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Building Robots

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TO

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putting an infrared (IR) transmitter on the bot that sends an invisible light beam out into the environment. That light is reflected off of objects back to a special infrared receiver elsewhere on the bot. The angle of that reflected light changes depending on the proximity of the robot to the object that's reflecting the light. The robot can use this change in angle to measure the distance and trigger an appropriate action (such as an obstacle avoidance sequence).

Light sensors are also used in line-following navigation. Commonly, a black or white line is put down to create a "track" for the robot to follow. Photosensitive sensors, on the front or bottom of the bot, straddle the line. If one of the sensors registers a high degree of change in light intensity (by crossing the line), it triggers the motors to adjust course to keep the line between the two sensors (and the robot on track).

Another use of light sensing is to engineer circuits outfitted with light sensors that make the robot "attracted" to light (in other words, it moves in the direction of the most intense light source), or repulsed by the light (it moves away). These "behaviors" are called, respectively, *photovoric* (*photo* meaning light, *vore* being Latin for "swallow up") and photophobic.

note

There are basically two ways of using reflected light intensity in robot navigation. In *proximity detection*, the photosensitive receiver is simply looking for a set trigger value (for example, a high light intensity level), that when reached, will prompt the robot's response. The robot will wait until that trigger value is reached before doing anything. Proximity detection is like an on/off switch. *Distance detection*, the more sophisticated of the two approaches, uses the changing angle of reflected light to actually measure the changing distance between the robot and obstacles. This allows for the taking of different actions depending on perceived distance.

Sound Sensors

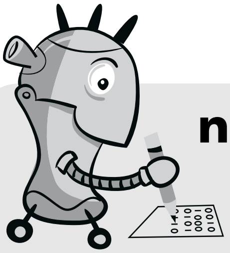
The most common type of sound sensor makes use of sonar technology. Sonar sensors basically use the speed of sound to measure distance and use that information to aid in robotic navigation. Inaudible sound waves (outside the range of human hearing) are projected out from a transmitter on the robot, bounce off of surfaces, and return to a receiver on the robot. The time it takes for the sound waves to

note

We'll be using light sensors in Project 2 and will discuss them in more detail then.

return to the sonar sensor (also called an *ultrasonic range sensor*) is used to calculate the robot's distance from an approaching object. This data is then passed along to the control circuitry of the robot and appropriate action is taken.

Another type of sound sensing involves the use of microphones. A robot outfitted with mics can be programmed to move toward a sound source, move a certain body part, or move all of its body parts. Entertainment robots such as Sony's forthcoming SDR-4X humanoid take in sounds via microphones so that the robot can dance (the sound input activates the robot's many servo motors). Robots are also being programmed to respond to certain voice characteristics (such as a raised voice or lowered voice). Of course, microphones are also used on robots that are programmed to respond to sets of human voice commands.



note

Inexpensive sonar systems for robots became popular when builders began to cannibalize the sonar range finders built into Polaroid's SX-70 instant camera (introduced in the 1970s). The sonar sensors in the camera were designed to measure distance for auto-focusing a shot. The demand for these sensors (and those in subsequent Polaroid cameras) became so great that they are now sold as standalone components.

Vision Systems

Cameras have been mounted on robots for decades (going all the way back to the bulky one that gave SRI's Shakey its shake). Cameras are most commonly used on robots that are *teleoperated*, that is, operated by a human at a distance (either at the end of a tether of control cables or over a radio link). With the advent of the Internet and cheap digital Web cameras, robots can now send video signals through the Net so that humans can see what the robot sees, or even control the robot remotely.

Getting a robot vision system to analyze its video input (moving, real-time, unpredictable input) and make sense of it is still a daunting challenge. However, those in the field of biometrics are making inroads into this challenge. Human facial identification is becoming a more common technology, especially in security systems. Here, face size and proportional information, skin tone, and other factors can be used to match a face with a database of stored faces. Unfortunately, this only works if the person is staring directly into the camera lens.

