- Acting as change agents, evaluating, initiating, and promoting change projects

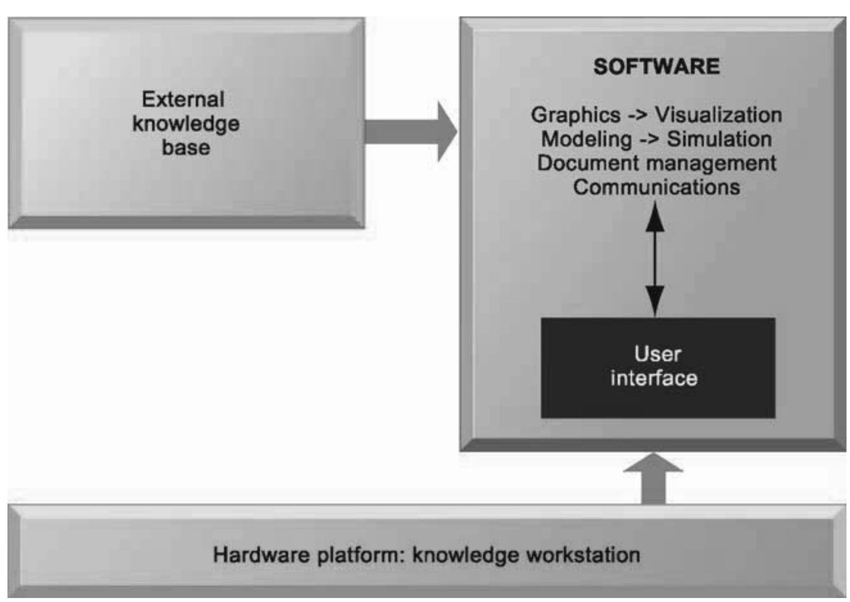
REQUIREMENTS OF KNOWLEDGE WORK SYSTEMS

Most knowledge workers rely on office systems, such as word processors, voice mail, e-mail, videoconferencing, and scheduling systems, which are designed to increase worker productivity in the office. However, knowledge workers also require highly specialized knowledge work systems with powerful graphics, analytical tools, and communications and document management capabilities.

These systems require sufficient computing power to handle the sophisticated graphics or complex calculations necessary for such knowledge workers as scientific researchers, product designers, and financial analysts. Because knowledge workers are so focused on knowledge in the external world, these systems also must give the worker quick and easy access to external databases. They typically feature user-friendly interfaces that enable users to perform needed tasks without having to spend a great deal of time learning how to use the system. Knowledge workers are highly paid—wasting a knowledge worker's time is simply too expensive. Figure 11.4 summarizes the requirements of knowledge work systems.

Knowledge workstations often are designed and optimized for the specific tasks to be performed; so, for example, a design engineer requires a different workstation setup than a financial analyst. Design engineers need graphics with enough power to handle three-dimensional (3-D) CAD systems. However, financial analysts are more interested in access to a myriad number of external databases and large databases for efficiently storing and accessing massive amounts of financial data.

FIGURE 11.4 REQUIREMENTS OF KNOWLEDGE WORK SYSTEMS



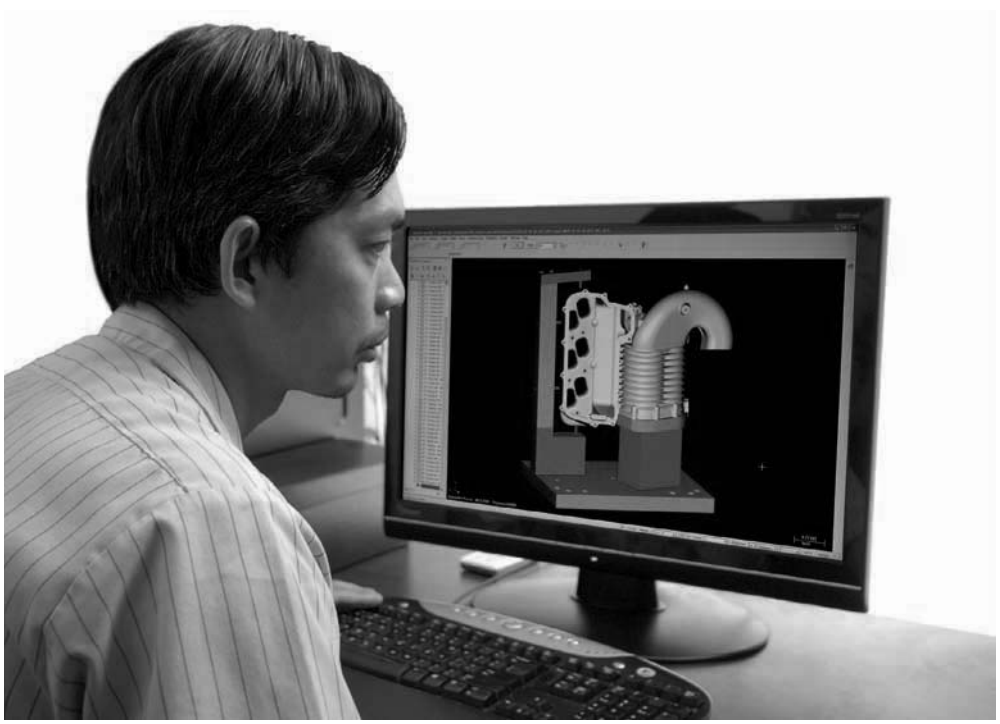
Knowledge work systems require strong links to external knowledge bases in addition to specialized hardware and software.

