

A Dictionary of
Computing

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cell array A computer-graphics output primitive defined by a rectangular grid of equal-size rectangular cells each having a single color.

cell relay A form of switching in which the individual packets, or *cells, have a fixed length and a fixed internal structure; in many cases the cells are also deliberately kept to a small size, typically a few tens of bytes. Once the initial decision on cell routing has been made, typically at the time of creating a *virtual circuit, it is possible to realize the actual switching activity almost entirely in table-driven hardware, rather than invoking a software implementation, allowing very short switching times. The large number of cells into which even a short message is subdivided increases the ratio of overheads to useful payload. *See also* ATM, FRAME RELAY.

cellular automata machine (CAM) A *multiprocessor machine based on an array of **cellular automata**. Each automaton is usually a simple processor capable of simple computational tasks. In a normal architecture, each of these processing nodes can interchange data only with its immediate neighbors and all processing nodes carry out the same computational operation. Although the operations available at each node are quite simple, the aggregated effect of many such nodes can exhibit complex behavior and can rapidly model quite complex dynamic systems.

CEN/CENELEC European Committee for Standardization (CEN; Comité Européen de Normalisation) and European Committee for Electrotechnical Standardization (CENELEC; Comité Européen de Normalisation Electrotechnique), voluntary associations of *ISO/*IEC members that in effect represent federations of all the national standards-making institutes of the European Union. CEN/CENELEC aims to harmonize members' national standards and adopt new European standards, including those for computing.

centralized structure store (CSS) The conceptual workstation-independent storage area for structure networks in *PHIGS.

central processor (CPU, central processing unit) The principal operating part of a computer. It is usually defined as the *ALU (arithmetic and logic unit) and the *control unit (CU). It must be joined to a *primary

memory to form the processor-memory pair of the basic *von Neumann machine.

Centronics interface A de facto standard plug-compatible *parallel interface for printers, first used in printers manufactured by Centronics Corp.

CEPIS Council of European Professional Informatics Societies. Thirty-seven professional informatics societies, from 33 European countries, are members of CEPIS. Together they represent more than 250 000 ICT professionals. CEPIS administers the European Computer Driving Licence (ECDL), a qualification for computer users, and the European Certification of Informatics Professionals (EUCIP), a first level qualification for IT professionals.

CERT *Acronym* for computer emergency response team.

certainty factor A device used in *rule-based systems to assign weight to facts or pieces of knowledge. The weights express the perceived certainty of a fact being true: usually -1 indicates certainly false, +1 indicates definitely true, and intermediate values represent varying degrees of certainty, with 0 meaning unknown. The medical *expert system MYCIN used certainty factors, with conjunctions of rules taking the minimum value. The use of certainty factors is similar to *probabilistic reasoning but is less formally related to probability theory.

certificate (public key certificate, digital certificate) A means of authenticating public keys (*see* CRYPTOGRAPHY). *Public key encryption is a very powerful system but has an important security hole: there is no intrinsic guarantee that the people or organizations distributing public keys are who they claim to be. A certificate is a file issued by a trusted third party – a *certificate authority – that contains both a public key and details of the person or organization to whom it belongs, which the third party declares to be correct. Crucially, the certificate is digitally signed by the third party. A recipient can verify that the certificate itself is genuine by using the third party's public key, and can then be confident in using the public key it contains. Certificate files comply with the *X509 standard and their use on the Internet is governed by RFC 3280.

 **SEE WEB LINKS**

- The Internet X509 specification

covert channel A communication path, usually indirect, by which information can be transmitted in violation of a *security policy. For example, a covert channel may exploit system flags to allow one program to send confidential information to another.

CPL *Abbrev. for combined programming language.* A language developed in the early 1960s at the Universities of Cambridge and London in the UK. Although it never came into general use, CPL is noteworthy for the fact that it anticipated many of the concepts that are now regarded as characterizing modern "advanced" languages, notably the control structures of *structured programming and the reference concept that formed a major feature of Algol 68. CPL was the direct precursor of *BCPL and thus an ancestor of *C.

CPM *Abbrev. for critical path method.*

CP/M *Trademark; abbrev. for control program/monitor or control program for microcomputers.* One of the earliest operating systems for 8-bit microprocessors from Digital Research, Inc. It is no longer used. *See also* MS-DOS.

cps *Abbrev. for characters per second.* A rate of processing, transferring, or printing information.

