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AI at Work Today and in the Future

In the 1960s, researchers felt that true AI would be created within 30 to 40 years. In the 1980s, AI researchers thought that artificial intelligence was about 20 to 30 years in the future. Today, AI researchers think that their goal might be reached between 2020 to 2040. True artificial intelligence consists of computers that can reliably pass the Turing test. These true AI computers seem to keep moving further and further into the future. This is largely because the more we learn about the research problems, the more complex it turns out to be.

At first, people thought that AI would emerge as soon as we had a computer that was as complicated as a human brain. Later, they thought that it would just take very good programming. There are still scientists in each of these camps, but more and more AI researchers are thinking there is more to the problem than that.

Because of what scientists have done and learned over the last half-century of AI research, a few things have happened. One is that researchers have realized that true artificial intelligence is going to show up later than they'd guessed. The other thing that's happened is that researchers have lowered some of their expectations. For example, instead of dreaming of carrying on a full conversation with a computer, we accept a computer that runs a voicemail system,

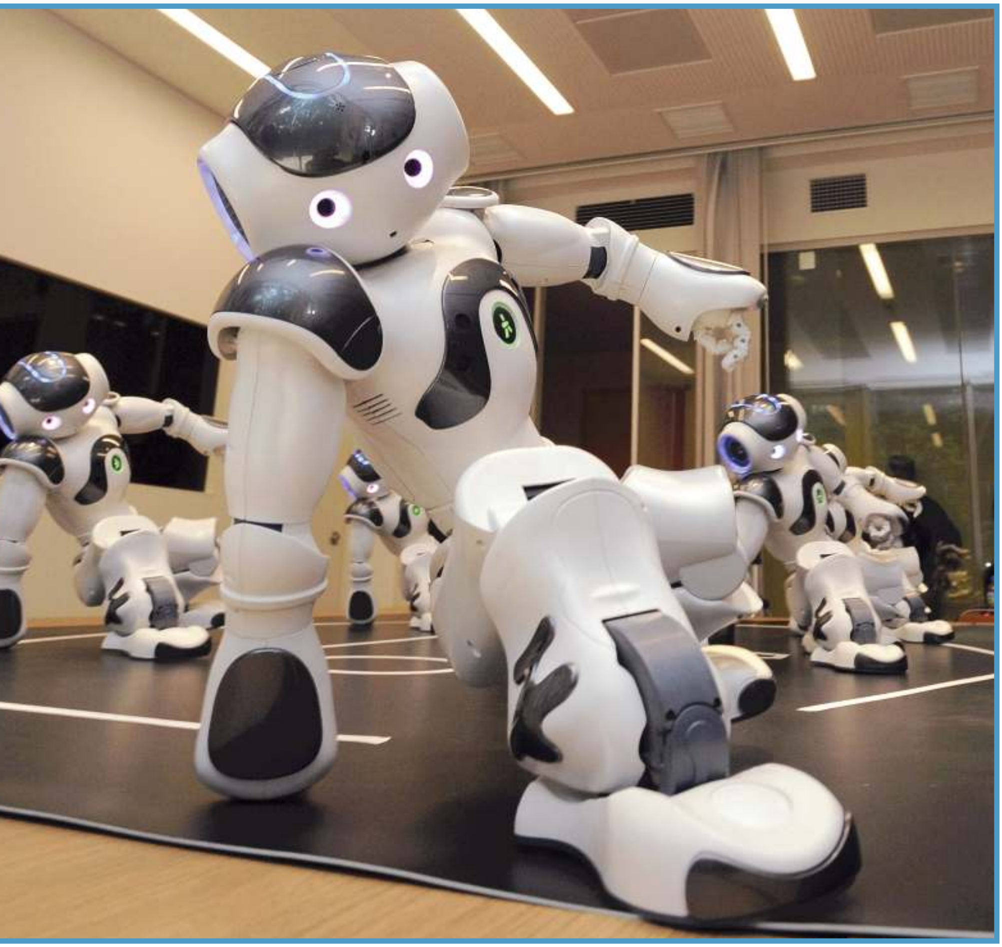

Figure 5.1 Nao Robots, created by the French company Aldebarane Robotics, dance to music at a Tokyo exhibition in October 2010. The University of Tokyo uses an academic version of Nao Robots for research.

voice-recognition telephone dialing, and voice-activated controls in some of the newest cars and fighter jets.