EXAMPLES OF KNOWLEDGE WORK SYSTEMS

Major knowledge work applications include CAD systems, virtual reality systems for simulation and modeling, and financial workstations. **Computer-aided design (CAD)** automates the creation and revision of designs, using computers and sophisticated graphics software. Using a more traditional physical design methodology, each design modification requires a mold to be made and a prototype to be tested physically. That process must be repeated many times, which is a very expensive and time-consuming process. Using a CAD workstation, the designer need only make a physical prototype toward the end of the design process because the design can be easily tested and changed on the computer. The ability of CAD software to provide design specifications for the tooling and manufacturing processes also saves a great deal of time and money while producing a manufacturing process with far fewer problems. The Interactive Session on Technology illustrates some of these benefits, and shows how they can be a source of competitive advantage.

CAD systems are able to supply data for **3-D printing**, also know known as additive manufacturing, which uses machines to make solid objects, layer by layer, from specifications in a digital file. 3-D printing is currently being used for producing prototypes and small items, such as jewelry and hip implants, as well as aircraft parts. In the future, it may be used for custom-fabricating parts for autos and military equipment.

Virtual reality systems have visualization, rendering, and simulation capabilities that go far beyond those of conventional CAD systems. They use interactive graphics software to create computer-generated simulations that are so close to reality that users almost believe they are participating in a real-world situation. In many virtual reality systems, the user dons special clothing, headgear, and equipment, depending on the application. The clothing contains sensors that record the user's movements and immediately transmit



CAD systems improve the quality and precision of product design by performing much of the design and testing work on the computer.

INTERACTIVE SESSION: TECHNOLOGY

FIREWIRE SURFBOARDS LIGHTS UP WITH CAD

Nev Hyman had been building surfboards in Australia for 35 years. In 2005, he teamed up with Mark Price and a group of longtime surfing friends in Carlsbad, California, to form Firewire Surfboards. This company thrives on innovation and was responsible for the first major change in surfboard composition and assembly methods in 40 years. Rather than polyurethane resin and polyurethane foam, Firewire's boards were composed of expanded polystyrene (EPS) foam and epoxy resins. Hyman and Price believed that this composition for the surfboard core, along with aerospace composites for the deck skin and balsa wood rails (the outside edge),created a more flexible and maneuverable product that would attract top surfers and set Firewire apart from its competitors.

Firewire is competing in a crowded field that includes Isle Surfboards, Surftech, Aviso Surf, Board works Surf, Channel Island, and Lost Enterprises. Firewire is alone in the reintroduction of balsa wood to the board rails for added flex response time and the ability to maintain speed during precarious maneuvers. Firewire believes it can compete successfully because its surfboards are far lighter, stronger, and more flexible than those of its competitors. An additional selling point is the reduced environmental impact: Firewire's materials emit only 2 percent of the harmful compounds of traditional boards and recycling excess expanded polystyrene (EPS) foam has earned Firewire international awards and acclaim.

But that isn't enough. To make sure it stays ahead of the competition, Firewire decided to start making custom surfboards instead of just the usual off-the-rack sizes. For the everyday surfer, the durability and flexibility of Firewire's materials was a key selling point. However, custom boards made to surfer specifications are critical in the elite surfboard market, and the ability to claim top-level competitive surfers as customers drives the broader surfboard market as well.

Traditionally, skilled craftsman, called shapers, designed and built surfboards by hand, but Firewire started doing some of this work using computer-aided designs (CAD) sent to cutting facilities. The company's computer-aided manufacturing process returned to the shaper a board that was 85 to 90 percent complete, leaving the artisan to complete the customization and the lamination process.

According to Price, who became Firewire's CEO, there are 29 time-consuming and labor-intensive steps in the surfboard manufacturing process. Initially, the multifaceted manufacturing process made it impossible to offer personalized CAD to the average consumer. Customized boards could only be produced for elite competitive customers. There was no way to offer customization to a wider market without overburdening Firewire's CAD system. Moreover, most custom boards had to be ordered by filling out a piece of paper with various dimensions for the requested changes. There was no way to see a visual representation of these adjustments or assess their impact on the board's volume, which directly affects buoyancy, paddling ability, and performance.

