

A Dictionary of Computing



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A Dictionary of
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encapsulation 1. See OBJECT, INFORMATION HIDING. 2. See INTERNETWORKING.

encoder 1. The means by which an encoding process is effected (see CODE). It may be implemented in hardware or software, the process being algorithmic in nature. 2. A logic circuit, usually an integrated circuit, that generates a unique n -bit binary word, indicating which of its 2^n input lines is active, i.e. at logic 1. A **keyboard encoder**, for example, may be required to generate a unique binary code indicating which key on the keyboard has been pressed.

If two or more of the device inputs can be active simultaneously then a **priority encoder** is required, which usually encodes only the highest-order data input.

encoding 1. The transformation of a message into an encoded form. See CODE. 2. The representation of symbols in some alphabet by symbols or strings of symbols in some other alphabet. A common example is *binary encoding.

encryption The processing of a message by a sender in order to render it unintelligible to other than authorized recipients. See also CRYPTOGRAPHY.

end-around-carry A type of carry that is required when a *radix-minus-one complement representation of integers is used and two integers so represented are summed. If a carry is generated at the most significant end of the two numbers, then this carry must be added to the digit at the least significant end of the result to give the radix-minus-one complement representation of the sum.

end-around shift Another name for circular shift. See SHIFT.

endomorphism A *homomorphism from an *algebra to itself.

endorder traversal Another name for postorder traversal.

end-to-end control Control acting between two applications that are communicating across one or more networks. Data traversing a network must be protected against a number of possible forms of error. An individual unit of data may be corrupted, lost completely, or delivered more than once; successive units of data may be delivered in the wrong order. The sender may attempt to transmit data more quickly than

the receiver can receive it, or some part of the route can actually carry it. Within the network, the transmitter and receiver at the two ends of an individual link will cooperate to control some of these errors, and this is known as **point-to-point control**. However, it may also be necessary to require the applications at each end of the overall connection to cooperate in protecting against other forms of error, and this is **end-to-end control**.

end-to-end encryption The transfer of an encrypted message across a system without intermediate stages of decryption and reencryption. Compare LINK ENCRYPTION.

energizer A hardware or software mechanism that is used as an aid in testing the behavior of a subsystem. The intention is that the energizer should drive the subsystem in a way that simulates its actual application, and should at the same time analyze the responses from the subsystem in order to detect any erroneous behavior.

engine 1. A component of a software system that handles a specific aspect of processing. Engines thus form part, or possibly the whole, of an application's *back end. For example, a database engine provides database services other parts of the system; a search engine provides searching services; and so on. Engines can be shared among several applications – for example, through the *client/server model – and are often bought from a third-party specialist supplier. 2. Another name for back end.

engineering of computer-based systems (ECBS) A narrower form of *systems engineering that addresses only those systems which are computer-based. This is a very important subset of systems engineering, but is still very much wider than *software engineering. It encourages a holistic view of a system, its environment, and its components. Often the components of computer-based systems are also (lower-level) computer-based systems. ECBS pays great attention to addressing nonfunctional properties of a proposed design, and the need for give-and-take between different design options prior to committing to an implementation. Give-and-take is seen as a crucial aspect of such developments because it is here that competing requirements and

informatics The use of computers to maintain and analyze large amounts of data. The term is applied particularly with respect to databases of chemical compounds or reactions (**chemoinformatics**) or databases in biochemistry or cell biology (**bioinformatics**).

information Generally, information is whatever is capable of causing a human mind to change its opinion about the current state of the real world. Formally, and especially in science and engineering, information is whatever contributes to a reduction in the uncertainty of the state of a system; in this case, uncertainty is usually expressed in an objectively measurable form. Commonly, this is done by means of Shannon's *entropy. Nevertheless, this formula for uncertainty involves probabilities, and these may well have to be subjective. If that is so, the formal measurement must be qualified as depending on subjective probabilities, and "uncertainty" must be replaced by "opinion, or personal estimate, of uncertainty".

Information must be distinguished from any medium that is capable of carrying it. A physical medium (such as a magnetic disk) may carry a logical medium (data, such as binary or text symbols). The information content of any physical objects, or logical data, cannot be measured or discussed until it is known what range of possibilities existed before and after they were received. The information lies in the reduction in uncertainty resulting from the receipt of the objects or the data, and not in the size or complexity of the objects or data themselves. Questions of the form, function, and semantic import of data are only relevant to information inasmuch as they contribute to the reduction of uncertainty. If an identical memorandum is received twice, it does not convey twice the information that its first occurrence conveyed: the second occurrence conveys no information at all, unless, by prior agreement, the number of occurrences is itself to be regarded as significant.

Information has ramifications in security, politics, culture, and the economy, as well as in science and engineering. The extent to which information is used as an economic commodity is one of the defining characteristics of the "post-industrial" society, hence the phrase "the information society".

information destination See SHANNON'S MODEL.

information engineering The engineering approach applied to *information systems. The term shows considerable variation in scope. At its broadest, it refers to the engineering discipline covering a spectrum from *software engineering and *systems engineering to device-level electronics. At its most limited (but perhaps best known), it is the name of a specific proprietary method for the development of organizational information systems, primarily associated with James Martin; this method begins with *enterprise modeling and carries through to the generation of program code, and a number of software toolsets are available for its support.

information hiding A principle, used when developing an overall *program structure, that each component of a program should encapsulate or hide a single design decision. The principle was first expounded by David Parnas, who advocated an approach to program development in which a list is prepared of design decisions that are particularly difficult or likely to change; individual components, known as **modules**, are then defined so that each encapsulates one such decision. The interface to each module is defined in such a way as to reveal as little as possible about its inner workings.

This approach leads to modules that are readily understood and can be developed independently. More important, it also leads to programs that are easy to change, with many desired changes requiring modification of only the inner workings of a single module.

information management system A term sometimes used synonymously with *database management system (DBMS) although normally used in a more general sense. The term has no widely accepted definition and thus can be applied to any system of software that facilitates the storage, organization, and retrieval of information within a computer system, without the implication that it need have all the essential characteristics of a DBMS. The information held may include sound fragments, images, and video sequences in addition to the usual textual and numerical information. These newer forms of computer-held information are sometimes argued as being a defining

Internet Architecture Board (IAB) *See* INTERNET SOCIETY.