THE CURRENT STATE OF THE ART FOR AI

As things stood as of 2011, many of the small problems associated with artificial intelligence have been solved. For the ones that haven't been solved, the path to a solution is in sight. "Small" problems include speech recognition, visual object recognition, large storage capacity, and extremely fast computing speeds. The issue with speech recognition is one problem that has not yet been fully solved. Today's systems are relatively good, and solving the problem seems to be within reach, following the same path being taken by current work. The technology is reaching the point where a computer can understand natural speech as well as a human can.

Much of the current hardware seems to meet the research needs of AI scientists. Digital cameras, microphones, and speakers are accurate and sensitive enough to be the artificial senses for AI. There has been a lot of progress in developing sensors that allow computers and robots to have the senses of touch, taste, and smell. Computer memory is still a challenge, though. In a 2010 article in *Scientific American*, Northwestern University professor Paul Reber noted that the human brain is thought to be able to store as much information as the hard drives of a thousand home computers. This means that it's difficult—but not impossible—to build a computer with the same amount of memory as a human brain.

Researchers can design a computer today with the same amount of memory as a human brain. The main obstacle is the processor. While **microprocessors** are still not as complex or as fast as a human brain, this goal is in sight. The current estimates are that by about the year 2020, there should be microprocessors that can process information as quickly as a human brain. Also, they should be as complex as a brain, with all of its interconnections. Thus, when we consider everything, today's hardware is not yet up to the task of imitating the human brain, mainly because the processors are not yet as powerful as our brains are. Yet, within a decade, it seems likely that the available hardware will be able to create a computer that is at least as complex as a brain.

Still, there remains the software question. Can researchers write software sophisticated enough to become intelligent? The biggest problem is how the software should work. Since the 1960s, there have been a number of ideas about the best way to program computers to mimic human thought. Some have focused on processing lists of information, some on recognizing patterns, some on recognizing and processing symbols, and more. Researchers are close to

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Is There a "Divine Spark"?

There has long been the question as to whether the human brain became intelligent simply because of the way it is put together or if our intelligence was given to us by God—what some refer to as a "divine spark" of intelligence. Most AI research is focused on either developing faster, more complex hardware, or on creating more flexible, sophisticated software. This work has taken up a lot of time and effort. It has kept some of the best AI researchers busy and frustrated for decades. Many AI scientists think that the combination of better hardware and software will one day create artificial intelligence. However, some scientists who study the way the human brain works are not so sure.

Although the human brain has many of the same components as animal brains, the human brain is more than just a large version of what animals have. At the core of every human brain is something very much like a lizard's brain. This part of the brain sends the nerve impulses that keep the heart and lungs working, and it also does all of the other tasks that keep our bodies alive and functioning. It keeps the body running properly, but it doesn't do any thinking. Added onto that is another layer that's similar to what's in a mouse's brain. It can feel some emotions and it can do a little thinking. On top of the mouselike brain are even more structures that make up the rest of the human brain. These are the parts that allow us to have long memories, help us think complex thoughts, and give us our sense of **morality**. According to some scientists, our brains are more like computers that have been slapped together without much of a master plan—like a bunch of separate components that weren't necessarily designed to work together. These researchers call our brain a kludge, a term used to refer to a sloppy device that works but that's not very elegant. The point is that while our brains are bigger and more complicated than the brains of other animals, they are made of a hodge-podge of components that have been put together; they were not built in the detail-oriented way that we design and build computers. But what does this mean for AI research?

The human brain didn't make us intelligent just by being bigger and faster than the brains of other animals. This suggests that computers might not become intelligent just because they are bigger and faster. Some brain researchers think that human intelligence came about by accident, a result of the way that our brains evolved by stacking one new component at a time atop the previous structure in a way that accidentally made our brains complex enough to suddenly develop intelligence. If that's true then it might take luck—and maybe even computers that are slapped together the same way our brains are—to become intelligent. In other words, developing a real AI might rely as much on luck as on skill.