Firewire needed a system that would allow customers to experiment with established designs, feed the CAD process, and integrate it with its computer numerical control (CNC) manufacturing process. Enter ShapeLogic Design-to-Order Live! For NX, which provides an online customization system with a Web-based user interface and advanced 3-D CAD tools.

Firewire started working with the ShapeLogic NX software in 2009 to develop its own Firewire Surfboards' Custom Board Design (CBD) system, which allows users to easily manipulate board dimensions of established models within design parameters. Any registered customer can choose a standard Firewire model and use drag-and-drop tools to adjust the board's length, midpoint width, nose width, tail width, and thickness, as long as these changes don't degrade the board's design integrity. CBD generates a precise three-dimensional model of the stock model used as the base design along with a 3-D portable document format (PDF) file of the customized board. The PDF file documents the board's dimensions and volume. A customer can manipulate the model from all angles and compare the customized board to the standard board to fully understand the design before placing an order. When the customer uses the system to order a custom board, CBD generates a precise solid CAD model of the board that is transmitted directly to the Firewire factory for driving the CNC machines that manufacture the board.

This combination of technologies results in a board that is 97 percent complete, minimizing the manufacturing time, finishing process, and thus, costs to the consumer. In contrast to the earlier CAD assisted, 10 to 15 percent hand-finished boards, once a surfer has designed the board of his or her dreams, it can be remade to those exact specifications time and again. Neither the ideal handmade board nor a shaper-finished board can be replicated with this degree of precision.

An additional benefit of Firewire's online design system is the social networking engendered by the sharing of customers' unique design files. Before placing an order, customers can show their modifications to fellow surfers and ask for opinions and advice. After placing an order and using the product, they can report their experiences and (hopefully) tout their design or suggest improvements to other customers. Interactive communication such as this drives customers to the Firewire site, creating a marketing buzz that boosts sales.

Sources: "Case Study: NX CAD technology drives custom surfboard design," http://www.plm.automation.siemens.com/en_us, accessed June 14, 2012; "Firewire Surfboards by Nev Hyman," www.allaboutsurfboards.com, accessed June 14, 2012; "Firewire Partners with NanoTune 'Board Tuning Technology,'" www.surfnewsdaily.com, February 22, 2012; William Atkinson, "How Firewire Surfboards Refined Its 3D Order Customization," www.cioinsight.com, November 21, 2011; "Firewire Surfboards Custom Board Design Blends Replicability of Machine Made Boards With Uniqueness of Custom Boards," http://surfingnewsdaily.com, October 12, 2011; and "Firewire Surfboards Garner Recognition for Technological Advances," www.surfermag.com, July 22, 2010.

CASE STUDY QUESTIONS

1. Analyze Firewire using the value chain and competitive forces models.
2. What strategies is Firewire using to differentiate its product, reach its customers, and persuade them to buy its products?
3. What is the role of CAD in Firewire's business model?
4. How did the integration of online custom board design software (CBD), CAD, and computer numerical control (CNC) improve Firewire's operations?

that information back to the computer. For instance, to walk through a virtual reality simulation of a house, you would need garb that monitors the movement of your feet, hands, and head. You also would need goggles containing video screens and sometimes audio attachments and feeling gloves so that you can be immersed in the computer feedback.

At NYU Langone Medical Center in New York City, students wearing 3-D glasses are able to "dissect" a virtual cadaver projected on a screen. With the help of a computer, they can move through the virtual body, scrutinizing layers of muscles or watching a close-up of a pumping heart along with bright red arteries and deep blue veins. The virtual human body was created by BioDigital Systems, a New York City medical visualization firm. The virtual cadaver being used at Langone is a beta version that BioDigital plans to develop into a searchable, customizable map of the human body for medical educators and physicians. NYU medical school has no current plans to phase out dissection, but the 3-D virtual cadaver is a valuable complementary teaching tool (Singer, 2012).

Ford Motor Company has been using virtual reality to help design its vehicles. In one example of Ford's Immersive Virtual Environment, a designer was presented with a car seat, steering wheel, and blank dashboard. Wearing virtual reality glasses and gloves with sensors, the designer was able to "sit" in the seat surrounded by the vehicle's 3-D design to experience how a proposed interior would look and feel. The designer would be able to identify blind spots or see if knobs were in an awkward place. Ford's designers could also use this technology to see the impact of a design on manufacturing. For example, is a bolt that assembly line workers need to tighten too hard to reach (Murphy, 2012)?