Internet café *See* CYBERCAFÉ.

Internet Engineering Steering Group (IESG) *See* INTERNET SOCIETY.

Internet Engineering Task Force (IETF) *See* INTERNET SOCIETY.

Internet Explorer Microsoft's web browsing software, first introduced in 1995. *See* BROWSER.

Internet Message Access Protocol *See* IMAP.

internet protocol A *protocol that allows traffic to pass between networks. The most widely used is *IP, the Internet Protocol. *See also* INTERNETWORKING.

Internet Protocol Security *See* IPSEC.

Internet service provider *See* ISP.

Internet Society (ISOC) A professional membership society that promotes the use and future development of the Internet. It has individual and organization members all over the world and is governed by an elected board of trustees. ISOC coordinates various groups responsible for Internet infrastructure. These include the Internet Engineering Task Force (IETF), the Internet Architecture Board (IAB), and the Internet Engineering Steering Group (IESG). The IETF develops technical standards for the Internet. The IAB has overall responsibility for the architecture and adjudicates on disputes about standards. The IESG, along with the IAB, reviews standards proposed by the IETF. *See also* IANA.

SEE WEB LINKS

- The Internet Society home page

internetworking Connecting several computer *networks together to form a single higher-level network, as occurs in the *Internet. There are two basic approaches: **encapsulation** and **translation**. The junctions between networks are called *gateways, and their functions depend on which internetworking approach is taken.

When encapsulation is used, a new protocol layer (or layers) is defined; this provides uniform semantics for services such as *datagram packet switching, *electronic mail, etc. When a message is entered into the internetwork, it is wrapped (encapsulated) in

a network-specific protocol (local network datagram headers, or *virtual circuits). The encapsulated packet is sent over the network to a gateway, which removes the old network-specific encapsulation, adds a new set of network headers, and sends the packet out on another network. Eventually the message reaches its destination, where it is consumed.

When protocol translation is used, messages are sent on a local network using the protocols and conventions of that network. A gateway receives the message and transforms it into the appropriate message on another network; this may involve interpreting the message at multiple protocol levels.

The encapsulation approach provides a uniform set of semantics across all networks, while the translation approach results in unanticipated problems due to subtle differences between protocols. The encapsulation approach generally requires that new software be written for all hosts on all networks, while the translation approach requires new software only in the gateways. *See also* IP.

interoperability The ability of systems to exchange and make use of information in a straightforward and useful way; this is enhanced by the use of standards in communication and data format. For example, a microcomputer conforming to the *SCSI standard can be connected to any SCSI peripheral device – i.e. many different hard disks, printers, etc. In software, operating systems that run on different CPUs, and Microsoft *Word's ability to read files created using *Excel are both examples of interoperability.

interpolation A simple means of approximating a function $f(x)$ in which the approximation, say $p(x)$, is constructed by requiring that

$$p(x_i) = f(x_i), \quad i = 0, 1, 2, \dots, n$$

Here $f(x_i)$ are given values $p(x_i)$ that fit exactly at the distinct points x_i (*compare* SMOOTHING). The value of f can be approximated by $p(x)$ for $x \neq x_i$. In practice p is often a polynomial, linear and quadratic polynomials providing the simplest examples. In addition the idea can be extended to include matching of $p'(x_i)$ with $f'(x_i)$; this is **Hermite interpolation**. The process is also widely used in the construction of many numerical methods, for example in *numerical integration and *ordinary differential equations.

lection and is usually associated with memory compaction.

garbage collection See GARBAGE.

garbage in garbage out (GIGO) An enunciation of the important computing principle that all input, however absurd, will be processed according to a program's algorithms and appropriate output generated. If the input is garbage, then the output will inevitably also be garbage. This truth is often not recognized, especially by non-computer specialists, who tend to blame "the computer" for incorrect results when the fault actually lies with mistakes in the input.

gate See LOGIC GATE.

gate array A form of *programmable device in which the component *logic gates can be interconnected in an arbitrary manner during manufacture to give a *combinational or *sequential circuit of considerable *height.

Gates, Bill (William Henry G.; 1955–) US businessman and programmer. Gates began programming at school and in 1975, while an undergraduate at Harvard, wrote a BASIC interpreter with his friend Paul Allen for an early microcomputer, the MITS Altair. This Gates-Allen partnership was the genesis of *Microsoft, and Gates left Harvard to develop the business. While he personally supervised Microsoft's products in the early years, he became better known for the business acumen that has built Microsoft into the world's largest software company, in the process making himself the world's richest person. Notable successes include securing the contract (1980) to supply an operating system for the original IBM personal computer while retaining the right to market it separately (as *MS-DOS); and the exploitation of the success of Windows 3.x after 1990 to achieve dominance of the PC marketplace. Gates was CEO of Microsoft until 2000, then chief software architect until 2006; he continues as Chairman. He has used part of his personal fortune for philanthropic purposes, founding the Bill & Melinda Gates Foundation with his wife in 2000.

gateway A device that interconnects two *networks, and whose presence is usually visible to network users (as distinct from a *bridge, whose presence is generally not vis-

ible). A gateway may be required to deal with one or more of the following differences between networks it connects:

- (a) change of addressing *domain – where the networks have addressing domains managed by separate groups, a gateway may be used to handle address transformations for messages traversing the gateway;
- (b) control of charging – where the networks have different approaches to charging (e.g. a local area network that imposes no charges connecting to a wide area network that charges on a per-packet basis), a gateway may be used to handle user authorization and usage accounting;
- (c) change of protocol – where the networks use different protocols, a gateway may be used to carry out necessary protocol conversion (if practicable) or to intercept attempts by a user on one network to use functions not available on the other and to supply suitable responses.

The terms bridge, gateway, and *relay are among those whose meanings vary between different communities of users at a given time, and within a given community of users at different times.

gather write The function of writing to memory a block of data comprising items of data that have been retrieved directly from scattered memory locations and/or registers.

Gaussian distribution Another name for normal distribution.

Gaussian elimination See LINEAR ALGEBRAIC EQUATIONS.

Gaussian noise *Noise whose distribution of amplitude over time is *Gaussian.

Gaussian quadrature See NUMERICAL INTEGRATION.

GB (or Gb) Symbols for gigabyte. See GIGA-, BYTE.

Gbps Abbrev. for gigabits per second, i.e. usually 10^9 bits per second. See GIGA-, BPS.

