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personal computers that was introduced in 1987 with the IBM PS/2. See also EISA.

MCAP *Abbrev. for modified constant angular velocity.* A modification of *CAV in which the rotation rate of the disk is constant but the clock rate and data transfer rate are varied in proportion to the radius of the track being accessed, thus obtaining the high data density of *CLV without the long access time that usually goes with it. In practice the tracks are usually grouped into 4 to 8 bands; clock and data rates vary between bands but not within a band.

MCLV *Abbrev. for modified constant linear velocity.* A modification of *CLV in which the data tracks on an optical disk are grouped in a number of bands; the same angular velocity is used while accessing all the tracks within a band, but a different velocity is used for each band. It is thus a compromise between CLV and *CAV.

MDNS *Abbrev. for managed data network service.*

MDR *Abbrev. for memory data register.*

Mealy machine See SEQUENTIAL MACHINE.

mean deviation See MEASURES OF VARIATION.

means/ends analysis A technique used in "artificial intelligence for forming plans to achieve goals. A plan consists of a sequence of actions. The sequence is put together by comparing the goals that each action achieves (the means) with the goals and action preconditions that must be achieved (the ends).

measure 1. A quantity ascertained or ascertainable by measurement. 2. A number assigned to a property of an entity according to well-defined rules, so as to describe or represent that property objectively. 3. A number or other "symbol assigned to a specific property by means of observation.

measurement of appearance The family of measurements necessary to characterize the color and surface finish of an object.

measures of location Quantities that represent the average or typical value of a "random variable (compare MEASURES OF VARIATION). They are either properties of a "probability distribution or computed "sta-

istics of a sample. Three important measures are the mean, median, and mode. The mean of a sample of n observations, denoted by $\bar{x}$, is

$$\sum x_i / n$$

The mean of a probability distribution, denoted by μ , is

$$\sum xp(x)$$

for a discrete distribution and

$$\int xf(x)dx$$

for a continuous distribution; it is also called the **expectation** of x , denoted by $E(x)$.

A **weighted mean** is used when members of a sample are known with different reliability. To each observation x_i corresponds a weight w_i , and now $\bar{x}$ is

$$\sum (w_i x_i) / \sum w_i$$

If each observation is the mean of w observations, the formulas for the weighted and unweighted means agree.

The **median** is the value of x exceeded by exactly half the sample or distribution. The median of a distribution is the value for which the cumulative distribution function, $F(x)$, equals 0.5 (see PROBABILITY DISTRIBUTIONS).

The **mode** is the most commonly occurring value. For distributions in which the frequency function, $f(x)$, has one or more local maxima, each maximum is called a mode. These measures may be illustrated on the following sample of eight values of x :

1, 1, 1, 2, 3, 3, 5, 7

The mean is 2.875, the median is 2.5, and the mode is 1.

measures of variation Quantities that express the amount of variation in a "random variable (compare MEASURES OF LOCATION). Variation is sometimes described as **spread** or **dispersion** to distinguish it from systematic trends or differences. Measures of variation are either properties of a "probability distribution or sample estimates of them. The **range** of a sample is the difference between the largest and smallest value. The **interquartile range** is potentially more useful. If the sample is ranked in ascending order of magnitude two values of x may be found, the first of which is exceeded by 75% of the sample, the second by 25%; their difference is the interquartile range. An analogous definition applies to a probability distribution.

The **variance** is the expectation (or mean) of the square of the difference between a "random variable and its mean; it is of fundamental importance in statistical analysis. The variance of a continuous distribution with mean μ is

$$\int (x - \mu)^2 f(x) dx$$

and is denoted by σ^2 . The variance of a discrete distribution is

$$\sum (x_i - \mu)^2 p(x_i)$$

and is also denoted by σ^2 . The sample variance of a sample of n observations with mean $\bar{x}$ is

$$\sum (x_i - \bar{x})^2 / (n - 1)$$

The **standard deviation** is the square root of the variance, denoted by σ (for a distribution) or s (for a sample). The standard deviation has the same units of measurement as the mean, and for a "normal distribution about 5% of the distribution lies beyond about two standard deviations each side of the mean. The standard deviation of the distribution of an estimated quantity is termed the **standard error**.

The **mean deviation** is the mean of the absolute deviations of the random variable from the mean.

mebi- See BINARY PREFIXES.

mechanical verifier A system that provides automated assistance to the production of a "program correctness proof. Typically such a system consists of two distinct parts: a **verification condition generator** and a **theorem prover**. The former is responsible for generating the theorems that must be proven in order to demonstrate that "preconditions and "postconditions are consistent with the semantics of the statements to which they relate. The theorem prover is then responsible for proving these verification conditions.