Augmented reality (AR) is a related technology for enhancing visualization. AR provides a live direct or indirect view of a physical real-world environment whose elements are augmented by virtual computer-generated imagery. The user is grounded in the real physical world, and the virtual images are merged with the real view to create the augmented display. The digital technology provides additional information to enhance the perception of reality, making the surrounding real world of the user more interactive and meaningful. The yellow first-down markers shown on televised football games are examples of augmented reality as are medical procedures like image-guided surgery, where data acquired from computerized tomography (CT) and magnetic resonance imaging (MRI) scans or from ultrasound imaging are superimposed on the patient in the operating room. Other industries where AR has caught on include military training, engineering design, robotics, and consumer design.

Virtual reality applications developed for the Web use a standard called **Virtual Reality Modeling Language (VRML)**. VRML is a set of specifications for interactive, 3-D modeling on the World Wide Web that can organize multiple media types, including animation, images, and audio to put users in a simulated real-world environment. VRML is platform independent, operates over a desktop computer, and requires little bandwidth.

DuPont, the Wilmington, Delaware, chemical company, created a VRML application called HyperPlant, which enables users to access 3-D data over the Internet using Web browser software. Engineers can go through 3-D models as if they were physically walking through a plant, viewing objects at eye level. This level of detail reduces the number of mistakes they make during construction of oil rigs, oil plants, and other structures.

The financial industry is using specialized **investment workstations** such as Bloomberg Terminals to leverage the knowledge and time of its brokers, traders, and portfolio managers. Firms such as Merrill Lynch and UBS Financial Services have installed investment workstations that integrate a wide range of data from both internal and external sources, including contact management data, real-time and historical market data, and research reports. Previously, financial professionals had to spend considerable time accessing data from separate systems and piecing together the information they needed. By providing one-stop information faster and with fewer errors, the workstations streamline the entire investment process from stock selection to updating client records. Table 11.2 summarizes the major types of knowledge work systems.

TABLE 11.2 EXAMPLES OF KNOWLEDGE WORK SYSTEMS

KNOWLEDGE WORK SYSTEM	FUNCTION IN ORGANIZATION
CAD/CAM (computer-aided manufacturing)	Provides engineers, designers, and factory managers with precise control over industrial design and manufacturing
Virtual reality systems	Provide drug designers, architects, engineers, and medical workers with precise, photorealistic simulations of objects
Investment workstations	High-end PCs used in the financial sector to analyze trading situations instantaneously and facilitate portfolio management

11.4 Intelligent Techniques

Artificial intelligence and database technology provide a number of intelligent techniques that organizations can use to capture individual and collective knowledge and to extend their knowledge base. Expert systems, case-based reasoning, and fuzzy logic are used for capturing tacit knowledge. Neural networks and data mining are used for **knowledge discovery**. They can discover underlying patterns, categories, and behaviors in large data sets that could not be discovered by managers alone or simply through experience. Genetic algorithms are used for generating solutions to problems that are too large and complex for human beings to analyze on their own. Intelligent agents can automate routine tasks to help firms search for and filter information for use in electronic commerce, supply chain management, and other activities.

Data mining, which we introduced in Chapter 6, helps organizations capture undiscovered knowledge residing in large databases, providing managers with new insight for improving business performance. It has become an important tool for management decision making, and we provide a detailed discussion of data mining for management decision support in Chapter 12.

The other intelligent techniques discussed in this section are based on **artificial intelligence (AI)** technology, which consists of computer-based systems (both hardware and software) that attempt to emulate human behavior. Such systems would be able to learn languages, accomplish physical tasks, use a perceptual apparatus, and emulate human expertise and decision making. Although AI applications do not exhibit the breadth, complexity, originality, and generality of human intelligence, they play an important role in contemporary knowledge management.