GBS method The Gragg-Burlisch-Stoer *extrapolation method based on theoretical results obtained by Gragg, implemented by Burlisch and Stoer. See GRAGG'S EXTRAPOLATION METHOD.

Gbyte Abbrev. for gigabyte. See GIGA-, BYTE.

GCD Abbrev. for greatest common divisor.

defined outside the function, except for the variables passed as parameters.

refinement The process in programming whereby higher-level or abstract ideas are progressively reexpressed in terms of lower-level or concrete ones. This can involve both the implementation of procedures in terms of lower-level procedures, and also the representation of abstract data in terms of more concrete data. Both kinds of refinement can involve *specifications, with each step of refinement being shown to preserve the specified behavior of the procedure or data type being refined. Although both terms are rather fluid in meaning, there is a possible distinction to be made between refinement and *program transformation, with the latter involving the replacement of one program fragment by an equivalent one at the same level of abstraction rather than its representation in terms of a lower level of abstraction.

Refinement and transformation are two of the main ideas in the increasingly important study of the systematic derivation of correct programs from specifications.

reflectance function A function that defines the spatial distribution and the wavelength composition of the light reflected from an object's surface.

reflectance model A mathematical model of how light is reflected from a surface based on a *reflectance function. The basic reflectance model assumes that all surfaces are perfect mirrors. More realistic models use reflectance functions that more accurately represent the properties of real surfaces (*see also* SPECULAR REFLECTION, COOK-TORRANCE MODEL).

reflexive closure *See* TRANSITIVE CLOSURE.

reflexive relation A *relation R defined on a set S and having the property that

$$x R x$$

for all elements x in S

The relation "is the same age as" defined on the set of people is reflexive. *Compare* IR-REFLEXIVE RELATION.

refresh (regenerate) 1. To replenish the charge on the storage capacitors used in *dynamic memory cells and other similar devices. Some devices are provided with

internal circuitry that automatically refreshes dynamic cells whenever these cells are read. The word refresh is also used as a noun. 2. To repeat at regular intervals the display of digital information on a *cathode-ray tube or television monitor in order that the display can appear persistent. *See also* REFRESH FREQUENCY.

refresh frequency The frequency with which a display on a cathode-ray tube is regenerated. To avoid *flicker this must be made as high as possible. *See* CFF.

refutation A method of reasoning used in logic to refute statements, i.e. to prove them false.

regenerate *Another term for* refresh.

register A group of (usually) *bistable devices that are used to store information within a computer system for high-speed access. A register of n bistables can store a word of length n bits, which can represent any n bits of information. Different interpretations can be given to the bit configuration stored in the register; for example, the configuration could represent an instruction, a binary number, an alphanumeric character, etc. A register is often the same size as the computer word; it may also be byte- or character-size or some other size as required. Some registers can behave as *counters as well, or they may behave as *shift registers. *See also* MEMORY HIERARCHY.

register insertion ring *See* RING NETWORK.

register optimization *See* OPTIMIZATION.

register transfer language (RTL) Any of several programming languages that allow the declaration of *register configurations within a structure to perform a computation. The timing of transfers between registers, to describe the behavior, is specified by the order in which such transfers are interpreted during the execution of the program. *See also* CHDL.

regression analysis A statistical technique that is concerned with fitting relationships between a dependent variable, y , and one or more independent variables, x_1, x_2, \dots , usually by the method of *least squares.

A **linear regression model** is one in which the theoretical mean value, μ_y , of the obser-

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MX

program is Symantec's ACT!, which includes a calendar and scheduling. See *personal information manager (PIM)*.

contact manager A program designed to help keep track of contacts by maintaining a list of addresses, phone numbers, and fax numbers. Information is also maintained through the use of a notepad, automatic telephone dialing with a modem, and search and sort capabilities.

container See *compound document*.

contention In local area networks (LANs), a channel access method in which access to the communication channel is based on a first-come, first-served policy. See *CSMA/CD* and *device contention*.

context-sensitive help In an application program, a user-assistance mode that displays documentation relevant to the command, mode, or action you are now performing. Context-sensitive help reduces the time and keystrokes needed to get onscreen help.

context switching Changing from one program to another without exiting either program. See *multiple program loading*.

contiguous Adjacent; placed one next to or after the other. A range of cells in a spreadsheet is often, but not always, made up of contiguous cells. Its opposite is *noncontiguous*.

continuous paper Paper manufactured in one long strip, with perforations separating the pages, so that you can feed the paper into a printer with a tractor-feed mechanism. Synonymous with continuous-feed paper. Also called *fanfold paper*. The opposite is *cut-sheet paper*, in which every sheet is a separate piece.

continuous speech recognition The decoding of continuous human speech (without artificial pauses) into transcribed text by means of a computer program.

continuous-tone image Printer output in which colors and shades of gray blend smoothly together, as they would in a chemically printed photograph.

continuous-tone printer A printer that can generate photo-realistic output, with smooth gradations between colors or shades of gray.

Component Object Model See *COM*.

component reusability In programming, the capability of creating a program module that can perform a specific task and be used in another program with little or no modification.

complex instruction set computer (CISC) A type of central processing unit (CPU) that can recognize as many as 100 or more instructions, enough to carry out most computations directly. Most microprocessors are CISC chips. The use of reduced instruction set computer (RISC) technology, however, is becoming increasingly common in professional workstations. Apple's Power Macintosh computers use a compromise RISC/CISC processor.

compose sequence A series of keystrokes that lets you enter a character not found on the computer's keyboard. See *ASCII character set* and *extended character set*.

composite See *comp*.

composite color monitor A monitor that accepts a standard video signal that mixes red, green, and blue signals to produce the color image. Display quality is inferior to that of RGB monitors. See *composite video*.

composite video A method for broadcasting video signals in which the red, green, and blue components, as well as horizontal and vertical synchronization signals, are mixed together. Regulated by the U.S. National Television Standards Committee (NTSC), composite video is used for television. Some computers have composite video outputs that use a standard RCA phono plug and cable, such as on the backplane of a hi-fi or stereo system. See *composite color monitor* and *RGB monitor*.

compound device In multimedia, a device, such as a MIDI sequencer, that reproduces sound or other output that you recorded in a specific media file.