Robot vision systems are getting better at detecting humans in a "scene," tracking moving objects, making out saturated colors, and roughly understanding three-dimensional objects. They still struggle with telling men from women, interpreting objects if the camera is in motion, determining what materials objects are made of, and determining "gaze direction" (where the person is looking). Honda has made some advances with the latter problem. The current version of its Asimo humanoid can tell where a person is looking if the person both looks at and points to the target object.

Heat Sensors

Security robots and others designed to detect fire are outfitted with what are called *infrared pyroelectric sensors*. These sensors detect a combination of heat and movement. If they see some nasty, dancing flames in front of them (registering both movement and heat), the sensors are triggered (and the robot will usually call for human backup). These same sensors are used as motion detectors and will detect the heat and movement of a person within a certain range (see Figure 4.13).

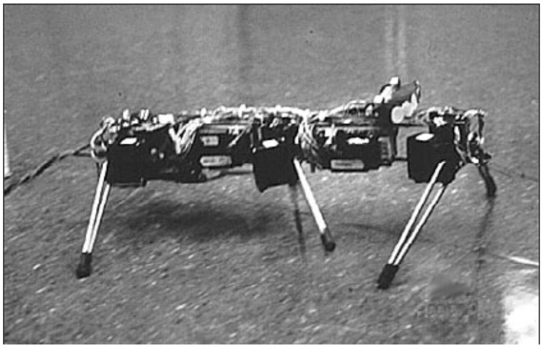


FIGURE 4.13

The infamous Genghis, the six-legged robo-critter built at MIT's AI Lab in the late '80s, used six pyroelectric sensors on its "head" so that it would follow humans around, attracted to their movement and body heat. Photo courtesy of Rodney Brooks and the MIT AI Lab.

Gas Sensors

Robots can be outfitted with "electric noses" that can sense a variety of toxic gases. Common on security or industrial robots, triggering this type of sensor usually means a call to a human who decides the nature of the threat. Robots might have become fairly sophisticated, but we're still not comfortable letting them handle a ruptured gas main on their own.

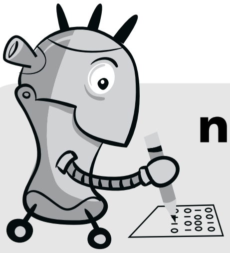
Other Types of Sensors

There are dozens more sensor types than what we've already covered. Here are just a few more and a word or two on each:

- **Encoders**—Optical or magnetic sensors that "read" the rotation of a robot's wheels to measure distance traveled.
- **GPS receiver**—A device that can access the Global Positioning Satellite (GPS) system, using the location of several orbiting satellites to pinpoint a robot's location on the ground (outdoor robots only).
- **Strain gauges**—For measuring the physical force exerted on an object. Used in touch sensors, gripper force feedback, and collision detection.
- **Tilt sensors**—Used to indicate the attitude of a robot. Sometimes used for balance, especially in walking robots. If the sensor detects that the robot is on a dangerous angle, and at risk of falling over, it will "ask" the robot's controller to back it away from the threatening terrain.

Controllers

All robots have brains of some sort. These can run the gamut from workstation-level computers to analog electronic circuits designed to give the robot basic bug-brained instincts. Here's a quick rundown of the types of controllers you're likely to find on a robot:



note

Many medium-to-large size robots often use the guts of a standard desktop computer for their controller. This is especially the case when weight is not a primary concern and computing power is. Robot programmers often grumble when they only have the limited memory space of an itty-bitty microcontroller to load programs into. A PC lets them stretch out a bit. Since PCs have been covered in…ah…a few other books, we won't detail this type of robot control here.