CPU *Abbrev. for central processing unit. See CENTRAL PROCESSOR.*

CPU cycle time Usually, the time required for the execution of one simple processor operation such as an addition; this time is normally the reciprocal of the *clock rate. The term has been used formerly for the time required for the fetching and execution of one simple (e.g. add or subtract) machine instruction; this use however is inappropriate now when most processors exploit *pipelining. The CPU cycle time is one of many figures-of-merit for a computer system. *See also* COMPUTER POWER, CYCLE.

CPU time (processor time) The time for which a *process has been receiving service from the processor. *See also* SYSTEM ACCOUNTING.

CR *Abbrev. for carriage return.*

cracking 1. Gaining, or attempting to gain, unauthorized access to computers with malicious intent. Distinguished from *hacking, which may be benevolent or neutral. 2. Ob-

taining plaintext passwords or encryption keys, usually from information protected by *irreversible encryption.

Craig's interpolation theorem A theorem that provides an answer to the question of whether an interpolant *I* exists such that given a formula $A \Rightarrow B$ then both $A \Rightarrow I$ and $I \Rightarrow B$ are valid.

crash A system failure that requires at least operator intervention and often some maintenance before system running can resume. The word is also used as a verb. *See also* RECOVERY.

crawler *See* SPIDER.

Cray Inc. A US manufacturer of supercomputers, primarily for the scientific and engineering fields. Cray Research was founded by Seymour Cray in 1972 and launched its first supercomputer, the Cray-1, in 1976. Cray Research and Silicon Graphics Inc. merged in 1996. The Cray Research Division of Silicon Graphics Inc. merged with Tera in 2000 and the resulting company changed its name to Cray Inc. It remains one of the leading suppliers of supercomputers.

CRC *Abbrev. for cyclic redundancy check, or for cyclic redundancy code.*

crisis time The time during which an *interrupt must be serviced, otherwise a fault, such as the loss of requested data, will occur.

criticality analysis *See* FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS.

critical path method (CPM) A project planning, management, and scheduling method that divides a project into activities, each with a statement of time and resources required, and their precedence dependencies. These activities are then connected in a graph that expresses the dependencies and the times. The critical path is defined as the path through the graph that requires the maximum time. Variations of this method allow for statistically distributed time and resources, time/resource tradeoffs, etc. *See also* PERT.

critical region A section of code that may only be executed by one *process at any one time. *See also* CRITICAL RESOURCE, CRITICAL SECTION, MUTUAL EXCLUSION.

critical resource A resource that can only be in use by at most one *process at any one

partly by the speed and power of the processor and partly by the characteristics of other components of the system, i.e. the memory, the disk units, the display, the keyboard, the flexibility of the hardware, and the operating system and other software.

Memory sizes range up to several gigabytes and the access speed can also vary considerably. *Optical disks' capacities lie in the tens of gigabyte range and hard disk capacities in the hundreds of gigabyte range. Microcomputer *displays are generally high-definition color monitors based on CRT and LCD technologies. *LCD and *plasma displays are used on *laptops, *notebooks, and other portable models. The flexibility of the hardware can be measured by the number and type of enhancements available. These might include extra memory, more disk drives, *pointing devices, communications interfaces, and the ability to participate in networks. The *operating system can be characterized by its use of memory, how much can be accessed and how well it is done, how many tasks can be run concurrently, and how it appears to the user. 2. A single integrated circuit containing all the logic elements needed for a complete computer system.

microcontroller 1. A single-chip computer designed specifically for use in device control, communication control, or process-control applications. It typically comprises a microprocessor, memory, and input/output ports. A typical microcontroller might have a relatively short word length, a rich set of bit-manipulation instructions, and lack certain arithmetic and string operations found on general-purpose microprocessors. 2. A microprocessor-based device or system designed for control applications.

microfiche, microfilm See COM.

microinstruction One instruction in a microprogram that specifies some of the detailed control steps needed to perform an *instruction. See MICROPROGRAMMING.

micropipeline An asynchronous processing pipeline (see PIPELINE PROCESSING). It is a self-timed FIFO buffer that may include computational elements between its stages.

microprocessor A semiconductor chip, or chip set, that implements the *central processor of a computer. Microprocessors consist of, at a minimum, an *ALU and a

*control unit. They are characterized by speed, word length (internal and external), *architecture, and *instruction set, which may be either fixed or microprogrammed. It is the combination of these characteristics and not just the *cycle time that determines the performance of a microprocessor.