compound document In object linking and embedding (OLE), a single file created by two or more applications. When you use OLE to embed a Microsoft Excel chart into a Microsoft Word document, for example, the resulting file contains the Word text as well as the Excel object. The object contains all the information Excel needs to open the chart for editing. This information results in file sizes considerably larger than normal. See *OpenDoc*.

emulation The duplication within a device of another device's functional capability, or a device designed to work exactly like another. In telecommunications, for example, a personal computer emulates a dumb terminal (a terminal without its own microprocessor) for online communication with a distant computer. With printers, lesser-known brands emulate popular models such as Hewlett-Packard's LaserJet line.

emulation sensing See *automatic emulation switching* and *automatic network switching*.

emulation switching See *automatic emulation switching*.

em In typesetting, a unit of measurement that equals half the width of an em space, which is the width of the capital letter M in a typeface. En dashes are used in place of the English words "to" or "through," as in January 9–January 23 or Pages 63–68. They also are used as minus signs, as in –30 degrees Fahrenheit. Compare to *em dash*.

Encapsulated PostScript (EPS) file A high-resolution graphic image stored in the PostScript page description language. The EPS standard enables users to transfer high-resolution graphics images between applications. You can size EPS images without sacrificing image quality. A major drawback of EPS graphics is that to print them, you usually need a PostScript-compatible laser printer. A second drawback is that with most application programs, you cannot view the image onscreen unless you attach a screen image to it. To provide an alternative to expensive PostScript printers, developers have created programs such as LaserGo, Inc.'s GoScript that interpret and print EPS files on standard dot-matrix printers or nonPostScript laser printers. See *PostScript*.

encapsulation In wide area networks (WANs), the process by which transmitted data is altered as it moves down the computer's protocol stack. As each layer's protocols alter the data, it is translated into a form that can be sent out over the network. At the receiving computer, this process is reversed so that the data is restored in such a form that it can be passed to an application and made intelligible to the user.

encryption In cryptography, the process of converting a message into a ciphertext (an encrypted message) by using a key so that the message appears to be nothing but gibberish. However,

D
E
F

garbage characters In modems, meaningless characters caused by line noise. In printers, meaningless characters caused by line noise, a faulty printer driver, or some other communication problem.

garbage collection A process by which a program goes through random access memory (RAM), decides which information stored there is no longer needed, and prepares the addresses housing the unneeded data for reuse. Garbage collection prevents programs from filling RAM with useless data and causing a crash.

gas plasma display See *plasma display*.

gateway 1. A means by which users of one computer service or network can access certain kinds of information on a different service or network. This may be achieved by means of hardware devices called bridges, by computer programs that perform the necessary translation, or both. For example, Internet e-mail users can exchange mail with CompuServe users by means of a gateway. Similarly, people using Web browsers can access the Archie service by means of a Web page that functions as an Archie gateway. 2. In networks, a device that connects two dissimilar local area networks (LANs) or connects a local area network to a wide area network (WAN), a minicomputer, or a mainframe. A gateway has its own microprocessor and memory, and may perform network protocol conversion and bandwidth conversion. See *bridge*.

GB Abbreviation for *gigabyte*.

Gbps One billion (one thousand million) bits per second.

GDI See *Graphical Device Interface*.

GDI printer See *Graphical Device Interface (GDI) printer*.

geek Slang expression for a technically obsessed person who spends so much time with the computer that other dimensions of personality (such as social skills) are poorly developed.

general format In most spreadsheet programs, the default numeric format in which all the numbers on either side of the decimal point (up to the farthest number that isn't a zero) are displayed but without commas or currency signs. When a number is too large to display with the current column width, scientific notation is used.



REGEDIT A Microsoft Windows 95/98 utility program that enables knowledgeable users to edit the Registry directly. This should not be attempted by novices.

regexp See *regular expression*.

Regional Bell Operating Companies (RBOC) The regional telephone companies (Baby Bells) that were created as a result of the 1982 breakup of AT&T, which forced the former telephone monopoly to leave the local and regional telephone business.

register A memory location within a microprocessor, used to store values and external memory addresses while the microprocessor performs logical and arithmetic operations on them. A larger number of registers enables a microprocessor to handle more information at one time.

register renaming A means of enabling software designed to run on x86 microprocessors, which can recognize only 8 registers, to use the 32 or more registers available in more advanced microprocessors with superscalar architecture. A microprocessor capable of register renaming differentiates between the registers an x86 program can address and the actual number of registers available, and will divert information sent to an occupied register to one that is not in use.

registration fee An amount of money that must be paid to the author of a piece of shareware to continue using it beyond the duration of the evaluation period.

Registry In Microsoft Windows 95/98, a database that provides programs a way to store configuration data, program file locations, and other information that is needed for the programs to execute correctly. The Registry replaces the text-based *.INI files used with Windows 3.1 applications. See *REGEDIT*.

regular expression (regexp) In Unix, the syntax by which users can type wildcard expressions.

relational database A type of database that uses the contents of a particular field as an index to reference particular records.

relational database management An approach to database management, employed by Microsoft Access and other database management programs, in which data that is stored in

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ded mode). The Intermediate COCOMO Model is an extension of the Basic COCOMO Model. The Intermediate Model uses an Effort Adjustment Factor (EAF) and slightly different coefficients for the effort equation than the Basic Model. The Intermediate Model also allows the system to be divided and estimated in components. The Detailed COCOMO Model differs from the Intermediate COCOMO model in that it uses effort multipliers for each phase of the project.

constructive solid geometry (CSG) a paradigm for representing 3D shapes in terms of mathematically based compositions of geometric primitives. Any volumetric primitives can be used provided the primitive can satisfy an "inside-outside" test which uniquely partitions points in the space near it. Typically, Boolean set theoretic composition operators (e.g., intersection, union, difference) are used. Affine transformations may be applied to alter the shape of the primitives. For example, the exterior of an igloo may be represented as the union of a sphere and a cylinder, intersected with a cube.

constructor in object oriented languages, a member function that initializes the memory space and the values of the object attributes in order to set the initial object state. *See also* destructor.

consultant a contract programmer or external software specialist.

consumer a program unit that uses data produced by other program units.

contact head *See* disk head.

container abstract data type storing a collection of objects (elements).

containment a grouping of heterogeneous individuals, possibly in space or time. *See also* collection.

content-addressable memory (CAM) *See* associative memory.

