The Mechanical Manipulation of Randomly Oriented Parts

It is one of the main obstacles to the broader application of robots in industry. A computer system can now "see" an object at the top of a bin of mixed parts and direct a mechanical arm to pick it up by Berthold K. P. Horn and Katsushi Ikeuchi

Consider the fine coordination between the eye and the hand of a young child who picks a cookie out of a jar. Although the cookies are roughly uniform in size and shape, the pile of cookies at the top of the jar is a jumble of visual cues, a ragged topography from which the child must extract enough information to determine what part of the visual or tactile field can be ascribed to the single, target cookie. As the child learns to take a cookie without crushing or breaking the ones around it, the child comes to realize that not every orientation of the hand can be successful. For example, seizing the edge of the cookie between thumb and forefinger is virtually useless because it can be done as a sequence of fixed motions. Mechanical manipulators have therefore been applied to spot welding, machine loading, painting, deburring, seam welding, sealing and other tasks that are hazardous.

There is much factory work that cannot readily be adapted to a fixed routine of movement. In manual assembly, for example, it is common to have parts stored in bins or trays surrounding the work station. There the blind playback robot is virtually useless because it can tolerate very little uncertainty in the position of a part it must handle. An obvious solution to the problem is to avoid jumbling the parts together in the first place, or in other words to maintain a controlled orientation from the time they are made. There is a trend among manufacturers in favor of this solution: parts can be organized on carriers or attached to pallets on which they can be mechanically manipulated without the need for sensing. Nevertheless, the solution has its costs. The carriers or pallets must be designed and manufactured, often to close tolerances. Moreover, the pallets are usually heavy, they take up a large amount of space and they often have to be redesigned when the part they carry is modified. The design of the part itself may have to be altered for the sake of automatic feeding. Suffice it to say there are many circumstances in which the volume of production has not presented enough economic incentive to the manufacturer to depart from more traditional, manual methods.

We are, of course, not the first to develop a sensing system that can be employed to guide the motions of a machine. Indeed, the first stage in our procedure is common to many other kinds of machine vision: we record a digitized image of the object on the image plane of an electronic camera. The image plane is made up of a large number of pixels, or picture elements, arranged in a regular pattern. The brightness values are measured, for each pixel, at a constant level, is measured for each area that corresponds to a pixel in the image plane. The brightness values are quantized.

MOTION OF A ROBOT that selects an object from a small pile of similar objects is depicted in a series of drawings based on photographs made by the authors. The object is a form, or doughnut-shaped solid, which is difficult for most computer-controlled systems to recognize and pick up. The photograph shows the robot grasping the doughnut. The image plane is made up of three images made by an electronic camera. A computer program determines the identity and orientation of an object and then finds the region that corresponds to the object in the image plane. The program also selects the points at which the robot is to grip the object. When an unpicked box, moving from one side of the gripper to the other in a predetermined sequence, moves along the ray in step. The gripper then moves its fingers to pick up the object. The object can be set down in any orientation.