BRITISH THESIS

IMAGE PROCESSING FOR ROBOTIC MANIPULATION.

Visual Detection, Recognition and Orientation Of Objects
For Robotic Manipulation Using Microprocessor Control.

Volume One Of Two.

Andrew Mark DEAN.

Doctor Of Philosophy.

University Of Bradford.
Postgraduate School Of Studies in Information Systems Engineering.

1985.

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1.0 Summary.

With the large increase in small batch production and the need for greater productivity and reduced costs, automation is taking over. Dedicated automation , such as is used on large production lines, is unable to cope with quick product changes hence the use of robots is increasing. At the moment these reprogrammable assembly devices have little intelligence and little or no sensing capabilities. If robotics is to expand into other production areas, the robots will require complex and intelligent sensors. It is for this need that the vision system developed in this thesis evolved.

There are many sensing systems used by man and machine of which vision is possibly the most useful, computer vision systems have been in existence for some years. The requirements of a computer vision system for robots are fundamentally different from those systems in existence, which have large computation times. A robot vision system must recognise and provide all the data required by the robot in a very short time, typically one second or less. This requirement was therefore set as one of the main design criteria. Other design criteria included object identification, calculation of object position and orientation, easy interfacing to any industrial robot and ease of operation. It was also felt that if vision was to become common place on industrial robots the cost should be kept low, less than £2000.

The methods of pattern recognition, grey level density, pixel array size, colour techniques and hardware and software filtering techniques were studied. From the design criteria specified and the recognition methods available, the decision theoretic approach was adopted as

other methods required lengthy recognition times or large memory storage. An array size of 256 pixels square at one grey level with as little image enhancement as possible was selected for the same reasons. With the recognition approach adopted the hardware and software was designed.

The hardware was designed round a Motorola direct-memory-access processor, transferring the image data from a closed-circuit television camera directly to memory. A Motorola state-of-the-art 16-bit MC68000 central-processing-unit then reduces and manipulates the data for recognition to occur. The MC68000 with its associated memory, interfacing, communication and timing circuitry are located on a Motorola KDM single board computer. Separate cards are used for the direct-memory-access, graphics and camera timing systems. The graphics unit displays components, data and results during the recognition phase.

The software is in two main sections, control is carried out by a Pascal master program, while the high speed recognition algorithms are performed by program segments written in MC68000 structured assembly language. The Pascal master section sets up and supervises all arrays and stacks, it also communicates with the user via a 'GUIDE' system during the teach phase. The teach phase is responsible for selecting the recognition models to be used and extracting the recognition data from sample components. During the recognition phase comparison of various component parameters takes place between taught and viewed items, this data is used to calculate recognition and orientation. Recognition is requested by the robot, carried out by high speed assembly sections and results are sent directly to the robot without intervention from the user.

The final system, consisting of 43 K bytes of program, was tested with a series of components designed to analyse the systems' effectiveness. Recognition was very good, at almost 100% success, with the correct models selected. Accuracies of better than +/- 1 pixel, or +/- 1 in 256 and better than 1 degree were attained. The time taken for recognition varies between 0.2 and 0.9 of a second dependant upon the number of components and the models selected. The cost of components for the complete system was approximately £400.

The system does however have some limitations which may affect its use in certain applications. These limitations are mainly due to the systems' requirement for contrasting, planar non-overlapping images to be presented within the field of view. Despite these limitations, some of which have partial solutions, it is felt that a usable robot vision system has been developed, built and tested.

2.0 Introduction.

With the growing cost of human resources and the pressing need for increased productivity, industry is turning more and more towards automation, specifically the use of robots. Exactly what is a robot? The word its«lf comes from the Czech word robota, meaning work, the Oxford dictionary defines it as "apparently human automation, intelligent and obedient but impersonal machine." However, with that description, even a washing machine can be considered a robot. The British Robotic Association gives a more precise definition and introduces some key concepts:

> " A reprogrammable device designed to both manipulate and transport parts, tools, or specialised manufacturing implements through variable programmed motions for the performance of specific manufacturing tasks. "

In short, a robot is a re-programmable, general purpose manipulator with external sensors that enable it to perceive and recognise its environment and to perform assembly tasks. As such, it must possess some "intelligence," which is normally due to the computer unit associated with its control system.

The word "robot" first entered the English language in 1922 when Karel Carpek, a Czechoslovakian philosopher and playwright, presented his most successful stage effort, "R.U.R." or "Rossum's Universal Robots." Old man Rossum and his son discovered a chemical composition that simulated protoplasm. They elected to organise it in the form of man and, they fondly hoped, in the service of man. Young Rossum said, "It's absurd to spend twenty years making a man. If you can't make him quicker than nature, you might as well shut up shop." The practical engineer Rossum overhauled the basic design to eliminate superfluous organs, dimensions, senses and especially a soul. Rossum opined, "A man is something that feels happy, plays the piano, likes going for walks, and, in fact, wants to do a whole lot of things that are really unnecessary....But a working machine must not play the piano, must not feel happy, must not do a whole lot of other things. Everything that doesn't contribute directly to the progress of work should be eliminated.

The next mention of robots came in the 1940's when Issac Asimov, the science fiction writer, envisaged robots in the service of man. Asimov's robots were kind, not being able to harm man or fellow machine. The final step came in the late 1950's when Joseph F. Engelberger, founder and president of Unimation Inc., developed and sold the first commercial industrial robots. Since then, only sixty two years after Carpek's prognostication, there have been considerable developments in the manufacturing industry, lighter and stronger materials, large use of integrated circuits and computers and a greater numbers of continuous production lines to name but a few. These changes have lead to the development and production of robots on a large scale, there currently being over one hundred types of commercially produced unit.

The type of robot we are concerned with in this thesis is the practical industrial robot described above, not the humanoid type depicted in the cinema and science fiction. This type does exist but is primarily for shows and does very little work. Indeed, the industrial robot is merely a simulation of a human arm, which when