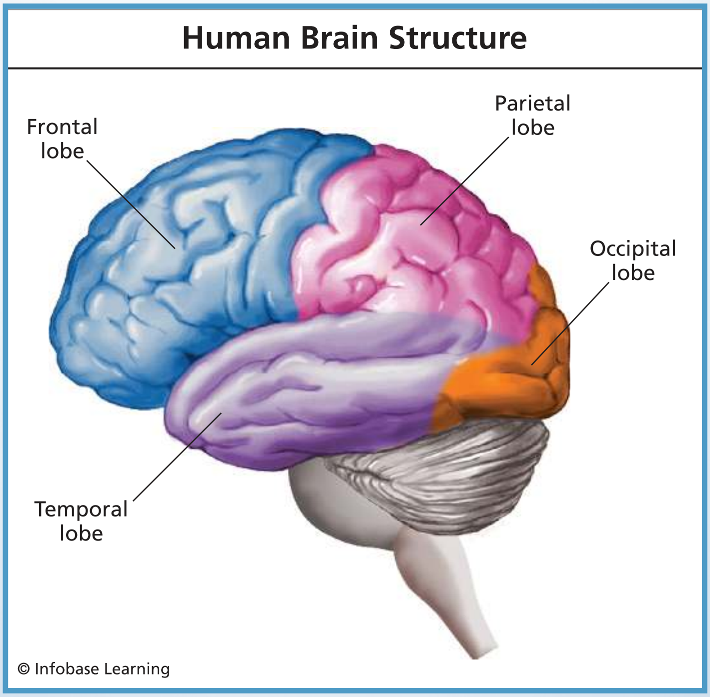

Figure 5.2 The four lobes of the brain work together to monitor and regulate the body's actions and reactions. They continuously receive sensory information, quickly analyze it, and then respond by controlling bodily actions and functions.

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knowing how to make hardware that will be as complex as a human brain, but they're not yet sure how to tell it how to work. This is where much of today's AI research is concentrated.

Given all of this, AI can tackle some very limited areas. Expert systems can solve problems in very specific areas almost as well as humans can. Expert systems, for example, can read heart monitors and interpret them as well as many human doctors. Software can translate from one language to another rather well. In addition, there are many clever programs to help solve specific problems in image recognition and more. At the same time, researchers continue to make progress in tackling the more difficult problem of developing a program that is self-aware and can think at the same level as a human. But AI research is not there yet.

LESSENED EXPECTATIONS IN RECENT YEARS

AI researchers and software companies have been talking about AI for years but they have not yet produced systems that can pass the Turing test. This means that the public keeps hearing about how impressive AI can be, yet reality does not live up to the promises. Many software and hardware manufacturers are eager to come out with "AI" systems, so they are lowering their expectations and starting to use the term *intelligent* for systems that are smart and sophisticated. These systems are not really genuinely intelligent.

One example of this is **data-mining** software. This type of software is designed to search through large amounts of data to extract useful information. Data mining is routinely used to detect credit card fraud, help determine who is likely to repay a loan, perform marketing research, sort through huge amounts of scientific data, and so forth. Data-mining software can be incredibly sophisticated. It can detect patterns most people just wouldn't notice. Still, even with all of this power, data-mining software is not intelligent. It does one thing exceptionally well, but it doesn't do much else. Also, it still needs humans to tell it what to look for and to interpret the data produced.

"Intelligent" wheelchairs and walkers are examples of tools made to help the disabled. In a 2004 research study, Professor Ulises Cortés of the Technical University of Catalonia, Spain, added sensors and computing power to a couple of these devices. This allowed the intelligent walkers and wheelchairs to adjust to the terrains and the people using them. When a walker is able to sense how strong a user is, his or her walking speed, and type of surface traveled, it can adjust itself to make walking as easy as possible for the user. Everyone gets to use something that's personalized for him or her. Yet, as with other "intelligent" tools, though these gadgets are good at what they do, each one can usually only do one thing—whatever they are programmed and designed to do—well (compared to people, who can do many different things).

Yet another example is the new automatic electronic defibrillator (AED) used to shock a person's heart back into a healthy rhythm. If a person is having chest pains, an AED can sense whether the heart rhythm is potentially dangerous. It can analyze what the heart is doing and decide whether an electric shock would help it get back into normal working order. It can even calculate the best type of shock and the time to give it. Other medical devices called EKGs (electrocardiograms) are used to analyze the electrical patterns given off by a heart. These devices help doctors understand if a heart is healthy or diagnose any problems. Both of these are also considered "intelligent" devices. Again, although they do one thing very well—in some cases just as well as trained doctors—they are limited.

Most of the "smart" devices and "intelligent" systems that are being sold today are incredibly useful. Some save lives, others help us to see patterns and to understand data better than ever before. We can program these devices with sets of rules to help them make decisions. In what they are programmed to do, they can be even better than humans are. These devices and programs are marvels and would have astounded scientists and engineers from the 1940s and 1950s—probably the 1960s as well. But can we really say that a data-mining program, a wheelchair, or an AED is intelligent? Most of us would say no.

