.

- Unsuitable for heavy traffic since collisions occur.
- Star



  - Consists of a central server ('Switch') and all other computers connected with a dedicated connection to each, hence server can send packets to different devices simultaneously and bi-directionally.
  - No collisions possible.
- Mesh
  - Network setup where every device (node) is directly interconnected to the each of the other devices (nodes)



  - It is commonly used for wireless networks (such as the Internet), via the mesh connection of routers
- Hybrid
  - Combination of two or more topologies.
  - E.g. when there is a connection between 2 or more LANs of different topologies
- Wired Networks: use (copper (twisted-pair cable or coaxial cable) or fibre-optic) cables connected to an Ethernet port on the network router

	Benefits	Drawbacks
Copper Cable	Less expensive and easier to install FlexibleEasier to make terminations	Doesn't perform well with small charges.Affected by electromagnetism
Fiber-Optic Cables	Greater bandwidthImproved security Lightweight: easy to installLess signal boosting required; used in long distance comm.	Needs expensive optical transmitters and receivers.

- Wireless Networks: use radio waves (including WiFi), microwaves, satellites to connect devices to networks without cables.

	Benefits	Drawbacks
Radio waves	Can travel over large distances since they have largest range of wavelengthRelatively inexpensive.Used for TV signals & mobile phone comms.	Low frequency so transmits less data at one time.Affected by radio stations with similar frequency
Micro-waves	Larger bandwidth, can transfer more data at a time	Emitting towers expensive to build Physical obstacles can interfere
Satellites	Cheap with long distanceUsed for Satellite phones, satellite radio broadcast	Easy to interfereExpensive set up

- Ethernet
  - Most common wired medium of transmission, that can be used to transfer data between LANs or WANs
  - Usually used in bus topology; since all data travelled on a single wire there is a possibility of data corruption by the "collision" of signals
  - This collision is prevented by the CSMA/CD (Carrier Sense Multiple Access Collision Detection) method:
    - Before transmitting, device checks if channel is busy
    - If busy, device calculates a random wait time and waits that time, after which it begins transmission
    - Then during transmission, the device listens for other devices also beginning transmission
    - If collision, transmission is aborted and both devices wait different random times, then tried again
- Bit Streaming
  - Sequence of digital signals (bits) transferred over a communication path at high speeds
  - Requires a fast broadband connection and some form of buffers (short-term memory)
  - Bits arrive in the same order they are sent

- Bit rate: number of bits transmitted per second
- Two methods of bit streaming:

Real-time	On-demand
Event captured live via video camera that is connected to a computer	Existing digital files converted to encoded bit-streaming format for broadcasting on the internet by uploading to a dedicated server
Video signal converted to an encoded streaming video signal	A link for encoded video is placed on website and the user clicks on link to view encoded streaming video
Encoded video signal uploaded from computer to a dedicated streaming server via cables or high-speed wireless internet connection	The data is streamed to a buffer in user's computer and the buffer stops the video from being paused as the bits are streamed
Server then sends live images to all users requesting it as a real-time video	As the buffer is emptied, it's filled again thus providing continuous viewing
Cannot be paused, fast-forwarded, etc.	Can be paused, fast-forwarded, etc.

- Importance of high broadband speed / bit-rate
  - User has to download and display bits at same time
  - If media is of higher quality, then higher broadband speed needed since each "frame" is of a larger size
  - Real-time needs faster broadband speeds as compared to on-demand, since there are a greater number of users simultaneously requesting same data
- Cloud Computing
  - Refers to the on-demand provision of computing services through the internet
  - Services provided include
    - Infrastructure: Storage capacity and higher processing power
    - Platform: Software, testing & debugging resources
  - Public cloud vs. Private cloud

Public cloud	private cloud
3rd-party cloud service provider grants access to multiple parties, accessible via a browser	A private cloud is owned by one organization and is not shared with any other organization
Cloud service provider owns, develops and manages the public cloud through large server farms	The private cloud can either be created and maintained by the organization itself or it can outsource these tasks to a third-party

- Benefits and drawbacks of cloud computing

benefits	drawback
Relatively less technical knowledge required and easy to implement	Cannot access the resources/data stored on the cloud, if there are bandwidth issues
Flexibility: Cloud Can Be Scaled To Match The Organization's Growth	Poor data privacy, since there may be data leakage in the multi-tenant architecture (public clouds)

- World Wide Web (WWW)
  - Collection of web pages stored on websites
  - Protocols are used to transmit data across the WWW
- Internet (Interconnected network)
  - Massive, open network of networks
  - Uses TCP/IP protocol, which uses IP addresses to identify devices connected to the internet
  - Access provided by Internet Service Provider
  - Communication used: wired, radio and satellite
- Router in a network
  - Connects two networks together which may operate on different protocols
  - Allows internal connections between LANs OR allows external connection from the main LAN to a WAN
  - Router acts as gateway & firewall
  - Usually will be attached to server or switch in a LAN
  - Router translates private IP addresses to public IP addresses AND vice versa.
- LAN-supporting hardware
  - Switch: Connected to all devices in a LAN and can simultaneously broadcast information to all devices
  - Server: device/software provides specific function for computers in the network
  - Network Interface Card (NIC)
    - Provides each device (an end-system) in the wired LAN with a unique (MAC) address to uniquely identify it on the network
    - Allows each individual device to connect to network
  - Wireless Network Interface Card (WNIC): Provides each end-system of a wireless (WiFi) LAN a unique network address to identify it.
  - Wireless Access Points (WAP):
    - Allows devices to connect to the LAN via WiFi (wireless radio communication) instead of using a cable
    - Usually built into router
  - Cables: A wired transmission medium that allows communication in wired networks
  - Bridge
    - Connects two LANs which work use the same protocol, which can be two segments of the same network
    - Stores network addresses for all devices (end-systems) between the 2 networks
    - A bridge looks for the receiving device before it sends the message.