contention additional latency incurred as the result of multiple requestors needing access to a shared resource, which can only be used one at a time.

contention protocol class of a multiple access protocol where the user's transmissions are allowed to conflict when accessing the communication channel. The conflict is then resolved through the use of a static or dynamic conflict resolution protocol. Static resolution means that the conflict resolution is based on some pre-assigned priority. A static resolution can be probabilistic if the statistics of the probabilities are fixed. A common example is the p-persistent ALOHA protocol. The dynamic resolution allows for the changing of the parameters of the conflict resolution algorithm to reflect the traffic state of the system. A common example is the Ethernet protocol.

context the privilege, protection, and address-translation environment of instruction execution.

context-free grammar a phrase structure grammar that is a Type 2 grammar in the Chomsky hierarchy. Characterized by productions of the form $N \rightarrow x$, where N is a member of the nonterminal symbols of the grammar and x is a sequence of zero or more symbols from the grammar's vocabulary, V ; that is, x can be defined as a member of V^* , where $*$ is the Kleene Star. *See also* pushdown automaton.

context of use the users, goals, tasks, equipment (hardware, software, and materials), and the physical and social environments in which a product is used.

context-sensitive grammar a phrase structure grammar which is a Type 1 grammar in the Chomsky hierarchy. Characterized by productions of the form $\mu_1 N \mu_2 \rightarrow \mu_1 A \mu_2$, where μ_1 and μ_2 are sequences of zero or more members of the grammar's vocabulary, N is a member of the set of nonterminal symbols, and A is a non-empty sequence of symbols of the grammar's vocabulary. *See also* nondeterministic push-down automaton.

emulator (1) the firmware that simulates a given machine architecture.

(2) a device, computer program, or system that accepts the same inputs and produces the same outputs as a given system. *Compare with* simulator.

enabled state in a dataflow architecture when all necessary tokens have arrived and the input lines are full. Also called the ready state.

encapsulation property of a program that describes the complete integration of data with legal processes relating to the data. Modularization produces chunks that are said to be encapsulated, i.e., they have an identifiable boundary. This boundary may be transparent (and thus the internal features are visible everywhere) or may be opaque (in which case we also have information hiding).

encode network a perceptron network designed to illustrate that the hidden layer nodes play a crucial role in allowing the network to learn about special features in the input patterns. Once it has learned about the "generalized" features of the training patterns, it can respond usefully in new situations.

encoder a displacement sensor that provides a digital output signal proportional to the relative displacement of the degree of freedom.

encoding (1) the act of placing information to be transmitted in a form which can be transmitted over a particular medium and which will be recognizable by the receiver. *See* coding, encoding.

(2) in computing systems, to represent various pieces of information by a defined sequence of the binary digits 0 and 1, called bits. To apply the rules of a code.

encryption the transformation employed to transform information to be transmitted (plaintext) into a format which is unintelligible (ciphertext or a cryptogram). The ciphertext can then be transmitted via a communication channel without revealing the contents of the plaintext. This is achieved by means of an encryption key. A system for performing encryption

is also known as a cipher. The information to be encrypted is referred to as plaintext, and the encrypted message resulting from encryption is referred to as ciphertext. The intended receiver of the ciphertext also has the encryption key and by having both the ciphertext and the encryption key available, the original plaintext can be recovered. *See also* encryption key, block cipher, stream cipher, public key cryptography, private key cryptography.

encryption key a codeword used for decryption of ciphertext into plaintext in encryption systems. Ciphertext can then be transmitted via a communication channel without revealing the contents of the plaintext. The plaintext can only be recovered by someone in possession of the encryption key. *See also* encryption, block cipher, stream cipher.

end-around borrow in subtraction, a borrow out of the least significant bit that is then immediately included in the most significant position of another subtraction (usually, in the same subtractor).

end-around carry (1) in addition, a carry out of the most significant bit that is then immediately included in the least significant position of another addition (usually, in the same adder).

(2) technique used in one's complement arithmetic, in which a carryover of the result of an addition or subtraction beyond the leftmost bit during addition (or subtraction) is "wrapped around" and added to the result.

end effector gripper or tool attached to the distal end of a robotic manipulator and used to make contact with the remote world. Position and orientation of the manipulator are referred to the end effector. The frame attached to the end effector is known as the end effector frame. The end effector can be a gripper or it can be attached to the end effector. The orthonormal end effector frame consists of three unit vectors a -approach (it approaches the object), o -orientation (which is normal to the sliding plane between the fingers of the gripper), and n -normal vector to two others so that the frame (n, o, a) is right-handed.

reflexive rule a relationship in a database system. Given sets of attributes A and B , then if $B \subset A$, then $A \rightarrow B$.

reformatting the functional equivalent transformation of source code which changes only the structure to improve readability. Examples are pretty-printers and tools that replace GOTO loops with equivalent loops. The latter case in some cases is not only a simple process of reformatting but a real process of transformation.

refraction the phenomenon of a beam of light bending as the light's velocity changes. This occurs when the refractive index of the material through which the light is passing changes. Let \mathbf{i} be the normalized incident ray vector (pointing towards the surface), which has unit surface normal \mathbf{n} . If \mathbf{t} is the transmitted (refracted) vector inside a transparent medium, then:

$$\mathbf{t} = \mu \mathbf{i} - \mathbf{n}(\mu(\mathbf{i} \cdot \mathbf{n}) + \left(1 - \mu^2(1 - (\mathbf{i} \cdot \mathbf{n})^2)\right)^{\frac{1}{2}}),$$

where μ is the ratio $n_{\text{outside}}/n_{\text{inside}}$ of the refractive indices of the inside and outside media. See Snell's law.

refresh refers to the requirement that dynamic RAM chips must have their contents periodically refreshed or restored. Without a periodic refresh, the chip loses its contents. Typical refresh times are in the 5 to 10 millisecond range. See also memory refresh.

refresh cycle (1) a periodically repeated procedure that reads and then writes back the contents of a dynamic memory device. Without this procedure, the contents of dynamic memories will eventually vanish.

(2) the period of time taken to "refresh" a portion of a dynamic RAM chip's memory. See also refresh.

refresh period the time between the beginnings of two consecutive refresh cycles for dynamic random access memory devices.

region a portion of memory allocated dynamically to an application program.

region growing the grouping of pixels or small regions in an image into larger regions.