Think about everything that doctors can do, and not just in the field of medicine. They know what they need to survive and fit into today's society. Any person can do hundreds of things—some of them well, some poorly, and most of them somewhere in between.

Any person can do an incredible number of tasks and activities—far more than any of the current AI systems can. Today's AI systems are specialists, but true intelligence is more general.

DRIVERLESS CARS AND OTHER PROJECTS

One of the most challenging problems in AI is navigating a car without human help. A car that can drive itself is called an **autonomous** vehicle. Although individual aspects of driving can be automated, the entire process is really a very tough problem to solve. The driver has to keep the car in its lane, follow the speed limit (or slow down if the roads are dangerous), and avoid obstacles. Also, the driver must read traffic signs, look out for pedestrians, and follow the curves and turns of a road, and so forth (if you really want to be impressed with our brains consider the fact that in addition to all of this we can also carry on a conversation with others in the car, listen to the radio, pay attention to the GPS, and more—all while driving safely). It's hard to see how something so complex can be automated, but progress is being made.

There are many advantages to finding a way to make driving automatic. Improving safety is one of them. More than 30,000 Americans die every year in traffic accidents. Some people feel that automated vehicles are likely to be safer than those driven by humans for the following reasons. For one, machines react more quickly than people do. Plus, many researchers in this area think that computer-driven cars would be able to drive faster and closer to the cars ahead of them while having fewer accidents. This means that traffic should move faster and there would be fewer traffic jams and accidents. Also, automated cars would use less fuel. This is because they can be driven more evenly and with greater efficiency.

Then there are the military applications. Such cars could be driven autonomously—without humans onboard—through dangerous areas without putting lives at risk. They would reduce human casualties from roadside bombs and mines. They could move cargo and supplies from place to place without the need to take soldiers from important duties. The military is extremely interested in automated vehicles. In fact, it has spent millions of dollars funding research in this area.

Figure 5.3 In October 2010, German engineers at Berlin's Free University unveiled the latest self-driving car, which proponents say will sharply reduce accidents, help the environment, and transform cities. The car is called "Made in Germany," or MIG, for short. Although it looks like an average Volkswagen Passat with a camera on top, MIG uses cameras, laser scanners, and satellite navigation to "see" other vehicles and pedestrians and deal with traffic situations.

So how does someone drive safely? Drivers need to be able to see well enough to detect other cars, the lane or lanes around the car, obstacles (including things that come up suddenly such as animals running into the road), road signs, brake lights, and more. They have to hear car horns, people yelling, police and fire truck sirens, and even the sounds of their own car engines. The sense of touch is also important. The driver needs to be able to get feedback through touching the steering wheel, brake pedal, and accelerator. What is important is that the driver has to be able to take in *all* of this information from vision, hearing, and possibly touch. Then, the driver must integrate all the information so that the destination can be safely reached. It is an incredible challenge to AI researchers but the expected benefits are significant.

Many organizations have offered prizes for the first company to develop a driverless car. The best-known challenge was offered by

How AI Systems Are Built and Tested

Designing an AI system is different from building one. Designing something in a laboratory does not always mean it can be made in a factory. Laboratory **prototypes** can be big, awkward, and ugly. The only truly important thing is to make them work. A scientist doesn't care if his or her model can be made cheaply, if it looks nice enough for people to want to buy, or if the manufacturing process can be streamlined so the device can be easily made. Yet, anything that is going to be made in large numbers has to be something that people want to buy and can afford to own.

The AI systems of the future will be more complex and intelligent than the ones we have today. For our purposes here, we will only talk about the ones presently available. Today's AI systems are useful for safety and for convenience—automated systems to keep the wheels from locking up and skidding, automated systems to help park the car in close quarters, and (in hybrid vehicles) systems to automatically adjust the flow of power between the gasoline engine and the vehicle's battery. Each of these systems has one or more common components: a computer connected to sensors, a way to take action, and a system loaded with software that takes information from the sensors and decides what to do with it.

Building an AI system (in this case we're talking about today's "smart" systems, although the same basic principles

DARPA, the Defense Advanced Research Projects Administration. DARPA is a U.S. military research organization that funds "high-risk, high-reward" research. This is high-risk research that DARPA officials expect may not work. Of course, if it does, it would be revolutionary. DARPA has offered a $2 million award to the first group that can make a car able to drive different courses without any human intervention.

apply to genuinely intelligent systems as well) requires designing the computer, the sensors (cameras, microphones, touch sensors), and the devices that the AI will operate, such as a voice synthesizer or a robot arm. Then, the computer is loaded with the software. So far, this sounds similar to putting together a home computer or stereo system. In reality, the process is a bit more complicated, even though the general idea is pretty much the same.