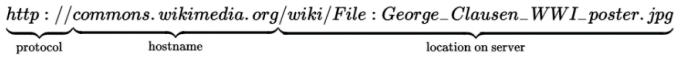
- Repeater
  - Connects two cables
  - regenerates the sent data signal over the same network before the signal weakens (attenuation) to prevent it from being corrupted
- Internet-supporting hardware
  - Modems
    - Allows a device to connect to the Internet via a telephone line.
    - A transmitter uses a modem to convert digital signals (from the transmitting device) to analogue signals that are then sent down the telephone line.
    - A receiver uses a modem on the other end to convert the analogue signals to digital signals so the receiving device can understand the data.
  - PSTN (Public Switched Telephone Network)
    - Refers to all telephone networks
    - Channel used between 2 endpoints for the call duration via circuit switching
    - Lines active even during power outage
    - Bi-directional communication
  - Dedicated lines
    - Telecommunication path between endpoints
    - Not shared with multiple users; it's bought/leased
    - Able to host websites as well as carry phone calls
    - Allows continuous, uninterrupted access on Web
  - Cell phone network
    - Wireless network spread over land areas divided into (hexagonal) 'cells'
    - Each cell is served by at least one base station (transceiver), which uses a different frequency range, as compared to adjacent cells, to transmit data
    - Larger capacity possible since same frequencies can be used, in non-adjacent cells
    - Radio waves are usually used for transmission
    - Can be broadcast in all directions over a wide area
    - Portable transceivers (e.g. mobile phones) are able to communicate and access internet via base stations
- IPv4 vs. IPv6

IPv4	IPv6
32 bit address, split into 4 blocks by "."	128 bit address divided into eight 16-bit blocks by ":".
Each block could have a value between 0 and 255 (00 to FF in hex).	Each block can have 4 hex values ranging from 0000 to FFFF
E.g.255.0.1.255	IPv6 can be shortened by removing >=2 blocks containing solely zeroesE.g.2001:0db8:85a3::8a2e:0070:7334

- IPv4 functionality
  - each IP address has 2 parts:
    - Network Identifier (netID)
    - Identifies the network to which the host (device) is connected to
    - Host Identifier (hostID): Identifies the host within the network
  - 'Classfull' addressing used for IPv4 where different bit lengths for identification and impose restrictions on available address
- Subnetting
  - Practice of dividing a network into two or more networks
  - IP addresses are broken down to 3 parts by not changing the netID but partitioning the host ID into a subnet ID and host ID
  - These subnet ID bits are used to identify each subnet within the network.
  - Subnet masks are numbers that hides (masks) the netID of a system's IP address and leaves only the host part as the machine identifier, allowing data to be routed within the subnet to the appropriate host.
- Public and Private IP address
  - Public IP is provided by the ISP while Private IP issued by the LAN's router
  - Public IP is unique and can be across the internet whereas Private IP is only unique within LAN and hence can only be accessed within LAN
  - NAT (Network address translation) required for private IP addresses to access internet directly.
  - Private IP more secure than public IP, since they are not directly accessible on the Internet and are hidden by NAT
  - Range of IP addresses used for private IP addressing can never be assigned to public IP addresses
- Static vs. Dynamic IP addresses

Static	Dynamic
IP address never changes.	IP address will change at regular time periods.
Static IP addresses are useful when websites need to remember a device for a long time. Eg) VPNs whitelisting	Dynamic IP address is relatively more secure, hence used where data privacy is important
Faster upload/download speeds	Maintaining cost of dynamic IP address is lesser

- URL (Uniform Resource Locator)
  - Unique reference address for the exact location of an internet resource on the WWW



- Protocol: enables browser to know what protocol is used to access info in domain
- Hostname: Domain name
- Location of server: path
- Domain Name Service (DNS)

- naming system used for computers or resources having internet connection
- Consists of a hierarchy of DNS servers which have a URLs database of and their corresponding IP addresses

3. Hardware

3.1. Computers and their components

- General-purpose computer system consists of a processor, memory, I/O functionality.
- Understanding the need for
  - Input: take in data from the outside world
  - Output: display data for humans' understanding
  - Primary storage: computer's main memory which stores a set of critical program's instructions & data
  - Secondary storage: non-volatile storage for noncritical data that will not be frequently accessed
  - Removable secondary storage:
    - File backup and archive
    - Portable transfer of files to second device
- Embedded systems
  - Small computer systems such as microprocessors that are often a part of a larger system
  - Each embedded system performs a few specific functions unlike general-purpose computers

benefits	drawbacks
Reliable since there are no moving parts	Difficult to program functions since there is either no interface
Require less power	Expensive expert help needed for repair
Cheap to mass-produce	

