Let's assume that we want a robot to pick up an object from one location and then place it somewhere else. One way of doing this is to fix end stops around the arm so that it can travel a set maximum distance in any given direction. The arm would then swing around until it came to the end stops, at which point (if everything was positioned correctly) the hand would be directly above the object to be grasped. After picking up the object, the arm could swing in the opposite direction until another set of end stops would let it know that the object should be released. This is a simple example, and it is one that is becoming less common, but it demonstrates that robots can use senses that are not possessed by humans.

Perhaps a better example is a robot's use of 'vision'. Humans see only visible light — a large part of the electromagnetic spectrum is invisible to the human eye — but there is no reason why a robot should be so confined. Infrared detectors may be fitted in place of photoelectric cells; these will allow the amount of heat generated by an object to be measured. Industrial robots can make use of these detectors to move away from any dangerously hot objects, for example. But a robot could also detect the warmth of a human body — so your personal robot could be programmed to come running to greet you as you walk through your front door! Robots can also be made to detect magnetic fields. This has already been discussed in connection with robots that follow a track laid in the ground, but this facility would also be useful in applications in which a robot must differentiate between magnetic and non-magnetic materials.

Proximity sensors have no direct human equivalent — these are merely devices that can detect when an object is near them. Humans use a combination of sight and touch for this purpose, but a simple proximity sensor is just as suitable for robot use. Such sensors work in a number of different ways. One type uses an air jet squirted through a nozzle; any object in the jet's path will deflect the air back towards the nozzle. This creates a back pressure that may be detected by a pressure transducer, thus warning the robot that something is near. Another type depends on the fact that an electrical circuit with a capacitance will change its behaviour if it approaches another object. An electrical 'leak' between the capacitor and the object (which will have a capacitance of its own) will inform the robot that an object is nearby.

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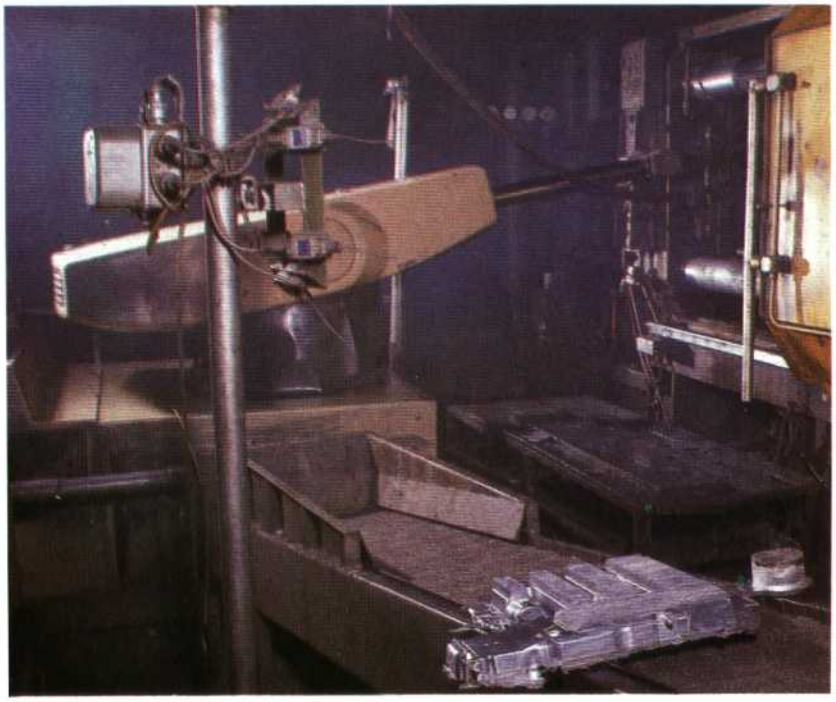
There are also ultrasonic sensors that work by emitting an ultrasonic signal and then picking up the echo from the nearby object. The time delay between the signal and the echo gives an exact measurement of the distance from the object. This is similar to the method used by bats for navigation, and the principle is also used in some auto-focusing cameras.

More sophisticated still are laser sensors. These direct a laser beam onto an object, which then reflects the laser light back to the sensor. By comparing the two beams it is possible to determine the object's distance with astonishing accuracy. This technique can be used over great distances. During the first manned lunar landing, a reflector was placed on the moon so that a laser sensor could measure the exact distance between the Earth and the Moon. The accuracy of this measurement is said to be within 15 centimetres (six inches) over a distance of 384,400 kilometres (250,000 miles)!

Force sensors are a means of obtaining tactile information by more sophisticated means than mechanical microswitches. These work by measuring the change in the electrical properties of a piezo-electric crystal when it comes under pressure, or by calculating the change in conductivity of carbon graphite granules under pressure (using a technique identical to that employed in the carbon microphone). Alternatively, strain gauges can be used to measure large forces by detecting changes in the electrical resistance of a wire as it is stretched.

These robot sensors come under the heading of 'transducers', as they take a measurement in one form (such as light, sound or pressure) and convert ('transduce') it into another form that in some way represents the original measurement. On a computer-controlled robot, the transducers almost invariably convert the measurement into an electrical signal that may be binary (i.e. the signal is either present or absent) or analogue (the signal varies as the original measurement changes). In the latter case, the electrical signal must be converted into a form the computer can understand by using an analogue-to-digital (A/D) converter.

It is fair to say that a robot's senses are not, at the moment, as comprehensive or as effective as the human equivalents. But the robot has more of them — and they are getting better all the time.



No Sense, No Feeling
This industrial robot arm is cleaning castings straight from the mould when they are still too hot to be touched by human hands. The robot is impervious to heat, of course, and therefore processes the work more quickly