The final step is to test the system to make sure it's operating correctly. Part of this process includes running simple checks, such as making sure that the computer can do simple addition. However, there's much more to testing an AI system than just making sure it can do small tasks. A new AI system must be tested with difficult problems in different conditions. A system designed to drive a car might first be tested in an open space such as a parking lot. Then it might be tested in a parking lot with traffic cones set up to make lanes to see if the AI can maneuver the car and avoid the cones. The next step might be to drive the car on a driving course. On the course, the car could be told to turn corners and avoid things in the street (people, wagons, branches, and so forth).

At all stages, designers should check to see if the driving AI goes where it's told, avoids running into things, follows traffic laws, and drives safely. The final test would be to put the system in a car with a human driver as a safety monitor. This person has to be there to take control if the AI makes a mistake. If the final test goes without any problems, then the system could be approved for use.

In the first challenge, in 2004, cars had to drive 150 miles (240 km) in the Mohave Desert. No team was able to finish this route. The second challenge, in 2005, was a repeat of the 2004 event. Five of the 23 teams that started the challenge reached the finish line. The Stanford University team took first place in just under 7 hours. In the third challenge in 2007, the cars had to drive 60 miles (96 km) over an urban course. This one was won by the Carnegie Mellon University team, in 4 hours and 10 minutes. All of these events showed that computerized cars could safely make it a long distance, around obstacles, and through hazards while following the traffic laws.

A more recent project is the Google Driverless Car project. The Google cars have driven up to 1,000 miles (1,600 km) without human help and a total of 140,000 miles (230,000 km) with very little human guidance. In all that time, the only accident was when one of the Google cars was run into by a human-driven car while it was stopped—a human error and not a machine mistake. It could be that the technology developed by Google might be the first of its kind to be sold.

The biggest problem is that traffic laws are all written for cars with humans behind the wheel. Say, for example, a car gets into an accident while it's driving itself. Who is responsible: the person who owns the car, the person sitting in it, or the company that wrote the software and built the vehicle? We might not have cars that drive themselves until there's an answer to that question, and others like it. Something else to remember is that any artificial intelligence—whether in a car, a computer, or a robot—must be thoroughly tested before we can trust it with our lives or our safety.

QUANTUM COMPUTING, FUZZY LOGIC, AND MORE FLEXIBLE PROGRAMMING

There are a few interesting areas of study that AI scientists think might help to bring us closer to a real artificial intelligence. One of these areas is quantum computing, which involves hardware development. The other two are software solutions: using fuzzy logic and a more flexible approach to programming. Each is interesting, cutting edge, and might help push researchers further along in the search for AI.

Quantum Computing

Quantum computing might turn out to be the greatest advance in the history of AI technology. Even the basic science is much too complex to discuss here. It is completely different from the way in which typical computers work. Today's computers solve problems through calculation. Each of the billions of transistors that are on the computer chip has a specific sequence of tasks to do. The transistors carry out their tasks one after the other until they reach an answer. A quantum computer, by comparison, can perform thousands, millions, or billions of tasks at the same time. This means that difficult problems that would take days to be solved by today's fastest computers can be solved almost instantly by a quantum computer.

Quantum computing is still a young field. Small-scale quantum computers have been built and have solved very simple problems. Researchers are focusing on the basic theories and scientific foundations of quantum computers. They hope that more powerful quantum computers can be made in the future. In this field, today's theory will lead to better computers tomorrow. No matter how scientists finally create an artificial intelligence, they are going to have to make use of extremely high-speed computers. By themselves, quantum computers are not going to be intelligent. However, they may give researchers the computing speed and power to help them create an AI.