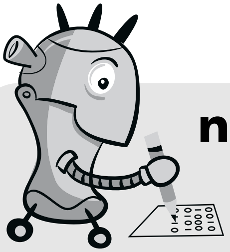
Microcontrollers

One of the most common forms of robot control is the *microcontroller*. A microcontroller is basically a computer on a chip that's been designed for embedded computing applications (like robot brains!). It typically has a CPU (a central processing unit), an erasable memory space (called an *EEPROM*) for storing control programs, some Random-Access Memory (RAM) for storing temporary data, a clock for controlling the speed at which the CPU barks its orders, and input/output (I/O) pins for getting data into and out of the chip.

Microcontroller chips usually come mounted on microcontroller boards, often called *modules*. The boards contain support electronics and sockets for connecting wires to input and output devices (sensors, motors, other controllers, and so forth) and to a power source. In most cases, creating the control programs that run the robot is done on another computer and then downloaded into the microcontroller's memory via a standard computer cable. Some robot controllers, like MINDSTORMS' RCX computer brick, use an infrared transmitter (on the PC end) and a receiver (on the microcontroller end) to load programs into the robot.

Off-Board Control

A lot of today's robots keep most of their brains someplace else, accessing the programs stored on a standalone computer (or network of computers) via a radio link. Before the increasing popularity of wireless data communications, robots of this type had to be tethered (connected via trunks of cables) to a computer, which greatly limited their range. Advantages of off-board computing include the availability of more computing muscle, less weight on the bot, and less power needs. The disadvantages are that the range can be limited (to the local radio range) and the robot is computer-dependent.



note

Evolution Robotics (`www.evolution.com`) has come up with a unique (and cost-effective) way of getting plenty of computing power to its ER1 robot. Evolution sells a kit that consists of only the frame, drive and power systems, sensors, and software. The frame has a place for you to park your laptop computer, which becomes your robot's brains (when you're not electronically balancing your checkbook or playing *Sims Online*).

Nervous Nets

A radical form of robotic control, originally developed by former Los Alamos robotics researcher Mark Tilden, doesn't use a computer at all. Called *BEAM (Biological Electronic Aesthetics Mechanics)* robotics, this scheme uses conventional analog electronic components (capacitors, resistors, transistors, and integrated circuits) to build what Tilden has dubbed *nervous nets* (a play on the *neural networks* of AI). BEAM technology is basically an updated version of what Grey Walter was doing in the late ’40s and ’50s with his robot tortoises. Inspired by nature, BEAM bots often take the form of robo-critters and can exhibit extremely lifelike behaviors given their simple components.

Other Controllers

Frequently, robots have special controllers to manage power and speed. Not surprisingly, they are called *power controllers* and *speed* (or *motor*) *controllers*. These usually take the form of separate circuit boards with all of the electronics needed to perform their tasks, and they are often located next to their respective system (the power source and the drive train). Wires send data to and from theses controllers to the robot’s main microcontroller. Sometimes, rather than power and speed controllers being on separate circuit boards, they’re located on the microcontroller board (either handled as part of the microchip’s duties, or separate circuitry on the main board).

Communication (Optional)

Although sensors are a way for a robot to listen to its world, there are a number of ways of making the conversation a little less one-sided. These include the following:

Two-Way Wireless

Increasingly, robots are communicating with their world in real time. This is largely thanks to increasingly inexpensive short-range radio technology (such as *Wireless Fidelity* or *WiFi*), developed for wireless computer networking. Using such a radio link, a robot can send real-time sensor data, video images, sounds, and more to a local computer (and that computer can send all this to remote locations via the Internet). This opens up all sorts of possibilities for interfacing robots with the rest of the world.

Speech

Getting a robot to respond to fixed speech commands has become near-commonplace. Numerous advances have been made over the past few years to the point where reasonably sophisticated voice command and speech synthesis systems are starting to show up in high-tech toys. But there’s still a long way to go.

There are two flavors of speech recognition. *Voice-dependent* recognition, the “easier” of the two, requires that the user (or users) teach the robot (or other digital device, such as a desktop computer or talking teddy bear) commands using their voice. The voice recognition system will then only recognize the voices to which it has been