Sensing in Robotic Control

Economy Vision

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Part manipulation by a robot is practicable provided the orientation of the presented part is known. Traditionally, a multi-part feeder will consist of either a number of dedicated feeders or else of plain feeders equipped with sophisticated electronics. The development of an inexpensive feeder with an uncomplicated recognizing device might be a good alternative. Two recognizing devices of this kind are described. One device includes a moving belt, 3 sensors, and a programmable logic controller, but the device is dedicated to one particular part. The other device consists of a moving belt, 16 sensors, and a microcomputer. This device has self-learning capability. Both devices are able to offer information about the orientation of the part that will be presented to a robot.

Keywords: Flexible assembly, Multi-part feeder, Recognizing device, Self-learning capability, Low cost.

1. Introduction

The Faculty of Mechanical Engineering at the Eindhoven University of Technology is engaged in research on flexible manufacturing systems. One of the main activities in manufacturing is assembling parts to obtain a complete product. Assembling necessarily consists of feeding, handling and joining parts. To obtain a product the parts must be transported from a disordered stock of parts or from a pack of regularly stored parts to a place where the parts will fit in the other parts or, sometimes, in the assembly tools. In many cases the parts are available in a disordered arrangement. The handling of these parts must include: separation of a small amount of parts, separation of one item with unknown orientation, comparing its orientation with the desired one in the completed assembly, properly orientating the part and finally feeding the parts one by one to the desired place.

The introduction of robots in flexible assembly systems makes it desirable to have a programmable, or even better, a self-teaching feeding device for discrete parts. Of course many kinds of feeding devices are available to deliver parts to a robot. But most of those devices are not flexible enough because they are designed and adjusted for just one kind of parts.

On the other hand, it is possible to grasp parts by a robot out of a bin containing randomly oriented parts. Then the parts will be manipulated to obtain the desired orientation in relation to the robot. This method requires the use of a lot of electronic equipment. For instance a robot camera, or sensors, a device for signal analysis, an interface to the robot control system, and so on. The equipment must work together with the control system of the robot. Or it can be arranged that the control of the robot and the control of the equipment is done by the same robot control...
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It is also necessary to use a complicated program for the control device. The execution of this program will take a long time. And the complete system asks for a lot of investments. Therefore we have searched for an uncomplicated and inexpensive vision system that will operate in conjunction with the other components of a robot feeding system.

2. The First Recognition System

The first, low level, approach was to develop a feeding device that is dedicated to a particular kind of parts. These parts are being used because a firm asked us to find a solution for the feeding problem. A main goal in the development of the device was to use off-the-shelf components as much as possible. These components have the benefit that they are readily available, and in many cases they offer an economical solution for a given problem.

The feeding device consists of a moving belt and a recognizing system (Fig. 1). The part is dropped on the belt at random. The belt transports the parts towards three sensors. A set of wipers forces the part in the position of one of the four possible orientations. A set of guiding rails keeps the part in that position during the observation of the part by the sensors. Because this particular part is made of steel we are able to use as sensors electronical proximity switches that are activated by an alteration of the inductance. We have used the Honeywell 922 AA 3W-AGN, operating voltage 24 Volts. The output of the sensors is connected to the input of a commonly used PLC (Programmable Logic Controller). The PLC activates a particular program in the robot control system depending on the result of the analysis of the sensor signals. These programs instruct the robot to handle the part in the appropriate manner.

The first sensor (A) and the second sensor (B) signal the presence of a part in the working area of the sensor. The third sensor starts the execution of the comparison. The orientation of the examined part is indicated by a logic combination of the signals of the sensor (A) and the sensor (B) (Fig. 2).

This recognition device can be used for a wide variety of objects. A disadvantage of the device is the need for adjusting the position of the sensors according to a characteristic feature of the object. If desired, more sensors can be added, but the program for the data analysis will become complicated. Also the program will take more executing time, and is not self-learning. So it was necessary to develop another system that better meets our wishes. A simular development of Boothroyd and Dewhurst [1] at the University of Massachussetts was a good example for us.

3. The Second Recognizing System

In this new development the parts are also dropped onto a moving belt (Fig. 3). Because of the action of wipers the parts are arranged into a straight line, but they also remain at a small distance from each other. The parts move to a stable orientation. We have tested the feeding device.
device with flat rectangular parts. These parts can have 8 possible stable orientations (Fig. 4).