Fuzzy Logic

AI researchers are also using fuzzy logic, a somewhat new branch of mathematics. Compared to the **crisp logic** of most computers, it does a better job of describing the types of situations in which we normally find ourselves. Computers usually see things as either yes or no, true or false, 0 or 1. A typical computer program can't understand "maybe." Fuzzy logic, on the other hand, sees a whole array of possibilities. If a standard computer program is trying to decide if a glass is full or empty, it might be programmed to call less than half-full "empty." Or, it would think that anything more than half-full is full. Just adding a tiny bit of water—enough to go from 49% full to 51% full—would change the glass from "empty" to "full" for a computer using standard logic. A fuzzy logic computer is able to classify the glass as "sort of" full. This, again, is more like the

Game-playing Computers

Some people think that computers started to master humans on May 11, 1997, the day that an IBM computer named Deep Blue became the first computer to beat the world chess champion. Some saw this as an important step on the path to true artificial intelligence. Others pointed out that, although complex, chess has only a limited number of moves, and the solutions to many chess problems can be calculated. In addition, programmers were allowed to work on Deep Blue's program between games. This helped the computer to avoid making a mistake in the last game that it had made twice earlier. Today, most AI researchers are willing to acknowledge that Deep Blue was not intelligent, but they also agree that this was an important step on the path to AI.

On February 16, 2011, another IBM computer—this one named Watson—was watched by millions as it beat two champions in the TV game show *Jeopardy!*. To many people, *Jeopardy!* was a tougher test of intelligence since the players not only have to know a lot of information in a lot of different categories, but they also have to be able to understand the questions well enough to know what's being asked. Watson not only beat two former *Jeopardy!* champions, but it beat them by a score of $77,147 to $24,000 (for the second-place contestant) and $21,600 (for the third-place contestant).

Nobody is saying that Watson is intelligent. The computer made a few mistakes that a person would have avoided. But many agree that Watson is another step on the path to artificial intelligence. This is a computer that can make sense of hard questions and can search through its memory to find an answer that makes sense.

world we live in: We have glasses that are partly full; people who are of tall, short, and medium height; and temperatures that are cool and warm as well as hot and cold (and very hot, very cold, and everything in between).

Perhaps what should impress us the most, however, is that Watson is a cutting-edge computer made up of hundreds of processors and vast amounts of memory. It was loaded with millions of documents, books, and encyclopedias. A team of 15 people spent three years on the programming, all to come up to the standard set by the human brain in this one skill. But for all its *Jeopardy!* skills, Watson still can't cook a meal, drive a car, or do any of the other things that people do every day, although IBM will be using Watson's design as a template to build other, more advanced computers that could be used to help make medical diagnoses or research legal matters.

Figure 5.4 *Jeopardy!* champions Ken Jennings (*left*) and Brad Rutter (*right*) look on as the IBM computer called "Watson" beats them to the buzzer to answer a question during a practice round of the quiz show in January 2011.

The world we live in is a "fuzzy" one and most of the decisions we make are based on information that is not complete. Computers using crisp logic run into problems when trying to make crisp decisions with fuzzy data. However, most everyday questions that humans face have no true or false answer. It is necessary for humans to program computers so that the machines can understand the fuzzy logic needed to reach conclusions and make decisions.

Flexible Programming

The human mind is a very flexible device. Consider all of the things we do every day: walk, talk, feel emotions, eat, understand what our senses are telling us, study, watch TV, play games, and much more. In addition, depending on the circumstances, our brains use the same information in different ways. For instance, imagine of the different ways you can interpret a blank computer screen. It can mean the computer is turned off, the monitor is turned off, or that the computer has been inactive for a while and the screensaver turned on. The way we react to a blank computer screen depends on why the screen is blank. Our flexibility means we can react differently to each situation. Suppose we treated every blank computer screen as though the screensaver were turned on. Every time we saw a blank screen, we would move the mouse to turn the screen back on. Most of the time the screen might light up, but there would be many times when nothing would happen. A computer programmed to be flexible is able to adapt to situations the same way that we do. One of the places where both fuzzy logic and flexible programming are heavily used is in game-playing computers.

One of the hallmarks of human intelligence is that we can tailor our response to the very situation we experience. Think beyond the computer monitor to other situations, such as driving. The speed limit might be 60 miles per hour (100 kilometers per hour), but a good driver doesn't always drive at this speed. If the road is slippery, if visibility is bad, or if the road is clogged with traffic, then a person can't drive safely at 60 miles per hour. A good driver would slow down. Drivers also slow down when they come to a curve or when they see a stop sign or traffic light coming up. If there's an emergency and the roads are safe, then the driver might speed up.

Even with something as simple as obeying a speed limit sign, we still respond with flexibility. We use our intelligence to decide what to do. We judge what is necessary and safe, instead of abiding by the same rule the same way each time. Another important tool for helping to develop an artificial intelligence will be to create software that is flexible in response to different situations, so it can deal with a fuzzy world in the same way we do.