Region growing is one approach to image segmentation. See also dilation, erosion, image segmentation, mathematical morphology.

region of interest (ROI) a restricted set of image pixels upon which image processing operations are performed. Such a set of pixels might be those representing an object that is to be analyzed or inspected.

region query a form of spatial query which requests objects that lie within a designated region.

register a circuit formed from identical flip-flops or latches and capable of storing several bits of data. Registers are usually limited in number, so that they can be designated by a small number of bits in each instruction (3 to 6 bits are typical). Most registers are disjoint from main memory, although this is not universally true (the DEC PDP-10, for example). Registers limited to use in address computations are designated index registers, those which can be involved in all arithmetic operations are designated accumulators, and most architectures that have registers which can serve any purpose are designated general registers. These distinctions become important for writing compilers.

register alias table See virtual register.

register allocation a method used by compilers for machines with limited register sets, which attempts to allocate intermediate computations and/or user-defined variables to the machine registers such that the number of times data has to be moved is reduced. Computationally, this problem is very difficult, and is often done by using a graph-coloring algorithm. Most commonly, a complete or optimal solution cannot be realized and a heuristic approximation is used.

register direct addressing (1) an instruction addressing method in which the memory address of the data to be accessed or stored is found in a general purpose register.

(2) a memory addressing scheme similar to direct addressing except that the operand is a CPU register and not an address.

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measures (*see* Blum's axioms) but will be more understandable in the context of time:

given any *total *recursive function

$$g(n) \geq n$$

there exists a total recursive function $S(n)$ such that

$$\text{DTIME}(S(n)) = \text{DTIME}(g(S(n)))$$

(*see* complexity classes). In other words there is a "gap" between time bounds $S(n)$ and $g(S(n))$ within which the minimal space complexity of no language lies.

This has the following counter-intuitive consequence: given two universal models of computation, say a Turing machine that makes one move per century and the other a random-access machine capable of performing a million arithmetic operations per second, then there is a total recursive function $S(n)$ such that any language recognizable in time $S(n)$ on one machine is also recognizable within time $S(n)$ on the other.

garbage Information in a memory that is no longer valid or wanted. It is usually the result of *memory compaction operations. The removal of this superfluous information from the memory is known as *garbage collection* and is usually associated with memory compaction.

garbage collection *See* garbage.

gate *See* logic gate.

gate array A form of *programmable device in which the component *logic gates can be interconnected in an arbitrary manner during manufacture to give a *combinational or *sequential circuit of considerable *height.

gateway A device that interconnects two *networks, and whose presence is usually visible to network users (as distinct from a *bridge, whose presence is generally not visible). A gateway may be required to deal with one or more of the following differences between networks it connects:

(a) change of addressing *domain – where the networks have addressing domains managed by separate groups, a gateway may be used to handle address transformations for messages traversing the gateway;

(b) control of charging – where the networks have different approaches to charging (e.g. a local area network that imposes no charges

connecting to a wide area network that charges on a per-packet basis), a gateway may be used to handle user authorization and usage accounting;

(c) change of protocol – where the networks use different protocols, a gateway may be used to carry out necessary protocol conversion (if practicable) or to intercept attempts by a user on one network to use functions not available on the other and to supply suitable responses.

The terms bridge, gateway, and *relay are among those whose meanings vary between different communities of users at a given time, and within a given community of users at different times.

gather write The function of writing to memory a block of data comprising items of data that have been retrieved directly from scattered memory locations and/or registers.

Gaussian distribution *Another name for normal distribution.*

Gaussian elimination *See* linear algebraic equations.

Gaussian noise *Noise whose distribution of amplitude over time is *Gaussian.

Gaussian quadrature *See* numerical integration.

GB (or Gb) *Symbols for gigabyte. See* giga-, byte.

Gbps *Abbrev. for gigabits per second, i.e. usually 10^9 bits per second. See* giga-, bps.

GBS method The Gragg–Burlisch–Stoer *extrapolation method based on theoretical results obtained by Gragg, implemented by Burlisch and Stoer. *See* Gragg's extrapolation method.

Gbyte *Abbrev. for gigabyte. See* giga-, byte.

GCD *Abbrev. for greatest common divisor.*

GCR *Abbrev. for group code recording. See* disk format, tape format.

GDI *Abbrev. for graphical device interface.*

generalized additive models Statistical models introduced by T. Hastie and R. Tibshirani and used for smoothing data with sums of components of linear or nonlinear

mood of the writer; emoticons are also called *smileys*, regardless of mood. E-mail messages are largely restricted to the *ASCII character set, which precludes the use of text attributes such as bold, italic, or underline but does have a full set of punctuation marks. These are typically used to make faces sideways on the line (see table).

empty list (null list) *See* list.

empty medium A *data medium that does not contain variable data but may have a frame of reference or preformatting. *Compare* virgin medium.

empty set (null set; void set) A *set with no elements. It is usually denoted by ϕ .

empty string (null string) A string whose *length is zero. It is commonly denoted by ϵ or Λ . The possibility of strings being empty is a notorious source of bugs in programs.

EMS memory *See* expanded memory.

emulation The exact execution on a given computer of a program written for a different computer, accepting the identical data and producing the identical results. Emulation is thus the imitation of all or part of one computer system by another system. It may be achieved by software, microprogram, or hardware. A particular emulation could be used as a replacement for all or part of the system being emulated, and furthermore could be an improved version. For example, a new computer may emulate an obsolete one so that programs written for the old one will run without modification. *See also* simulation, compatibility.

emulator Any system, especially a program or microprogram, that permits the process of *emulation to be carried out.

enable To selectively activate a device or function. When a number of devices are connected in parallel, selective operation can be achieved by an enabling action – such as a signal on a discrete line or a pattern of signals on the common line or lines – that will set only the desired device into a state in which it can receive further signals. *Compare* inhibit.

enable pulse A pulse that must be present to allow other signals to be effective in certain electronic logic circuits. Although the term is

now used to describe an electronic logic function it was originally used in an analogous way in connection with *core stores, where the coincidence of two pulses was required to change the state of a core: one of the pulses was the write pulse and could be common to a number of cores; an enable pulse was simultaneously applied to a particular core and thus enabled the write pulse to change the state of that core.

encapsulation 1. *See* object, information hiding.

