By providing the screen with a backlight panel instead of reflecting just the incidental light, light can be produced in order to provide more brilliant images. Small LCD displays for watches or personal assistants just reflect incidental light. LCD screens for desktop computers have powerful backlight panels. Obviously, the latter consume more energy.

Thin-film **transistor** LCD (TFT-LCD) screens are arrangements similar to the one described above, in which a transistor is placed in the glass substrate to drive the electric field needed for each pixel. The transistors are so small and thin ("thin film") that they are not visible for the user. Each transistor can be selected and driven individually using an *active matrix arrangement.* The response time of the transistors is so short that now LCD screens can be used also for video images. Previous generations of LCD screens could not display them, because the time needed to adjust the liquid crystal was too large.

LCD screens usually have a problem with the viewing angle. Since the direction of the crystal molecules is adjusted for users viewing the screen from the front, users viewing the screen from the side are actually looking through several pixel columns, and the polarization angle is not the optimal one. Light will be blocked and the image on the screen is not visible.

FURTHER READING

Friedman, Peter S., ed. *Advanced Flat Panel Display Technologies: 7–8 Feb. 1994, San Jose, Calif.* Bellingham, Wash.: SPIE, 1994.

Yeh, Pochi, and Clair Gu. *Optics of Liquid Crystal Displays.* New York: Wiley, 1999.

—*Raúl Rojas*

LISP

LISP, an acronym for List Processing Language, is a high-level programming language developed by **John McCarthy** (1927–) at the Massachusetts Institute of Technology (MIT) in the late 1950s and early 1960s. LISP is one of the oldest programming languages and is still very popular for **artificial intelligence** (AI) applications.

LISP is a functional language, which means that computations are performed by defining functions and applying them to data and to other functions. Each function application requires a set of parentheses—extensive programs tend to end in long strings of closing parentheses. The main data structures in LISP are lists, which can contain atomic elements or other lists. Nested lists provide a representation for trees. LISP programs themselves are also lists. Therefore, it is fairly easy to write LISP programs that process other LISP programs. This is LISP's main difference from languages such as **Fortran** and **Pascal**, which are not geared toward this kind of reflective computing.

At the 1955 Dartmouth Summer Research Project on Artificial Intelligence, a seminal conference in the history of AI, McCarthy formulated his thoughts about a new programming language and the line of research he intended to follow: "It therefore seems to be desirable," he wrote, "to attempt to construct an artificial language which a computer can be programmed to use on problems and self-reference....I hope to try to formulate a language having these properties...with the hope that using this language it will be possible to program a machine to learn to play games well and do other tasks." McCarthy's first approach was extending Fortran with list processing functions, but very soon he was developing an entirely new language. Looking for a way to describe a universal function capable of evaluating any other function, he finally hit on the idea of using list processing, the functional notation, and list processing instructions. Some of these commands, such as CAR (take the first element of a list) and CDR (take the rest of a list by deleting the first element), took their names from similar assembler instructions in IBM machines. The canonical version of LISP was defined in 1962 by McCarthy in his book about LISP 1.5.

Mac-Lisp, a version of LISP written at MIT in the late 1960s for the PDP-10 computer, became very popular and contributed to the dissemination of the language. However, LISP was still much slower than other, more conventional languages—thus the idea arose to build LISP machines, to lower the semantic gap between the **software** and **hardware**. In the early 1980s, several companies were formed that tried to build these machines; the most successful of them was Symbolics Inc., which stayed in business almost 10 years. However, the creation of faster workstations, combined with advances in compiler technology, eventually made LISP machines obsolete. Interestingly, the system code for those later machines was also written in LISP. For example, the design philosophy of the Japanese Fifth Generation Project (1981–91) owed a great deal to LISP machines.

The very success of LISP led to several incompatible versions for different computers. Therefore, at a 1981 meeting sponsored by the Advanced Research Projects Administration (**ARPA**), several of the main LISP developers met and formed a committee to explore the possibility of agreeing on a common language. The definition of Common LISP was published in 1984 in a book titled *Common Lisp: The Language*. Several software companies implemented this new version immediately. To this day, LISP continues to be the favorite programming language of AI researchers.

FURTHER READING

McCarthy, John. *LISP 1.5 Programmer's Manual.* Cambridge, Mass.: Massachusetts Institute of Technology, Computation Center and Research Laboratory of Electronics, 1962; 2nd ed., 1973.

Steele, Guy L. *Common LISP: The Language.* Burlington, Mass.: Digital Press, 1984; 2nd ed., Bedford, Mass., 1990.

—*Raúl Rojas*

Local Area Network

A local area network (LAN) interconnects computers in a geographic area of limited size, usually a building or one floor in a building. LANs represent the lowest level in the global connection hierarchy. Their "width" is measured in hundreds of meters, whereas the width (reach) of **metropolitan area networks** (MANs) is measured in kilometers, the width of **wide area networks** (WANs) in hundreds of kilometers, and of the **Internet** in thousands of kilometers. LANs were conceived in the 1970s and became ubiquitous with the success of the **Ethernet** networking cards. LANs are used to connect personal computers and workstations, and to share printers and **file servers**.

The main aspects distinguishing LANs from other types of networks are their topology and the protocols and connection media they use. A popular LAN topology consists of using a single **bus** to connect all computers in the network. The bus is used to broadcast messages to all machines, marking each message with the number of the computer that is the intended recipient. A bus topology is simple and inexpensive, since only a cable has to be laid out in the building. In some cases, the preexisting **twisted-pair** cables for telephones can be used to transmit data. Sending a message can lead to collisions if two computers try to send packets at the same time. Therefore, before sending a packet every computer monitors the line until it is free. If there is a collision even after having done this, both computers back off and wait some time to restart the transmission. This method of collision detection is the one implemented in the **Ethernet** standard.

The first Ethernet networks were installed as part of a research project started by **Robert Metcalfe** (1946–) and David Boggs (1950–) at **Xerox Palo Alto Research Center** (PARC) in the early 1970s. On 22 May 1973, Metcalfe used the term *Ethernet* for the first time, superseding the name *Aloha Alto* that had been used until then. Although that particular date has been called the birthday of Ethernet, Metcalfe has observed that the entire design actually took several years to converge to its final form. The motivation for the development of the Ethernet was to allow entire work groups to share the laser printers that Xerox was developing.

Ethernet is the paradigmatic LAN: simple to install, inexpensive, and as fast as a single user may wish. Ethernet cards cost several thousand dollars when they were first announced, but they are now commodity products packaged in single chips for personal computers.

LANs in organizations are now more sophisticated than the single Ethernet cable mentioned above. Most LANs now have a star topology. Individual machines in a room, for example, are connected to a single cable. This in turn is connected to a switch, which receives all packets from such bus subnetworks (called *segments*). The switch passes packets from one segment to another at full speed, and all packets going out of this area go through a faster line (e.g., a gigabit link) connected to another switch or router. This type of topology is called *switched Ethernet.*