- Principle Operations of Hardware Devices
  - Laser printer
    - A laser beam and rotating mirrors are used to draw image of the page on a photosensitive drum
    - Image converted into electric charge which attracts charged toner such that it sticks to image
    - Electrostatic charged paper rolled against drum
    - Charge pulls toner away from drum and onto paper
    - Heat applied in the fuser to fuse toner to the paper
    - Electrical charge removed from drum and excess toner collected
  - 3D printer
    - Process starts from saved digital file that holds the blueprint of object to be printed
    - Object is then built by sequentially adding layers of a material (e.g. polymer resin) until object created
    - Object is then cured (e.g. resin-made objects are hardened by UV light)
  - Microphone
    - Incoming sound waves enter wind screen and cause vibrations about a diaphragm
    - Vibrations cause coil to move past a magnetic core
    - Electrical current generated which is then digitized
  - Speaker
    - Takes electrical signals and translates into physical vibrations to create sound waves
    - Electric current in voice coil generates an electromagnetic field
    - Change in digital audio signal causes current direction to change which changes field polarity
    - Electromagnet is either attracted or repelled to a permanent magnet, causing a diaphragm that is attached to the coil to vibrate
    - Vibration transmitted to air in front of speaker
    - Degree of vibration determines amplitude and frequency of sound wave produced
- Magnetic Hard Disk
  - Hard disk has platters whose surfaces are covered with a magnetisable material.
  - Platters are mounted on central spindle and rotated at high-speed
  - Surface of platters divided into concentric tracks & sectors, where data is encoded as magnetic patterns
  - Each surface is accessed by read/write heads
  - When writing, current variation in head causes magnetic field variation on disk
  - When reading, magnetic field variation from disk produces current variation in read head
- Solid State (Flash) Memory
  - Most use NAND-based flash memory
  - Consist of a grid of columns & rows that has 2 transistors at each intersection
  - Two transistors:
  - Floating Gate: stores electros and the presence or absence of charge (electrons) represents either 1 or 0
  - Control Gate: controls charge (electrons) flow for read/write
- Optical Disc Reader/Writer
  - Disc surface has reflective metal layer and is spun
  - Tracking mechanism moves laser assembly
  - Lens focuses laser onto disc
  - Laser beam shone onto disc to read/write
  - Tracks have sequences of amorphous and crystalline states on the metallic layer
  - When reading, the reflected light from the different states on the track are encoded as bit patterns
  - When writing, laser changes surface to crystalline and amorphous states along the track, which correspond to 1s or 0s.
- Touchscreen
  - Considered as both an input & output device
  - 2 types:

Resistive	capacitive

Resistive	capacitive
Consists of two charged plates	Made from materials that store electric charge
Pressure causes plates to touch, completing circuit	When touched, charge transferred from finger
Point of contact registered with coordinates used to calculate position	

- Virtual (Reality) headset
  - Virtual headsets consist of 2 lenses, (LCD) display, circuit board with sensors, cover and foam padding
  - The display provides a simulation of a 3D environment, generated by a 3D graphics package
  - The user can 'move' in the virtual environment by moving their head or using controllers
- Buffers: short-term memory storage that stores data right before it's used, typically in RAM.
- Random Access Memory vs. Read Only Memory

RAM	rom
Volatile memory: loses content when power turned off	Non-volatile memory: does not lose content when power turned off
Can be read and altered	Can only be read
Used to store currently executing program	Used for storing OS kernel and boot up instructions

- Types of RAM - Static RAM vs. Dynamic RAM

sram	dram
Doesn't need to refresh hence uses less power and faster access time	Has to be refreshed, hence has slower access times and needs higher power
More complex circuitry, hence more expensive	Only single transistor & capacitor, hence less expensive to purchase
Each bit stored in flip-flop	Each bit stored as a charge
Has lower data density	Has higher data density
Used in cache memory	Used in main memory

- Types of ROM – PROM vs. EPROM vs. EEPROM

pROM	EPROM	EEPROM
Programmable ROM	Erasable Programmable ROM	Electrically Erasable Programmable ROM
Can be programmed only once after it is created	Can be erased by UV light exposure and can then be reprogrammed	Can be erased by an electrical signal and can then be reprogrammed
Data cannot be erased or deleted	Chip has to be removed for reprogramming	Can update data without removing chip.

- Monitoring and Control Systems
  - Monitoring System
    - Monitors some state external to computer system
    - No changes made to environment by the system and hence no feedback
  - Control System
    - Regulates the behaviour of other devices or systems.
    - Event-driven system: the controller alters the state of the system in response to some event.
    - Time-driven system: the controller takes action at a specific point in time
  - Hardware typically used in a system
    - Sensor: measures an (analogue) property and transmits it to a processing unit, generally as an electrical or optical signal.
    - Actuators: switch on/off heavy appliances (e.g. heater to heat/fan to cool)
    - ADC: converts analogue signals to digital signals
    - Transmission cable: to transfer signals
  - Feedback Systems
    - Output from system affects the input of sensors.
    - Ensures system operates within the given criteria
    - By enabling the system output to affect subsequent system inputs, it may cause a change in the actions taken by the system
    - Thus enables the system to automatically adjust conditions in a continuous process

3.2. Logic Gates and Logic Circuits

- Logic Gates: use one or more inputs and produces a single logical output
- AND gate: If both inputs high, output is high ($A \cdot B$)

A	B	Output
0	0	0
0	1	0
1	0	0
1	1	1

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A	B	Output
0	0	0
0	1	1
1	0	1
1	1	1

- OR gate: If either inputs high, output is high ($A+B$)

- NOT gate: an inverter (A)