CAPTURING KNOWLEDGE: EXPERT SYSTEMS

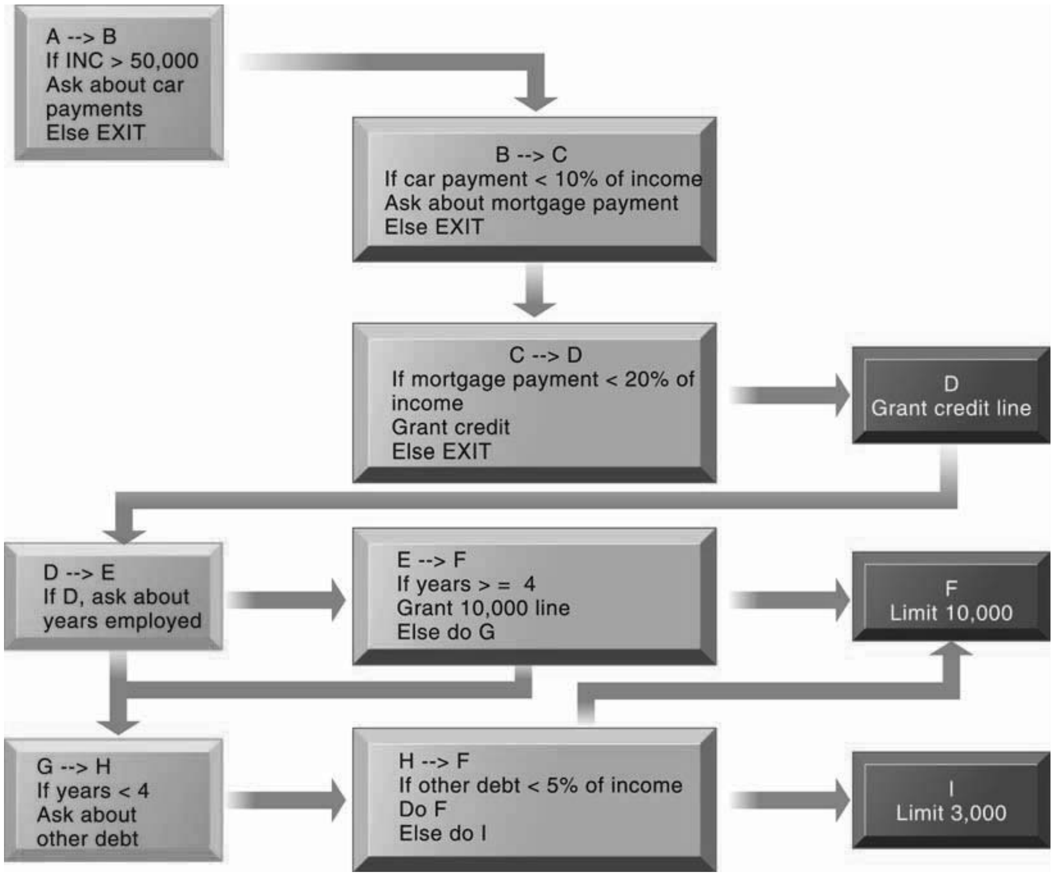
Expert systems are an intelligent technique for capturing tacit knowledge in a very specific and limited domain of human expertise. These systems capture the knowledge of skilled employees in the form of a set of rules in a software system that can be used by others in the organization. The set of rules in the expert system adds to the memory, or stored learning, of the firm.

Expert systems lack the breadth of knowledge and the understanding of fundamental principles of a human expert. They typically perform very limited tasks that can be performed by professionals in a few minutes or hours, such as diagnosing a malfunctioning machine or determining whether to grant credit for a loan. Problems that cannot be solved by human experts in the same short period of time are far too difficult for an expert system. However, by capturing human expertise in limited areas, expert systems can provide benefits, helping organizations make high-quality decisions with fewer people. Today, expert systems are widely used in business in discrete, highly structured decision-making situations.

How Expert Systems Work

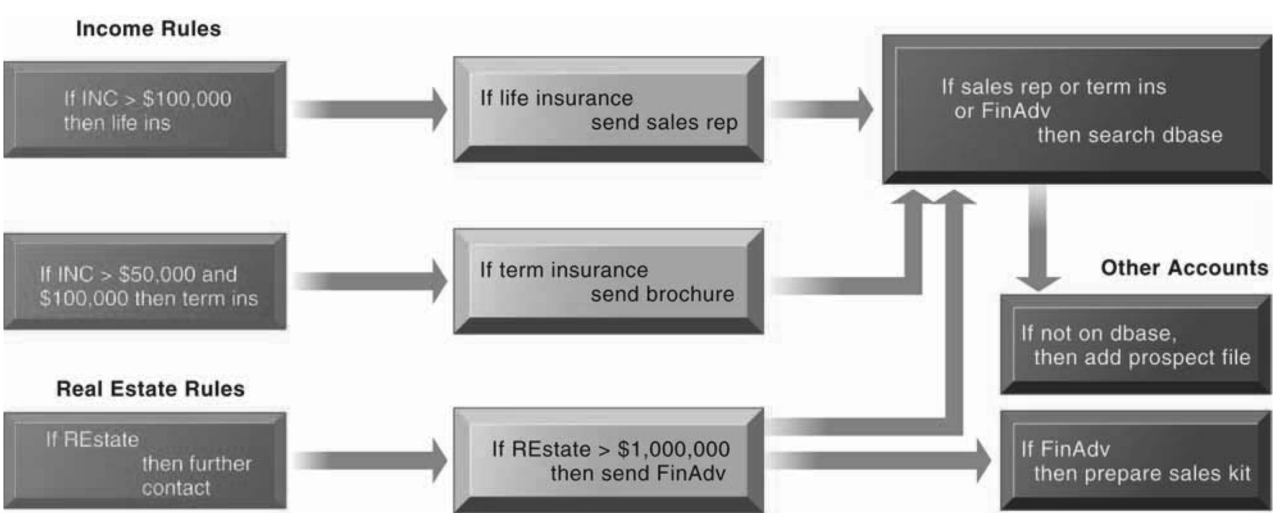
Human knowledge must be modeled or represented in a way that a computer can process. Expert systems model human knowledge as a set of rules that collectively are called the **knowledge base**. Expert systems have from 200 to many thousands of these rules, depending on the complexity of the problem. These rules are much more interconnected and nested than in a traditional software program (see Figure 11.5).