Most microprocessors have a fixed instruction set. Microprogrammed processors have a control store containing the microcode or firmware that defines the processor's instruction set; such processors may either be implemented on a single chip or constructed using *bit-slice architecture elements. *RISC microprocessors are designed to execute a small number of simple instructions extremely fast.

The processor's architecture determines what register, stack, addressing, and I/O facilities are available, as well as defining the processor's primitive data types. The data types, which are the fundamental entities that can be manipulated by the instruction set, have included bit, nibble (4 bits), byte (8 bits), word (16 bits), double words (32 bits), and quadruple words (64 bits). Note that a word is usually defined as the number of bits in the processor's internal data bus rather than always being 16 bits. Instructions generally include arithmetic, logical, flow-of-control, and data movement (between stacks, registers, memory, and I/O ports).

The first microprocessor, the four-chip set Intel 4004, appeared in 1971 accompanied by considerable debate about its utility and marketability. It was the outcome of an idea proposed by Ted Hoff of *Intel Corp. for a calculator that could implement a simple set of instructions in hardware but permitted complex sequences of them to be stored in a read-only memory (ROM). The result of his proposal was a design for a four-chip set consisting of a CPU, *ROM, *RAM, and a *shift-register chip, the chip design proceeding in 1970 under the direction of Federico Faggin, later the founder of Zilog, Inc. The Intel 4004 had a 4-bit data bus, could address 4.5 Kbytes of memory, and had 45 instructions. Its 8-bit counterpart, the Intel 8008, was introduced in 1974 and its improved derivative, the Zilog Z80, in 1976. By this time there were over 50 microprocessors on the market.

The next generation of microprocessors included the Zilog Z8000, Motorola 68000, Intel 8086, National 16000, as well as the

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older Texas Instruments 9900 and Digital Equipment Corporation LSI-11. All of these chips use a 16-bit-wide external data bus. Microprocessors that use 32-bit external data buses include the Intel386, Intel486, Motorola 68030, and Digital's VAX 78032 and 78132 (processor and FPA). Modern processors, for example recent products in Intel's Pentium family and its derivatives and in AMD's Athlon family, use a 64-bit external data bus and 32- or 64-bit data types. RISC microprocessor chips with a 64-bit architecture include the PowerPC and SPARC families. *See also* MULTI-CORE PROCESSOR.

microprogramming A method of accomplishing the *control unit function by describing the steps in that function as a sequence of register-transfer level operations that are much more elementary than *instructions. In this method of designing and building a control unit, an additional memory, commonly called a **microprogram store**, contains a sequence of **microinstructions**. A number of microinstructions will be required to carry out an ordinary machine instruction, thus the microprogram store should be faster – have a shorter *cycle time – than the normal fast memory.

Microinstructions are usually classified as either **horizontal** or **vertical**. In a horizontal microinstruction most of the bit positions have a one-to-one correspondence with specific control functions. Horizontal microinstructions provide explicit control of functions at particular points within the CPU. For example, a particular bit in the microinstruction would call for a specific register to be cleared at a specific clock time. A vertical microinstruction generally contains highly coded fields describing elementary operations to be performed by certain elements of the control unit and *ALU, and the sources and destinations of information passing between these units. In such a microinstruction, a field, say of three bits, might be decoded to indicate which of eight registers is to be one source of an operation to be performed in an ALU. Other fields would define the operation and any other necessary sources. Horizontal microinstructions will in general contain more bits, or be wider, hence the word horizontal. Vertical microinstructions, although containing fewer bits, require more decoding.

Some microprogrammed control units go through two levels of microprogramming.

The first level consists of addresses of horizontal microinstructions. The second level is the used or useful subset of all horizontal microinstructions. This provides for more efficient use of a horizontal microprogram memory at the expense of two memory references per microinstruction execution. In this form of microprogramming the first memory has been called the **microprogram store** and the second memory has been called the **nanostore**.