A	Output
1	0
0	1

A	B	Output
0	0	1
0	1	1
1	0	1
1	1	0

- NAND gate: (A•B) \n

A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0

- NOR gate: (A+B) \n

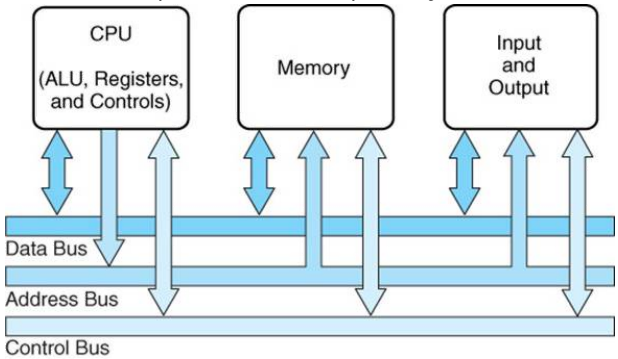
A	B	Output
0	0	0
0	1	1
1	0	1
1	1	0

- XOR gate: ($A \oplus B$) \n

4. Processor Fundamentals

4.1. Central Processing Unit Architecture

- Von Neumann model
  - Von Neumann realized data & programs are indistinguishable and can therefore use same memory.
  - Von Neumann architecture uses a single processor.
  - It follows a linear sequence of fetch–decode–execute operations for the set of instructions i.e. the program.
  - In order to do this, the processor uses registers.
- Registers: smallest unit of storage of microprocessor; allows fast data transfer between other registers
- General Purpose registers
  - Used to temporarily store data values which have been read from memory or some processed result
  - Can be used by assembly language instructions
- Special Purpose Registers
  - Some are accessible by assembly language instructions
  - Only holds either data or memory location, not both
  - Special purpose registers include:
    - Program Counter (PC): holds address of next instruction to be fetched
    - Memory Data Register (MDR): holds data value fetched from memory
    - Memory Address Register (MAR): Holds address of memory cell of program which is to be accessed
    - Accumulator (ACC): holds all values that are processed by arithmetic & logical operations.
    - Index Register (IX): Stores a number used to change an address value
    - Current Instruction Register (CIR): Once program instruction fetched, it is stored in CIR and allows the processor to decode & execute it
    - Status Register: holds results of comparisons to decide later for action, intermediate and erroneous results of arithmetic performed
- The Processor (CPU)
  - Arithmetic and Logic Unit (ALU): part of processor that processes instructions which require some form of arithmetic or logical operation
  - Control Unit (CU): part of CPU that fetches instructions from memory, decodes them & synchronizes operations before sending signals to computer's memory, ALU and I/O devices to direct how to respond to instructions sent to processor
  - Immediate Access Store (IAS): memory unit that can be directly accessed by the processor
  - System Clock: timing device connected to processor that is needed to synchronize all components.
- Buses
  - set of parallel wires that allow the transfer data between components in a computer system



  - Data bus: bidirectional bus that carries data instructions between processor, memory, and I/O devices.

    - Address bus: unidirectional bus that carries address of main memory location or input/output device about to be used, from processor to memory address register (MAR)
  - Control bus
    - Bidirectional and unidirectional
    - used to transmit control signals from control unit to ensure access/use of data & address buses by components of system does not lead to conflict
- Performance of Computer System Factors
  - Clock Speed
    - number of pulses the clock sends out in a given time interval, which determines the number of cycles (processes) CPU executes in a given time interval
    - usually measured in Gigahertz (GHz)
    - If the clock speed is increased, then execution time for instructions decreases. Hence, more cycles per unit time, which increases performance.
    - However, there is a limit on clock speed since the heat generated by higher clock speeds cannot be removed fast enough, which leads to overheating
  - Bus Width
    - Determines number of bits that can be simultaneously transferred
    - Refers to number of lines in a bus
    - Increasing bus width increases number of bits transferred at one time, hence increasing processing speed and performance since there
  - Cache Memory
    - Commonly used instructions are stored in the cache memory area of the CPU.
    - If cache memory size is increased, more commonly executed instructions can be stored and the need for the CPU to wait for instructions to be loaded reduces, hence CPU executes more cycles per unit time, thus improving performance
  - Number of Cores
    - Most CPU chips are multi-core — have more than one core (essentially a processor)
    - Each core simultaneously processes different instructions through multithreading, improving computer performance
- Ports
  - Hardware which provides a physical interface between a device with CPU and a peripheral device
  - Peripheral (I/O) devices cannot be directly connected to CPU, hence connected through ports
  - Universal Serial Bus (USB): Can connect both input and output devices to processor through a USB port
  - High Definition Multimedia Interface (HDMI)
    - Can only connect output devices (e.g. LCD display) to the processor through a HDMI port
    - HDMI cables transmit high-bandwidth and high-resolution video & audio streams through HDMI ports
  - Video Graphics Array (VGA)
    - Can only connect output devices (e.g. second monitor/display) to the processor through a VGA port
    - VGA ports allows only the transmission of video streams, but not audio components
- Fetch-Execute (F-E) cycle
  - Fetch stage
    - PC holds address of next instruction to be fetched
    - Address in PC is copied to MAR
    - PC is incremented
    - Instruction loaded to MDR from address held in MAR
    - Instruction from MDR loaded to CIR
  - Decode stage: The opcode and operand parts of instruction are identified
  - Execute stage: Instructions executed by the control unit sending control signals
  - Register Transfer Notation (RTN)
    - MAR ← [PC]
    - PC ← [PC] + 1
    - MDR ← [[MAR]]
    - CIR ← [MDR]
    - Decode
    - Execute
    - Return to start
    - *Square brackets: value currently in that register*
    - *Double square brackets:* CPU is getting value stored at the address in the register
- Interrupts
  - A signal from a program seeking processor's attention
  - Interrupt Service Routine (ISR):
    - Handles the interrupt by controlling the processor
    - Different ISRs used for different sources of interrupt
- Typical sequence of actions when interrupt occurs:
  - The processor checks interrupt register for interrupt at the end of the F-E cycle for the current instruction
  - If the interrupt flag is set in the interrupt register, the interrupt source is detected
  - If interrupt is low priority: then interrupt is disabled
  - If interrupt is high priority:
    - All contents of registers of the running process are saved on the stack
    - PC is loaded with the ISR, and is executed
    - Once ISR is completed, the processor restores registers' contents from the stack, and the interrupted program continues its execution
    - Interrupts re-enabled and
    - Return to start of cycle

4.2. Assembly Language

- Assembly language: low-level programming language with instructions made up of an op code and an operand
- Machine code: code written in binary that uses the processor's basic machine operations
- Relationship between machine and assembly language: every assembly language instruction (source code)

translates into exactly one machine code instruction (object code)
- Symbolic addressing
  - Symbols used to represent operation codes
  - Labels can be used for addresses
- Absolute addressing: a fixed address in memory
- Assembler
  - Software that changes assembly language into machine code for the processor to understand
  - The assembler replaces all mnemonics and labels with their respective binary values (that are predefined before by the assembler software)
- One pass assembler
  - Assembler converts mnemonic source code into machine code in one sweep of program
  - Cannot handle code that involves forward referencing
- Two pass assembler: software makes 2 passes thru code
  - On the first pass:
    - Symbol table created to enter symbolic addresses and labels into specific addresses
    - All errors are suppressed
  - On the second pass:
    - Jump instructions access memory addresses via table
    - Whole source code translates into machine code
  - Error reported if they exist
- Grouping the Processor's Instruction Set