FIGURE 11.5 RULES IN AN EXPERT SYSTEM



An expert system contains a number of rules to be followed. The rules are interconnected; the number of outcomes is known in advance and is limited; there are multiple paths to the same outcome; and the system can consider multiple rules at a single time. The rules illustrated are for simple credit-granting expert systems.

FIGURE 11.6 INFERENCE ENGINES IN EXPERT SYSTEMS



An inference engine works by searching through the rules and "firing" those rules that are triggered by facts gathered and entered by the user. Basically, a collection of rules is similar to a series of nested IF statements in a traditional software program; however, the magnitude of the statements and degree of nesting are much greater in an expert system.

The strategy used to search through the knowledge base is called the **inference engine**. Two strategies are commonly used: forward chaining and backward chaining (see Figure 11.6).

In **forward chaining,** the inference engine begins with the information entered by the user and searches the rule base to arrive at a conclusion. The strategy is to fire, or carry out, the action of the rule when a condition is true. In Figure 11.6, beginning on the left, if the user enters a client's name with income greater than $100,000, the engine will fire all rules in sequence from left to right. If the user then enters information indicating that the same client owns real estate, another pass of the rule base will occur and more rules will fire. Processing continues until no more rules can be fired.

In **backward chaining,** the strategy for searching the rule base starts with a hypothesis and proceeds by asking the user questions about selected facts until the hypothesis is either confirmed or disproved. In our example, in Figure 11.6, ask the question, "Should we add this person to the prospect database?" Begin on the right of the diagram and work toward the left. You can see that the person should be added to the database if a sales representative is sent, term insurance is granted, or a financial adviser visits the client.

Examples of Successful Expert Systems

Expert systems provide businesses with an array of benefits including improved decisions, reduced errors, reduced costs, reduced training time, and higher levels of quality and service. Con-Way Transportation built an expert system called Line-haul to automate and optimize planning of overnight shipment routes for its nationwide freight-trucking business. The expert system captures the business rules that dispatchers follow when assigning drivers, trucks, and trailers to transport 50,000 shipments of heavy freight each night across 25 states and Canada and when plotting their routes. Line-haul runs on a Sun computer platform and uses data on daily customer shipment requests, available drivers, trucks, trailer space, and weight stored in an Oracle database. The expert system uses thousands of rules and 100,000 lines of program code written in C++ to crunch the numbers and create optimum routing plans for 95 percent of daily freight shipments. Con-Way dispatchers tweak the routing plan provided by the expert system and relay final routing specifications to field personnel responsible for packing the trailers for their nighttime runs. Con-Way recouped its $3 million investment in the system within two years by reducing the number of drivers, packing more freight per trailer, and reducing damage from rehandling. The system also reduces dispatchers' arduous nightly tasks.

Although expert systems lack the robust and general intelligence of human beings, they can provide benefits to organizations if their limitations are well understood. Only certain classes of problems can be solved using expert systems. Virtually all successful expert systems deal with problems of classification in limited domains of knowledge where there are relatively few alternative outcomes and these possible outcomes are all known in advance. Expert systems are much less useful for dealing with unstructured problems typically encountered by managers.

Many expert systems require large, lengthy, and expensive development efforts. Hiring or training more experts may be less expensive than building an expert system. Typically, the environment in which an expert system operates is continually changing so that the expert system must also continually change.