Different mechanical verifiers vary considerably in their capabilities. A relatively simple verifier might require that assertions giving all relevant information are attached between every pair of successive statements (simple or compound), and would present any nontrivial verification conditions to the user for manual proof; this approach is sometimes called an **assertion checker**. A more sophisticated mechanical verifier requires only major assertions to be attached prior to verification (perhaps only the input

assertion and output assertion) and is able to generate its own intermediate assertions as necessary. Further, the theorem prover is capable of proving complex verification conditions, perhaps presenting only the occasional lemma to the user for confirmation.

mechatronics An engineering discipline that attempts to integrate technologies from mechanical engineering, electronics, and computer software and hardware in order to design and create flexible "smart" machines. Mechatronics is closely related to "robotics, but covers relatively less complex systems such as intelligent door locks, cameras, photocopiers, and washing machines.

Media Access Control address See MAC ADDRESS.

median See MEASURES OF LOCATION.

medium (*plural: media*) See DATA MEDIUM.

meet operator See LATTICE.

mega- (symbol: M) A prefix indicating a multiple of one million (10^6), as in megahertz and megawatt. When the binary number system is used in a structure or process (as in semiconductor RAM or ROM), the prefix then indicates a multiple of 2^{20} , i.e., 1 048 576, as in megabyte or megabit. The context usually clarifies which meaning is intended, although being numerically close the meanings are often considered more or less equivalent. See also BINARY PREFIXES.

Megastream *Trademark* British Telecom's higher-speed digital leased-circuit service. Megastream circuits (for more correctly "virtual circuits) are available as a fully digital service, operating at 1 and 622 Mbps. See also KILOSTREAM.

member (element) of a "set S . An object x that is in S , usually denoted by $x \in S$. One of the basic actions that can be performed on sets is asking whether or not an object is in a set. See also OPERATIONS ON SETS.

member disk A disk that is under the control of array management software (see DISK ARRAY). Disk drives may be array members for part of the time and be used as conventional disk drives otherwise. See also RAID.

memory A device or medium that can retain information for subsequent retrieval. The term is synonymous with **storage** and **store**, although it is most frequently used for

referring to the internal storage of a computer that can be directly addressed by operating instructions. See MAIN MEMORY, CACHE, SEMICONDUCTOR MEMORY, MEMORY HIERARCHY, MEMORY MANAGEMENT.

memory card An *add-in card containing memory chips either directly mounted on the card or arranged in *SIMMS that plug into sockets on the card.

memory compaction (block compaction) Any of several methods used to relocate information blocks in main memory in order to maximize the available free space in the memory. See also STORAGE ALLOCATION.

memory cycle 1. The complete sequence of events for a unit of memory to go from a quiescent state through a read and/or write phase and back to a quiescent state. 2. The minimum length of time that is required between successive accesses (read or write) to a memory. See also CYCLE.

memory data register (MDR) A *register used for holding information (either program words or data words) that is in the process of being transferred from the memory to the central processor, or vice versa.

memory dump A representation, which can be read by a person, of the contents at some time of some part of the main memory of a computer system. A variety of representation formats might be employed, but typically these would all be relatively low-level - e.g. purely numeric or assembler-code format. A memory dump is normally taken for *postmortem purposes.

memory element A device that stores one item of information: if it has q stable states it is said to be * q -ary, and if $q = 2$ it is said to be binary. It is usually implemented electronically, sometimes with the assistance of the magnetic, optical, or acoustic properties of a storage medium. In practice, most memory elements are binary. In fast computer circuitry, the *flip-flop is the most common type of memory element.

Memory elements are employed specifically in computer memories and generally in *sequential circuits. A memory element is any smallest part of such a system that possesses more than one stable state. For example, a binary *shift register contains four flip-flops and has 16 states, but each of its four memory elements has only two states: a

similar ternary shift register would have 81 states, but would still consist of four memory elements, each having three states.

memory fill An aid to program debugging in which every location in the memory is filled with a predetermined character before being overwritten by the incoming program.

memory guard A form of hardware *interlock used in some systems to control access to memory that is currently involved in a peripheral transfer. At the time of initiating the transfer the channel sets an indication that the buffer area is associated with the transfer; this indication is cleared by the channel on completion of the transfer. Any attempt to access the buffer area (other than by the channel) will suspend the process attempting to access the buffer until the transfer has been completed.

memory hierarchy For physically different kinds of *memory there are significant differences in the time to read or write the contents of a particular *location in memory, the amount of information that is read or written on a given occasion, the total volume of information that can be stored, and the unit costs of storing a given amount of information. To optimize its use and to achieve greater efficiency and economy, memory is organized in a hierarchy with the highest performance and in general the most expensive devices at the top, and with progressively lower performance and less costly devices in succeeding layers. The contents of a typical memory hierarchy, and the way in which data moves between adjacent layers, might be organized as follows.