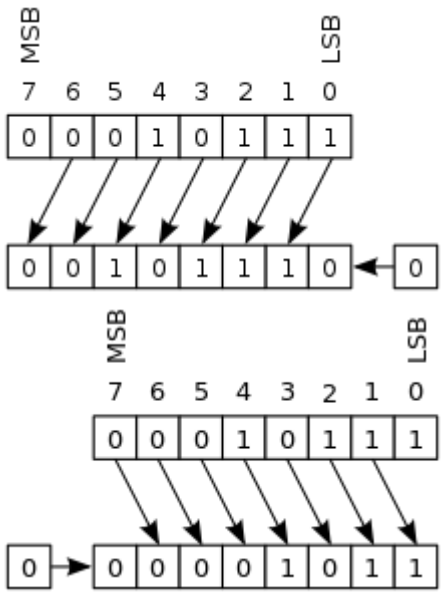
Op Code	Operand	Explanation
Adressing		
LDM	#n	Immediate: Load n into ACC
LDD		Direct: load contents at address into the ACC
LDI		Indirect: load contents of address at given address into ACC
LDX		Indexed: load contents of given address + IR into ACC
Data Movement		
STO		Store contents of ACC into address
Arithmetic Operations		
ADD		Add contents of register to ACC
INC		Add 1 to contents of the register
Comparing		
CMP		Compare contents of ACC with that of given address
CMP	#n	Compare contents of ACC with n
Conditional Jumps		
JPE		Jump to address if compare TRUE
JPN		Jump to address if compare FALSE
Unconditional Jumps		
JMP		Jump to given address
I/O Data		
IN		Input any character and store ASCII value in ACC
OUT		Output character whose ASCII value is stored in ACC
Ending		
END		Return Control to operating system

#denotes immediate addressing
B denotes a binary number, e.g. B01001010 & denotes a hexadecimal number, e.g. &4A

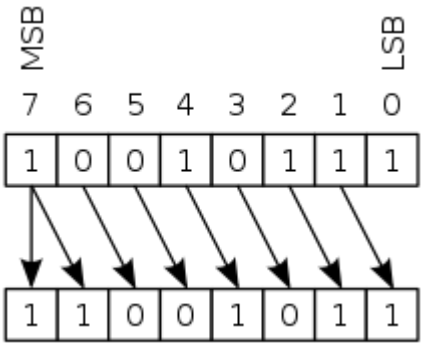
- Modes of Addressing
  - Direct Addressing: loads contents at address into ACC
  - Indirect Addressing: The address to be used is at given address. Load contents of this second address to ACC
  - Indexed addressing: form the address to be used as *+ the contents of the IR (Index Register)*
  - Relative addressing: next instruction to be carried out is an offset number of locations away, relative to address of current instruction held in PC; allows for relocatable code
  - Conditional jump: has a condition that will be checked (like using an IF statements)
  - Unconditional jump: no condition to be followed, simply jump to the next instruction as specified

4.3. Bit Manipulation

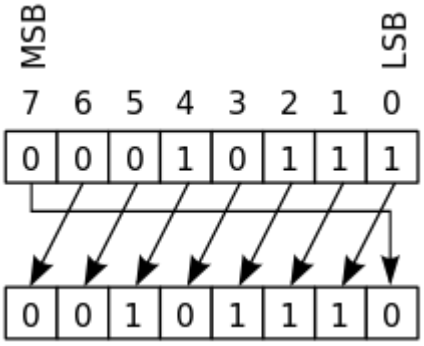
- Binary numbers can be multiplied or divided by shifting
- Left shift (LSL #n)
  - Bits are shifted to the left to multiply
  - E.g. to multiply by four, all digits shift two places to left
- Right shift (LSR #n)
  - Bits are shifted to the right to divide
  - E.g. to divide by four, all digits shift two places to right
- Logical shift: zeros replace the vacated bit position



- Arithmetic shift: Used to carry out multiplication and division of signed integers represented by bits in the accumulator by ensuring that the sign-bit (usually the MSB) is the same after the shift.



- Cyclic shift: the bit that is removed from one end by the shift is added to the other end.



- Bit Masking
  - Each bit can represent an individual flag.
  - ∴ by altering the bits, flags could be operated upon.
  - Bit manipulation operations:
    - Masking: an operation that defines which bits you want to keep and which bits you want to clear.
    - Masking to 1: The OR operation is used with a 1.
    - Masking to 0: The AND operation is used with a 0.
    - Matching: an operation that allows the accumulator to compare the value it contains to the given value in order to change the state of the status register.
- Practical applications of Bit Masking:
  - Setting an individual bit position:
    - Mask the content of the register with a mask pattern which has 0 in the 'mask out' positions and 1 in the 'retain' positions.
    - Set the result with the match pattern by using the AND command with a direct address.
  - Testing one or more bits:
    - Mask the content of the register with a mask pattern which has 0 in the 'mask out' positions and 1 in the 'retain' positions.
    - Compare the result with the match pattern by using the CMP command or by "Checking the pattern".
  - Checking the pattern
    - Use AND operation to mask bits and obtain resultant.
    - Now subtract matching bit pattern from resultant.
    - The final 'non-zero' result confirms the patterns are not the same else vice versa.