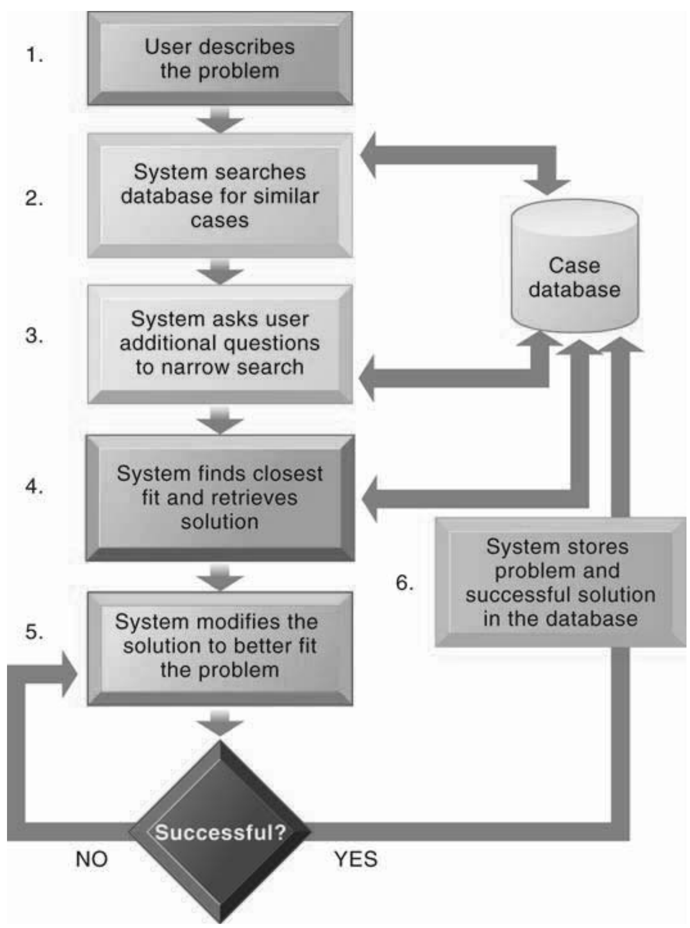
Some expert systems, especially large ones, are so complex that in a few years the maintenance costs equal the development costs.

ORGANIZATIONAL INTELLIGENCE: CASE-BASED REASONING

Expert systems primarily capture the tacit knowledge of individual experts, but organizations also have collective knowledge and expertise that they have built up over the years. This organizational knowledge can be captured and stored using case-based reasoning. In **case-based reasoning (CBR)**, descriptions of past experiences of human specialists, represented as cases, are stored in a database for later retrieval when the user encounters a new case with similar parameters. The system searches for stored cases with problem characteristics similar to the new one, finds the closest fit, and applies the solutions of the old case to the new case. Successful solutions are tagged to the new case and both are stored together with the other cases in the knowledge base. Unsuccessful solutions also are appended to the case database along with explanations as to why the solutions did not work (see Figure 11.7).

Expert systems work by applying a set of IF-THEN-ELSE rules extracted from human experts. Case-based reasoning, in contrast, represents knowledge as a

FIGURE 11.7 HOW CASE-BASED REASONING WORKS



Case-based reasoning represents knowledge as a database of past cases and their solutions.
The system uses a six-step process to generate solutions to new problems encountered by the user.

series of cases, and this knowledge base is continuously expanded and refined by users. You'll find case-based reasoning in diagnostic systems in medicine or customer support where users can retrieve past cases whose characteristics are similar to the new case. The system suggests a solution or diagnosis based on the best-matching retrieved case.