1. **Register** - A single word held in each *register of the *processor; typically a word contains 4 bytes. This is sometimes not thought of as part of the hierarchy.

2. **Cache** - Groups of words within the *cache; typically a single group in the cache will hold 64 words (say 256 bytes), and there will be, say, 1024 such groups, giving a total cache of 256 Kbytes. Single words pass between the cache and registers within the processor. All transfers into and out of the cache are controlled entirely by hardware.

3. **Main memory** - Words within the main (*random-access) memory. On a very high performance system, groups of words corresponding to a group within the cache are transferred between the cache and the main memory in a single cycle of main memory.

On lower-performance systems the size of the group of words in the cache is larger than the width of the memory bus, and the transfer takes the form of a sequence of memory cycles. The algorithm that controls this movement is implemented entirely in hardware. Main memory sizes are very variable - from 256 Mbytes on a small system up to several Gbytes on a high-performance system.

4. **Online backing store** - Blocks of words held on permanently connected *backing store. There may be two somewhat distinct forms of activity here:

(a) **swapping device** - pages (of say 4 Kbytes) or segments (up to many Mbytes) of memory held on a *swapping device are transferred as complete units between their backing-store home and a page frame or segment area in main memory, under the control of an algorithm implemented by the software of the operating system but with hardware assistance to indicate when pages or segments are to be moved;

(b) **backing store** - complete files, or clearly identifiable subsections of large files, are moved between the backing-store device and the main memory in response to explicit actions by the programmer, usually by a supervisor call to the operating system.

5. **Demountable storage** - Complete files, backed up onto removable disks or magnetic tape within the file store system and the archiving system. Complete files are transferred in either direction. The creation of backup copies and the reinstatement of a backed-up file may be automatic, or may require direct intervention by the end user. The backup medium is typically a modified form of a video or audio cassette system, possibly mounted in some form of computer-controlled cassette-handling robot system.

6. **Read-only library** - Complete files, and collections of associated files relating to a single application, held on read-only devices such as *CD-ROM, or on a device with some form of write-protection control. Complete sets of files are read into the system from the read-only device, but for obvious reasons there are never any transfers from the system to the device.

memory management Control of the *memory hierarchy of a system as a whole, or control of allocation at a fixed level within the memory hierarchy. In the former case in-

formation stored within the system is shuttled between one realization of memory and another, the objective being to maintain maximum *hit rate in each form of memory. This movement may be controlled by

(a) voluntary user action, e.g. copying a file from disk to memory in order to edit it;

(b) system software, e.g. transfer of a page between swapping device and memory when a page fault occurs;

(c) system hardware, e.g. movement of a set of words from memory to cache when a word within the set is accessed.

At a given level of the hierarchy the operating system will control what fraction of that level is to be allocated to each process. This can clearly only occur where control is by system software, and refers most particularly to the allocation of memory to a process, or to the allocation of space on the swapping device. Movement between disk and magnetic tape is often separately treated as archiving. See also STORAGE PROTECTION.

memory map A schematic presentation of the use to which memory is being put, often presented as a byproduct during the compilation of a program. The memory map may be useful in the diagnosis of faults in the compiled program, especially when used in association with a *memory dump.

memory mapping 1. A technique for managing peripheral devices. The control registers of the peripheral device appear to the processor as words in memory whose contents can be written and read using the normal store and fetch operations. 2. A similar technique for reading and writing *files. A file's contents are mapped to a section of a process's virtual memory and treated as an array of bytes.

memory protection Any of many methods for controlling access to or use of memory. This control may be to prevent inadvertent user interference, to provide for system security, or both.

A mechanism for controlling the types of access permitted to an area of memory is known as a **memory protect**. In virtual memory systems it may be possible to assign certain areas as being capable of designated modes of access; for example, an area that is known to contain only the code of shared subroutines may be designated as having "execute only" access, and can only be read during the instruction-fetch phase of execut-

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