5. System Software

5.1. Operating System

- Need for OS
  - A set of programs designed to run in the background on a computer system which
    - Controls operation of computer system
    - Provides a user interface
    - Controls how computer responds to user's requests
    - Controls how hardware communicate
    - Provides an environment in which application software can be executed
  - OS hardware is unusable without an OS, as the OS acts as an interface since it controls communication between user and hardware
- Key Management Tasks
  - (Main) Memory Management
    - Memory protection to ensure 2 programs do not try to use same memory space
    - Paging
    - Use of virtual memory
  - File Management
    - Provides file naming conventions
    - Maintains a directory structure
    - Allocates space to particular files
  - Security Management
    - Proves usernames & passwords
    - Ensures data privacy
    - Prevents unauthorized access

    - Carries out automatic backup
  - Hardware (input/output/peripherals) Management
    - Installation of appropriate driver software
    - Controls access to data sent to and from peripherals
    - Receives & handles interrupts from hardware devices
  - Processor Management
    - Enables multiprogramming and multitasking
    - Resolution of conflicts when 2 or more processes requires the same resource
    - E.g. via Round-robin method
- Utility Software
  - Disk Formatter
    - Prepares a hard disk to allow data to be stored on it
    - Deletes any existing data on disk
    - Performs formatting, process where computer 'draws lines' on disk surface to split it into small areas
  - Virus checker
    - Checks for and then removes any viruses found
    - Constantly checks all incoming and outgoing files
  - Defragmentation Software
    - Files can be big so have to be stored in multiple sectors, which can result in fragmentation (contents of file scattered across >2 non-contiguous sectors)
    - Fragmentation slows down disk access and thus the performance of the entire computer.
    - Defragmenting software works by physically reorganizing disk contents (files) such that they are stored in contiguous sectors.
    - This defragmentation reduces number of movements of the read/write heads require to access the disk contents, hence increasing computer performance
    - The defragmentation also creates larger contiguous free space regions
  - Disk contents analysis/disk repair software
    - Software utility for visualization of disk space usage
    - Gets size for each folder and files, and generates a graphical chart showing disk usage distribution according to folders or other user defined criteria.
    - Allows disk to report errors (e.g. "bad sector")
    - Software will attempt to offer a solution
  - File Compression
    - Reduces file size by removing redundant data in files
    - Causes improvements in the computer's performance by reducing the data that needs to be stored
  - Back-up Software
    - Makes copy of files on another storage medium in the event of a hard drive failure, user error, disaster or accident.
    - Should be a regular process
    - Can provide synchronization between devices
- Program Libraries
  - Pre-written code that can be linked to a software under development without any amendments
  - Can perform common or complex tasks
  - Takes the form of classes
  - Benefits:
    - Saves time: less code needs to be written
    - Smaller testing time: pre-tested and used by others
    - Library file be a complex algorithm which the user need not understand for using it
- Dynamic Link Library (DLL) files
  - Shared library file that contains code and data
  - Code saved separately from the main .EXE file, reducing the .EXE file's size
  - Code only loaded to main memory when required
  - DDL file can be made available to several applications simultaneous, thus reducing strain on memory
  - DLL files act as modules in more complex programs, making it easier to install and run updates

5.2. Language Translators

- Assembler
  - Software that translates assembly language statements into machine code (binary) for execution
  - The mnemonics used translates into machine opcodes
  - Process simple because assembly language has a one-to-one relationship with machine code.
- Compiler and Interpreter

compiler	Interpreter
Translates a high-level language program to machine code.	Translates and executes a high-level language program, line-by-line.
Creates a .exe file which can be easily distributed.	No .exe file created.
Once compiled, .exe file does not need to be compiled again, resulting in faster execution.	Execution very slow – translated each time program run.
Reports all errors at the end of compilation: difficult to locate errors∴ development process long.	Debugging easier/faster, since it stops translating when it reaches an error. This allows real time error correction.
Only be produced when all errors are fixed.	Can run program any time, even before code finished.
Used when development is completed.	Used during development.

- Two-step translation
  - Java and some other high level language programs may require two-step translation, i.e., they will be

partially compiled and partially interpreted
    - Java code first translated to bytecode by Java compiler
    - Bytecode finally interpreted by the Java Virtual Machine to produce machine code
- Integrated Development Environment (IDE) features
    - Coding
        - Context-sensitive prompts: Displays choice of keywords and available identifiers appropriate at current insertion point and provides choices in alphabetical order
        - Highlights undeclared/unassigned variable identifiers
    - Initial Error Detection
        - Dynamic syntax checks: Automatic checking and highlighting of syntax errors, as soon as line typed
        - Type checking & parameter checking
    - Presentation
        - Prettyprint: Automatic indentation and color-coding of keywords
        - Expand and Collapse code blocks: Saves excessive scrolling if collapsed, and easy to see global variable declarations and main program body when collapsed
    - Debugging
        - Single stepping: Executes program line-by-line to see the effect of each statement on variables
        - Breakpoints: Pauses program at a specific line to ensure program operates correctly up to that line
        - Variables/expressions Report Window: Monitors variables for comparing values.

6. Database and Data Modelling

6.1. File Based System

- Data stored in discrete files, stored on computer, and can be accessed, altered or removed by the user

Disadvantages of File Based System:

- No enforcing control on organization/structure of files
- Data repeated in different files; manually change each
- Sorting must be done manually or must write a program
- Data may be in different format; difficult to find and use
- Impossible for it to be multi-user; chaotic
- Security not sophisticated; users can access everything

6.2. Database Management Systems (DBMS)

- **Database:** collection of non-redundant interrelated data
- **DBMS:** Software programs that allow databases to be defined, constructed and manipulated

Features of a DBMS:

- **Data management:** data stored in relational databases - tables stored in secondary storage
- **Data dictionary** contains:
    - List of all files in database
    - No. of records in each file
    - Names & types of each field
- **Data modeling:** analysis of data objects used in database, identifying relationships among them
- **Logical schema:** overall view of entire database, includes: entities, attributes and relationships
- **Data integrity:** entire block copied to user's area when being changed, saved back when done
- **Data security:** handles password allocation and verification, backups database automatically, controls what certain user's view by access rights of individuals or groups of users

Data change clash solutions:

- Open entire database in **exclusive mode** – impractical with several users
- **Lock all records** in the table being modified – one user changing a table, others can only read table
- **Lock record** currently being edited – as someone changes something, others can only read record
- User specifies **no locks** – software warns user of simultaneous change, resolve manually
- Deadlock: 2 locks at the same time, DBMS must recognize, 1 user must abort task

Tools in a DBMS:

- **Developer interface:** allows creating and manipulating database in SQL rather than graphically
- **Query processor:** handles high-level queries. It parses, validates, optimizes, and compiles or interprets a query which results in the query plan.