2. *See* internetworking.

encoder 1. The means by which an encoding process is effected (*see* code). It may be implemented in hardware or software, the process being algorithmic in nature.

2. A logic circuit, usually an integrated circuit, that generates a unique n -bit binary word, indicating which of its 2^n input lines is active, i.e. at logic 1. A *keyboard encoder*, for example, may be required to generate a unique binary code indicating which key on the keyboard has been pressed.

If two or more of the device inputs can be active simultaneously then a *priority encoder* is required, which usually encodes only the highest-order data input.

encoding 1. The transformation of a message into an encoded form. *See* code.

2. The representation of symbols in some alphabet by symbols or strings of symbols in some other alphabet. A common example is *binary encoding.

encryption The processing of a message by a sender in order to render it unintelligible to other than authorized recipients. *See also* cryptography.

end-around-carry A type of carry that is required when a *radix-minus-one complement representation of integers is used and two integers so represented are summed. If a carry is generated at the most significant end of the two numbers, then this carry must be added to the digit at the least significant end of the result to give the radix-minus-one complement representation of the sum.

end-around shift *Another name for* circular shift. *See* shift.

infobahn *Informal* Any form of high-speed computer network, especially the *Internet.

informatics A word that first appeared in Russian (informatika) in 1966 with the following definition (OED): the scientific discipline that investigates the structure and properties (not specific content) of scientific information, as well as the regularities of scientific information activity, its theory, history, methodology, and organization. It has since acquired a less specialized meaning and a wide usage in German (Informatik) and French (l'informatique): broadly, the study and practice of computer science, information technology, and information processing. Its use in English falls within that range of meaning, but the word is rarely used.

information Generally, information is whatever is capable of causing a human mind to change its opinion about the current state of the real world. Formally, and especially in science and engineering, information is whatever contributes to a reduction in the uncertainty of the state of a system; in this case, uncertainty is usually expressed in an objectively measurable form. Commonly, this is done by means of Shannon's *entropy. Nevertheless, this formula for uncertainty involves probabilities, and these may well have to be subjective. If that is so, the formal measurement must be qualified as depending on subjective probabilities, and "uncertainty" must be replaced by "opinion, or personal estimate, of uncertainty".

Information must be distinguished from any medium that is capable of carrying it. A physical medium (such as a magnetic disk) may carry a logical medium (data, such as binary or text symbols). The information content of any physical objects, or logical data, cannot be measured or discussed until it is known what range of possibilities existed before and after they were received. The information lies in the reduction in uncertainty resulting from the receipt of the objects or the data, and not in the size or complexity of the objects or data themselves. Questions of the form, function, and semantic import of data are only relevant to information inasmuch as they contribute to the

reduction of uncertainty. If an identical memorandum is received twice, it does not convey twice the information that its first occurrence conveyed: the second occurrence conveys no information at all, unless, by prior agreement, the number of occurrences is itself to be regarded as significant.

Information has ramifications in security, politics, culture, and the economy, as well as in science and engineering. The extent to which information is used as an economic commodity is one of the defining characteristics of the "post-industrial" society, hence the phrase "the information society".

information destination *See* Shannon's model.

information engineering The engineering approach applied to *information systems. The term shows considerable variation in scope. At its broadest, it refers to the engineering discipline covering a spectrum from *software engineering and *systems engineering to device-level electronics. At its most limited (but perhaps best known), it is the name of a specific proprietary method for the development of organizational information systems, primarily associated with James Martin; this method begins with *enterprise modeling and carries through to the generation of program code, and a number of software toolsets are available for its support.

information hiding A principle, used when developing an overall *program structure, that each component of a program should *encapsulate* or hide a single design decision. The principle was first expounded by David Parnas, who advocated an approach to program development in which a list is prepared of design decisions that are particularly difficult or likely to change; individual components, known as *modules*, are then defined so that each encapsulates one such decision. The interface to each module is defined in such a way as to reveal as little as possible about its inner workings.

This approach leads to modules that are readily understood and can be developed independently. More important, it also leads to programs that are easy to change, with

many desired changes requiring modification of only the inner workings of a single module.

information management system A term sometimes used synonymously with *database management system (DBMS) although normally used in a more general sense. The term has no widely accepted definition and thus can be applied to any system of software that facilitates the storage, organization, and retrieval of information within a computer system, without the implication that it need have all the essential characteristics of a DBMS. The information held may include

sound fragments, images, and video sequences in addition to the usual textual and numerical information. These newer forms of computer-held information are sometimes argued as being a defining characteristic of the term, notwithstanding that DBMS are developing to provide for such forms of information.

information processing The derivation of "information objects" from other "information objects" by the execution of algorithms: the essential activity of computers.

The term has related meanings outside the computing field. It is used in psychology, for instance, and may also be used to refer to clerical operations.

information retrieval Strictly, the activity of retrieving previously stored information. The term is sometimes used to mean *information storage and retrieval (as in information retrieval application).

information science The branch of knowledge concerned with the storage, organization, retrieval, processing, and dissemination of information. The term was coined in the aftermath of the spread of computers and the corresponding revolution in information-handling techniques. Information science therefore inevitably pays substantial attention to, but is not confined to, what can be achieved with computers.

information sciences A cluster of separate but related branches of knowledge, including *computer science, *information systems, and library science.

information source See Shannon's model.

information storage and retrieval (ISR)

The linked activities of storing and retrieving information, and the strategies and techniques for doing so. The activities are linked because the means of retrieving information are dependent on the means by which it was stored. The storage strategy must be designed for the most efficient retrieval, consistent with the characteristics of the information and the time and cost that can be tolerated.

information structure Another name for data structure.

information superhighway Informal Any form of high-speed computer network, especially the *Internet. See also National Information Infrastructure.

information system A computer-based system with the defining characteristic that it provides information to users in one or more organizations. Information systems are thus distinguished from, for example, real-time control systems, message-switching systems, software engineering environments, or personal computing systems.

The term could have a very much wider meaning than that suggested, considering the range of meaning of the words *information and *system. It could, for instance, be broadened to include all computer-based systems, or further broadened to include many non-computer-based systems. Thus, within the domain of computer-based systems, the more specific term *organizational information system* is sometimes used.

Information systems include *data processing applications, *office automation applications, and many *expert system applications. When their primary purpose is to supply information to management, they are commonly called *management information systems.