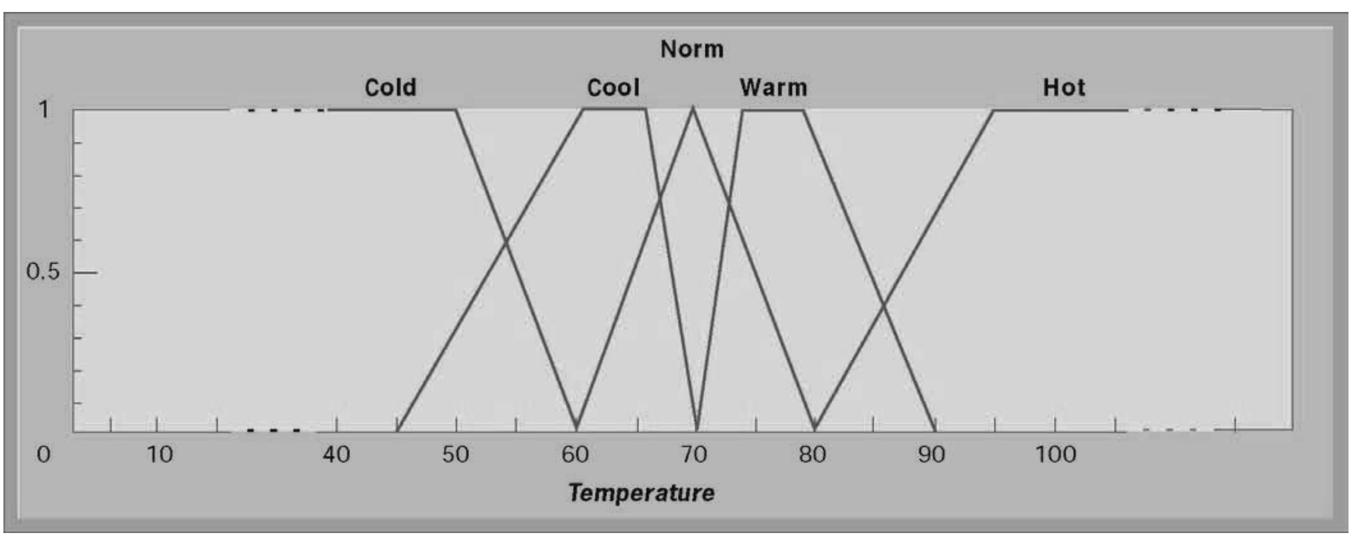
FUZZY LOGIC SYSTEMS

Most people do not think in terms of traditional IF-THEN rules or precise numbers. Humans tend to categorize things imprecisely using rules for making decisions that may have many shades of meaning. For example, a man or a woman can be *strong* or *intelligent*. A company can be *large*, *medium*, or *small* in size. Temperature can be *hot*, *cold*, *cool*, or *warm*. These categories represent a range of values.

Fuzzy logic is a rule-based technology that can represent such imprecision by creating rules that use approximate or subjective values. It can describe a particular phenomenon or process linguistically and then represent that description in a small number of flexible rules. Organizations can use fuzzy logic to create software systems that capture tacit knowledge where there is linguistic ambiguity.

Let's look at the way fuzzy logic would represent various temperatures in a computer application to control room temperature automatically. The terms (known as *membership functions*) are imprecisely defined so that, for example, in Figure 11.8, cool is between 45 degrees and 70 degrees, although the temperature is most clearly cool between about 60 degrees and 67 degrees. Note that *cool* is overlapped by *cold* or *norm*. To control the room environment using this logic, the programmer would develop similarly imprecise definitions for humidity and other factors, such as outdoor wind and temperature. The rules might include one that says: "If the temperature is *cool* or *cold* and the humidity is low while the outdoor wind is high and the outdoor temperature is low, raise the heat and humidity in the room."

FIGURE 11.8 FUZZY LOGIC FOR TEMPERATURE CONTROL



The membership functions for the input called temperature are in the logic of the thermostat to control the room temperature. Membership functions help translate linguistic expressions such as *warm* into numbers that the computer can manipulate.

The computer would combine the membership function readings in a weighted manner and, using all the rules, raise and lower the temperature and humidity.

Fuzzy logic provides solutions to problems requiring expertise that is difficult to represent in the form of crisp IF-THEN rules. In Japan, Sendai's subway system uses fuzzy logic controls to accelerate so smoothly that standing passengers need not hold on. Mitsubishi Heavy Industries in Tokyo has been able to reduce the power consumption of its air conditioners by 20 percent by implementing control programs in fuzzy logic. The autofocus device in cameras is only possible because of fuzzy logic. In these instances, fuzzy logic allows incremental changes in inputs to produce smooth changes in outputs instead of discontinuous ones, making it useful for consumer electronics and engineering applications.

Management also has found fuzzy logic useful for decision making and organizational control. A Wall Street firm created a system that selects companies for potential acquisition, using the language stock traders understand. A fuzzy logic system has been developed to detect possible fraud in medical claims submitted by health care providers anywhere in the United States.

MACHINE LEARNING

Machine learning is the study of how computer programs can improve their performance without explicit programming. Why does this constitute learning? A machine that learns is a machine that, like a human being, can recognize patterns in data, and change its behavior based on its recognition of patterns, experience, or prior learnings (a database). For instance, a car-driving robot should be able to recognize the presence of other cars and objects (people), and change its behavior accordingly (stop, go, slow down, speed up, or turn). The idea of a self-taught, self-correcting, computer program is not new, and has been a part of the artificial intelligence field at least since the 1970s. Up until the 1990s, however, machine learning was not very capable of producing useful devices or solving interesting, business problems.

Machine learning has expanded greatly in the last ten years because of the growth in computing power available to scientists and firms and its falling cost, along with advances in the design of algorithms, databases, and robots. The Internet and the big data (see Chapter 6) made available on the Internet have proved to be very useful testing and proving grounds for machine learning.

We use machine learning everyday but don't recognize it. Every Google search is resolved using algorithms that rank the billions of Web pages based on your query, and change the results based on any changes you make in your search, all in a few milliseconds. Search results also vary according to your prior searches and the items you clicked on. Every time you buy something on Amazon, its recommender engine will suggest other items you might be interested in based on patterns in your prior consumption, behavior on other Web sites, and the purchases of others who are "similar" to you. Every time you visit Netflix, a recommender system will come up with movies you might be interested in based on a similar set of factors.

Neural Networks

Neural networks are used for solving complex, poorly understood problems for which large amounts of data have been collected. They find patterns and relationships in massive amounts of data that would be too complicated and difficult for a human being to analyze. Neural networks discover this knowledge by using hardware and software that parallel the processing patterns of