6.3. Relational Database Modelling

- **Entity:** object/event which can be distinctly identified
- **Table:** contains a group of related entities in rows and columns called an entity set
- **Tuple:** a row or a record in a relation
- **Attribute:** a field or column in a relation
- **Primary key:** attribute or combination of them that uniquely define each tuple in relation
- **Candidate key**: attribute that can potentially be a primary key
- **Foreign key:** attribute or combination of them that relates 2 different tables
- **Referential integrity:** prevents users or applications from entering inconsistent data
- **Secondary key:** candidate keys not chosen as the primary key
- **Indexing:** creating a secondary key on an attribute to provide fast access when searching on that attribute; indexing data must be updated when table data changes

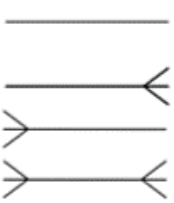
6.4. Relational Design of a System

one-to-one represented by

one-to-many represented by

many-to-one represented by

many-to-many represented by



6.5. Normalization

1st Normal Form (1NF): contains no repeating attribute or groups of attributes. Intersection of each tuple and attribute contains only 1 value. Example:

DELNOTE

Num	CustName	City	Country	ProdID	Description
005	Bill Jones	London	England	1	Table
005	Bill Jones	London	England	2	Desk
005	Bill Jones	London	England	3	Chair
008	Mary Hill	Paris	France	2	Desk
008	Mary Hill	Paris	France	7	Cupboard
014	Anne Smith	New York	USA	5	Cabinet
002	Tom Allen	London	England	7	Cupboard
002	Tom Allen	London	England	1	Table
002	Tom Allen	London	England	2	Desk

2nd Normal Form (2NF): it is in 1NF and every non-primary key attribute is fully dependent on the primary; all the incomplete dependencies have been removed. Example:

DELNOTE

Num	CustName	City	Country
005	Bill Jones	London	England
008	Mary Hill	Paris	France
014	Anne Smith	New York	USA
002	Tom Allen	London	England

DEL_PROD

Num	ProdID
005	1
005	2
005	3
008	2
008	7
014	5
002	7
002	1
002	2

PRODUCT

ProdID	Description
1	Table
2	Desk
3	Chair
7	Cupboard
5	Cabinet

3rd Normal Form (3NF): it is in 1NF and 2NF and all non-key elements are fully dependent on the primary key. No inter-dependencies between attributes.

- MANY-TO-MANY functions cannot be directly normalized to 3NF, must use a 2 step process e.g.

becomes:

6.6. Data Definition Language (DDL)

- Creation/modification of the database structure using this language
  - written in SQL
- Creating a database:

```
CREATE DATABASE <database-name>
```

- Creating a table:

```
CREATE TABLE <table-name> (…)
```

- Changing a table:

```
ALTER TABLE <table-name>
```

- Adding a primary key:

```
PRIMARY KEY (field)
ADD <field-name>:<data-type>
```

- Adding a foreign key:

```
FOREIGN KEY (field) REFERENCES <table>(field)
```

- Example:

```
CREATE DATABASE 'Personnel.gdb'
CREATE TABLE Training
(EmpID INT NOT NULL,
CourseTitle VARCHAR(30) NOT NULL,
CourseDate Date NOT NULL,
PRIMARY KEY (EmpID, CourseDate),
FOREIGN KEY (EmpID) REFERENCES Employee(EmpID))
```

6.7. Data Manipulation Language (DML)

- Query and maintenance of data done using this language – written in SQL

Queries:

- Creating a query:

```
SELECT <field-name>
FROM <table-name>
WHERE <search-condition>
```

- SQL Operators:

=	Equals to
>	Greater than
<	Less than
>=	Greater than or equal to
<=	Less than or equal to
<>	Not equal to
IS NULL	Check for null values

- Sort into ascending order:

```
ORDER BY <field-name>
```

- Arrange identical data into groups:

```
GROUP BY <field-name>
```

- Joining together fields of different tables:

```
INNER JOIN
```

Data Maintenance:

- Adding data to table:

```
INSERT INTO <table-name>(field1, field2, field3)
VALUES (value1, value2, value3)
```

- Deleting a record:

```
DELETE FROM <table-name>
WHERE <condition>
```

- Updating a field in a table:

```
UPDATE <table-name>
SET <field-name> = <value>
WHERE <condition>
```

7. Ethics and Ownership

- Ethics: a system of moral principles that guide behaviour based on philosophical views
- Computer Ethics
  - Regulate how computing professionals should make decisions regarding professional & social conduct.
  - A computing professional can be ethically guided by joining a professional ethical body such as the BCS and IEEE, which have codes of conduct.
- Ownership
  - Data ownership: having legal rights and complete control over a single piece or set of data elements.
  - Copyright gives the creators of some types of media rights to control how they're used and distributed.
  - Programming ideas and methods can be stolen by competitors, software can easily be copied and bootlegged (sold illegally) hence legislation is needed to protect the ownership, usage and copyright of data.
- Software Licencing
  - Free Software Foundation:
    - License gives user freedom to run, copy, distribute, study, change and improve software.
    - Condition: any redistributed version of software must be distributed with original terms of free use, modification, and distribution (aka copyleft)
  - The Open Source Initiative:
    - Source code of an open-source software is readily available to users under a copyright; does not enable user to re-distribute the software
    - Concept of open-source program relies on fact that user can review source-code for eliminating bugs in it
  - Shareware:
    - Demonstration software that is distributed for free but for a specific evaluation period only
    - Distributed on trial basis and with an understanding that sometime later a user may be interested in paying for it
    - Used for marketing purposes
  - Commercial: Requires payment before it can be used, but includes all program's features, with no restrictions
- Artificial Intelligence (AI): ability of a computer to perform tasks in such a way that are conventionally associated with human intelligence:
  - AI can learn from past mistakes