The choice for this kind of parts is based on the wish to develop a recognizing device for an arc-welding robot. And also a research by Frank [2] made it clear that 23 per cent of the parts used for assembly are flat, non-tanglesome parts. Almost 71 per cent of these parts have dimensions in the order of 20 to 200 millimeters.

In order to find the desired orientation out of the orientations in which the parts are presented the vision system must be able to deliver significant information about the existing orientation of the observed part. The recognizing system will operate in two working modes. The first mode is a teaching mode. In the second mode the system is able to recognize the orientation of the presented part. Therefore the part must arrive in one of the possible orientations in the teaching mode. Then a part is presented in another possible orientation, and so on till all orientations are absorbed by the recognizing system. In the observing zone the parts become illuminated by a flat beam of light. This beam projects a thin line perpendicular to the direction of movement of the belt. A row of photosensors pointed at portions of the line will collect the light that is reflected by the passing objects.

We started by using 4 phototransistors made by Philips, code BPX25. These sensors are optimally sensitive in the infrared wave spectrum. The phototransistors are also provided with a small optical lens. The control of the illumination is restricted to control of the intensity of the light.

Sensors operating on other physical principles, for instance air flow or air pressure, ultrasonic waves, and induction testing have not been used here. The reason is what we wanted to use a
sensor that has a working range of at least 50 millimeters. Also it must be able to distinguish in the object a hole of 6 millimeters in diameter or more. And no interference with other sensors is allowed. The chosen phototransistor satisfies these requirements (Fig. 5). Also this sensor is widely available and not expensive.

A disadvantage of the sensor is that the output is influenced by the color of the object. Specially if the parts are made of cold rolled steel a great variation is found in the output of these sensors. The signal obtained by sensing the light reflected by the illuminated line on the object is sampled and stored each time the belt has made a progress of 1.56 mm.

The sampling, storing and all the necessary data processing is done with an Apple IIe microcomputer. The signal is amplified by an Op-amp, converted to a digital signal by an 8-bit AD-convertor (with 8 channels) and fed to the microcomputer. As said before, there are unequal reflection conditions for the objects, so it is better to collect the data from more than one object. For each sensor and for each presented orientation of the parts the minimum and the maximum values of all samples will be stored (Fig. 6).

Now the system is ready to operate in the recognizing mode. Therefore a part in an unknown orientation will move past the row of sensors. In the same routine as in the teaching mode new samples are taken. Then the comparison can be executed (Fig. 7).

The comparison starts with the examination of the number of samples made in both modes. It is permitted to have a small difference between those numbers. If the difference is too large the number of samples of the next possible orientation of the part will be compared. If the difference in numbers is admissible a limited amount of samples is compared with the corresponding samples of that possible orientation of the part. The values of the chosen samples of the observed object must lie between the minimum and maximum of the stored values.

The limited amount of selected samples is found by testing the values of the stored samples for a particular condition. This condition might be a sudden increase or decrease of the value of samples taken in the direction of transportation. For instance, this condition exists during passage of a hole in the object. Of course the selection of samples must be carried out during the teaching mode.

If the values of the selected samples are not between the minimum and maximum values of the corresponding memorized samples the next orientation position of the part will be compared. If a great deal of the samples meet the criterion the part will be declared to be in that particular orientation.

If that is not the case, even after comparison with the data of the other possible orientations the part is considered to be unrecognized. A recognized orientation of the part will activate the
corresponding program in the robot, which will handle the parts to a desired orientation and location.

As mentioned before the recognition device is equipped with 4 sensors. This made the comparing time short, but it was necessary to adjust the sensors above a characteristic element of the surface of the object. Therefore this device was not sufficiently self-learning.

To improve self-learning we increased the number of sensors. To avoid long comparing time a sensor selection routine was added. In this routine 4 sensors are indicated which give the most significant signal of the area of the surface of the object. Because the parts we want to test have a maximum length of 200 mm and a maximum width of
200 mm a row of 16 sensors with a spacing of 12.5 mm seemed to be sufficient.

The program for the comparison routine is written in Pascal. It has the advantage that the program is easy to read and alterations are easy to make, because programs of this kind are well structured. But the execution time is rather long. Translating the program or parts of the program into direct machine code will speed it up again.

4. Conclusions

It is possible to operate an inexpensive multi-feeder together with a robot. The parts may be offered to the feeder in a disordered arrangement. A recognizing system is able to produce data about the orientation of the moving part. Manual adjusting is needed for the first example of recognizing system, and a teaching mode is used to adjust the second example of recognizing system.

References