The control units of most CISC processors are microprogrammed. This permits a more orderly and flexible approach to control unit design and permits changes in a control unit by changing the memory contents. Most microprogram stores are made with *ROM. These memories are generally faster and are potentially less prone to errors. Other microprogram stores, usually called **writeable control stores** (WCS), are made with *RAM. These provide greater ease of change of control unit function; in some cases users are permitted or encouraged to "build" specialized instructions. Some microprogrammed control units have a mixture of ROM and RAM microprogram stores. These permit special microprograms to be loaded for maintenance and diagnostic purposes.

Manufacturers of supercomputers have not, in general, employed microprogramming because they have been prepared to accept the higher complexity of *hardwired control for the sake of ultimate performance. The simpler designs of current RISC processors have also opted for hardwired techniques to optimize instruction-execution rates of their simple instruction sets.

microprogram sequencer The part of a microprogrammed control unit that provides the equivalent of a *program counter at the microprogram level. *See* MICROPROGRAMMING.

microprogram store (control memory) The memory that contains a microprogram. It may be fixed (ROM) or alterable (writeable control store). *See* MICROPROGRAMMING.

microrelief A technique used in optical recording. The surface of the medium is impressed with a very fine pattern that scatters light. When a spot on the surface is heated by a laser beam, the material flows to leave a smooth reflective surface. The technique is sometimes called **moth-eye** recording be-

information (the resource descriptor) on the resources allocated to the process and on the permissible operations on these resources.

process model See SOFTWARE DEVELOPMENT PROCESS MODEL.

process modeling A form of modeling where the model produced is a *software or system development process.

processor A computer, usually/often the *central processor. See also MICROPROCESSOR, I/O PROCESSOR, COMMUNICATION PROCESSOR.

processor allocation The measure of the amount of processor resource that is available to a *process. Normally the allocation will be expressed as a time, or as a number of instructions to be executed.

processor status word (PSW) A word that describes fully the condition of a processor at each instant. It indicates which classes of operations are allowed and which are forbidden, and the status of all interrupts associated with the processor. It will also contain the address of the instruction currently being executed. The PSW is held in a *register known as the **processor status register**. See also PROGRAM STATUS WORD.

processor time (CPU time) The time for which a *process has been receiving service from the processor. See also SYSTEM ACCOUNTING.

product group Another name for direct product.

production See GRAMMAR, SEMI-THUE SYSTEM.

production rule system (production system) A programming language in which the programs consist of condition $\Rightarrow$ action rules; these rules are known as **productions** or **production rules**. The programs are processed by an interpreter which repeats the following operations: all rules whose conditions are satisfied are found (rule matching), one of them is selected (conflict resolution), and its action is called (rule firing). Such systems are often known as **rule-based systems** in artificial intelligence and form the basis of many *expert systems.

production run Execution of a program in the normal way to produce useful results. Compare DRY RUN.

productive time See AVAILABLE TIME.

product of sums expression (POS expression) A *Boolean function expressed as a product of sum terms, i.e. as an AND of OR terms containing uncomplemented or complemented variables. An example is

$$f = (x \vee y) \wedge (x' \vee z)$$

The function is also realizable as the NOR of a group of NOR terms. See also STANDARD PRODUCT OF SUMS, SUM OF PRODUCTS EXPRESSION.

product term A product (AND) of Boolean variables, uncomplemented or complemented. See also SUM OF PRODUCTS EXPRESSION.

profiling Production of a histogram (or equivalent) concerning some aspect of a system. For example, an **execution profile** for a program might show the proportion of time spent in each individual procedure during a run of the program, while a **statement profile** might show the distribution of the statements in a program between the different kinds of statement provided by the language.

program A set of statements that (after translation from programming-language form into executable form – see COMPILER) can be executed by a computer in order to produce a desired behavior from the computer. A **procedural program** gives a precise definition of the procedure to be followed by the computer system in order to obtain the required results. By contrast, a **nonprocedural program** specifies constraints that must be satisfied by the results that are produced but does not specify the procedure by which these results should be obtained; such a procedure must be determined by a problem-solving shell based on the defined constraints.

program analysis See STATIC ANALYSIS.

program compatibility A measure of the degree to which programs can effectively be used together in a common environment. Factors affecting program compatibility include machine and operating system dependencies, and the structure of the data that are read and written by the programs.

program control Control of a computer's functioning by a sequence of instructions that comes from a memory and is called the program.

program correctness proof A formal