        - they adapt to stop the same problem occurring again
        - they learn to predict what might happen & raise alert
    - AI can learn to work more efficiently
        - when an action slows the system down, it can prevent this from happening again
        - when an action increases the speed of the system, it can repeat this when necessary to improve efficiency
- AI Applications
    - Developing autonomous mechanical products
    - Machine learning through data sets
- AI Impacts
    - Social
        - Replacement of manual labour with automation could lead to massive unemployment
        - However, could lead to increased leisure time
    - Economic: Due to increased innovation and efficiency with automation provided by AI, there'd be lower manufacturing costs in general
    - Environmental: Detrimental impact on environment due to robot manufacture with limited resources and its waste disposal

8. Data Integrity

8.1. Data Security

- Data Security: making sure that data is protected against loss and unauthorized access.
- Data Integrity: making sure that data is valid and does not corrupt after transmission
- Data Privacy: ability to determine what data is shared with a third party
- Data Security and Computer System Security

Data Security	System Security
Protection of data on a computer system	Protection of the computer system
To prevent corruption of data and prevent hackers from using data	To prevent access of viruses to the system and prevent hackers to enter your computer system
E.g. encryption	E.g. ID & Password

- Threats to Computer & Data Security
    - Malware
        - software intentionally designed to damage a computer or computer network
        - Includes Virus & Spyware
        - Virus: Software that replicates itself by inserting a copy of itself into another piece of software, which may cause computer to crash and can lead to deletion or corruption of data
        - Spyware: software that gathers information about user's online and offline activity including accessed sites, applications, and downloaded files.
        - Risk restriction: Ensure anti-virus and anti-spyware software is installed, regularly updated and run.
    - Hacking
        - illegal access to a computer system
        - Hackers can obtain user's confidential data which can cause identity theft
        - Can lead to deletion or corruption of data
        - Risk restriction: Use strong passwords and ensure firewall
    - Phishing
        - Attempt through emails to obtain user's confidential data which can cause identity theft
        - Risk restriction: Ignore suspicious mails and ensure firewall criteria include SPAM filters, blacklist, etc.
    - Pharming
        - Redirects user to a fake website that appears legitimate to gain confidential data
        - Risk restriction: use a reliable ISP; check that links are genuine and ensure https is present in the URL
- Computer System Security Measures
    - User Accounts and Passwords
        - Usernames & passwords to deny access to unauthorized users
        - User assigned privilege which access to only the user's workplace, preventing the user to have admin rights.
        - Can assign privilege to files so users with low privileges do not have access.
    - Firewalls
        - Hardware or software that filters information traveling between the computer system and the internet
        - (software) firewall can make decisions about what to allow and block by detecting illegal attempts by specific softwares to connect to the internet
    - Authentication • Process of determining whether someone is who they claim to be
    - •Helps prevent unaut
    - •Log-on using digita
    - Anti-virus software
        - Runs in background to detect & remove viruses.
        - Checks files for known malicious patterns
    - Anti-spyware software: detects & removes spyware.
    - Encryption:
        - Conversion of data to code by encoding it
        - Doesn't stop illegal access but appears meaningless
        - Necessary to use decryption software to decode data
    - Data Security Measures
        - Encryption

    - Access Rights to data (authorization): different users assigned different authorization levels which prevent them from accessing all data ∴ increases security
- Data Backup
    - An exact copy of an original piece of data in case the original is lost or corrupted
    - Within the same computer system or at different site
- Disk-mirroring strategy
    - Real-time strategy that writes data to two or more disks at the same time.
    - If one fails, the other is still there to be read off of

8.2. Data Integrity

- Data validation and data verification help protect the integrity of data by checking whether the data entered is sensible and accurate, respectively.
- Data Validation: checks if data entered is valid, but not its accuracy
- Data Validation Methods
    - Range check: data must be between a set of values
    - Format check: data must follow correct pattern/order
    - Length check: data must have exact no. of characters
    - Presence check: checks if some data has been entered
    - Existence check: data entered must exist
    - Limit check: checks whether a value entered is within acceptable minimum and maximum values.
    - Check digit: A digit is used as the answer to an arithmetic operation of other digits in data. If not matched, then data entered incorrectly
- Data Verification: checks data entered is accurate during data entry and data transfer
- Data Entry Verification Methods
    - Visual Check: Person manually compares original data with that entered to check if correct
    - Double Entry: Enter data into computer twice and compares.
    - If differences found, go back to raw data to fix error
- Data Transfer Verification Methods
    - Errors may occur when data moved in system.
    - Parity Check
        - All data transmitted as bits
        - Number of 1s in a byte must always be either an odd number or an even number
        - Parity can be set either as even or odd
        - E.g. two communicating devices decide there will always be an odd number of 1s. A byte is received that has even number of 1s so error occurred and receiving device would ask for it to be sent again
        - Used also when data sent between parts of the CPU
        - Not foolproof: if 2 bits are transposed, data accepted
    - Checksum Check
        - Data sent from one place to another as block of bytes rather than individual bytes
        - Computer adds together all bytes being sent
        - Any bits lost at most-significant end as carry ignored so answer is an 8-bit number
        - Checksum calculated before and after data sent
        - If two bytes different, error occurred therefore block of bytes must be sent again

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