The following are among the more important characteristics of information systems, and make their design and construction particularly difficult.

- (a) Their environment is complex, not fully definable, and not easily modeled.
- (b) They have a complex interface with

internal schema of a database. *Another name for storage schema.*

internal sorting *See* sorting.

Internet (Net) The global informal network that now links a very substantial fraction of the world's computer networks. The Internet is an extraordinary development that stems from the original *ARPANET, which was initiated in North America in 1969. In broad terms the Internet does not offer services to end-users, but serves primarily to interconnect other networks on which end-user services are located. It provides basic services for *file transfer, *electronic mail, and remote login, and high-level services including the *World Wide Web and the *MBONE.

The Internet is global, with connections to nearly every country in the world; the qualification "nearly" is present in part because the number of countries connected continues to increase, and in part because the Internet is deliberately nonpolitical and tends to deal with nongovernmental levels within a country. The Internet is informal, with a minimal level of governing bodies and with an emphasis in these bodies on technical rather than on administration or revenue generation. To date (Spring 1995) the major users of the Internet have been the academic and research communities, but it is inevitable that this situation will change rapidly in the next few years with the growth in commercial interest in the exploitation of the Internet. In addition the flow of data across borders is a highly complex legal matter, involving the *copyright and *data protection legislation of the countries involved.

internet protocol A *protocol that allows traffic to pass between networks. The most widely used is *IP, the Internet Protocol. *See also* internetworking.

internetworking Connecting several computer *networks together to form a single higher-level network, as occurs in the *Internet. There are two basic approaches: *encapsulation* and *translation*. The junctions between networks are called *gateways, and their functions depend on which internetworking approach is taken.

When encapsulation is used, a new protocol layer (or layers) is defined; this provides uniform semantics for services such as *datagram packet switching, *electronic mail, etc. When a message is entered into the internetwork, it is wrapped (encapsulated) in a network-specific protocol (local network datagram headers, or *virtual circuits). The encapsulated packet is sent over the network to a gateway, which removes the old network-specific encapsulation, adds a new set of network headers, and sends the packet out on another network. Eventually the message reaches its destination, where it is consumed.

When protocol translation is used, messages are sent on a local network using the protocols and conventions of that network. A gateway receives the message and transforms it into the appropriate message on another network; this may involve interpreting the message at multiple protocol levels.

The encapsulation approach provides a uniform set of semantics across all networks, while the translation approach results in unanticipated problems due to subtle differences between protocols. The encapsulation approach generally requires that new software be written for all hosts on all networks, while the translation approach requires new software only in the gateways. *See also* IP.

interoperability The ability of systems to exchange and make use of information in a straightforward and useful way; this is enhanced by the use of standards in communication and data format.

interpolation A simple means of approximating a function $f(x)$ in which the approximation, say $p(x)$, is constructed by requiring that

$$p(x_i) = f(x_i), i = 0, 1, 2, \dots, n$$

Here $f(x_i)$ are given values $p(x_i)$ that fit exactly at the distinct points x_i (*compare* smoothing). The value of f can be approximated by $p(x)$ for $x \neq x_i$. In practice p is often a polynomial, linear and quadratic polynomials providing the simplest examples. In addition the idea can be extended to include matching of $p'(x_i)$ with $f'(x_i)$; this is *Hermite interpolation*. The process is also widely used in the construction of many numerical methods, for

use reflectance functions that more accurately represent the properties of real surfaces (see also specular reflection, Cook-Torrance model).

reflexive closure See transitive closure.

reflexive relation A *relation R defined on a set S and having the property that

$$x R x$$

for all elements x in S

The relation "is the same age as" defined on the set of people is reflexive. Compare irreflexive relation.

refresh (regenerate) 1. To replenish the charge on the storage capacitors used in *dynamic memory cells and other similar devices. Some devices are provided with internal circuitry that automatically refreshes dynamic cells whenever these cells are read. The word refresh is also used as a noun.

2. To repeat at regular intervals the display of digital information on a *cathode-ray tube or television monitor in order that the display can appear persistent. See also refresh frequency.

refresh frequency The frequency with which a display on a cathode-ray tube is regenerated. To avoid *flicker this must be made as high as possible. See CFF.

refutation A method of reasoning used in logic to refute statements, i.e. to prove them false.

regenerate Another term for refresh.

register A group of (usually) *bistable devices that are used to store information within a computer system for high-speed access. A register of n bistables can store a word of length n bits, which can represent any n bits of information. Different interpretations can be given to the bit configuration stored in the register; for example, the configuration could represent an instruction, a binary number, an alphanumeric character, etc. A register is often the same size as the computer word; it may also be byte- or character-size or some other size as required. Some registers can behave as *counters as well, or they may behave as *shift registers. See also memory hierarchy.

register insertion ring See ring network.

register optimization See optimization.

register transfer language (RTL) Any of several programming languages that allow the declaration of *register configurations within a structure to perform a computation. The timing of transfers between registers, to describe the behavior, is specified by the order in which such transfers are interpreted during the execution of the program. See also CHDL.

regression analysis A statistical technique that is concerned with fitting relationships between a dependent variable, y , and one or more independent variables, x_1, x_2, \dots , usually by the method of *least squares.

A *linear regression model* is one in which the theoretical mean value, μ_y , of the observation y , is a linear combination of independent variables,

$$\mu = \beta_0 + \beta_1 x_1 + \dots + \beta_k x_k$$

when k x -variables are included in the model. The multiples $\beta_0, \beta_1, \dots, \beta_k$ are parameters of the model and are the quantities to be estimated; they are known as *regression coefficients*, β_0 being the *intercept* or *constant term*. A model with more than one x -variable is known as a *multiple regression model*.

Nonlinear regression models express μ as a general function of the independent variables. The general functions include curves such as exponentials and ratios of polynomials, in which there are parameters to be estimated.

Various procedures have been devised to detect variables that make a significant contribution to the regression equation, and to find the combination of variables that best fits the data using as few variables as possible. *Analysis of variance is used to assess the significance of the regression model. See also generalized linear model, influence.

regression testing Following maintenance to a system, tests performed to demonstrate that the system still performs all the functions required prior to the maintenance. Regression testing is additional to tests made to ensure that the modifications work satisfactorily. See also performance testing.

regula falsi Another name (Latin) for false position method.