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Preface

Fuzzy Days in Dortmund were held for the first time in 1991. Initially, the conference was intended for scientists and practitioners as a platform for discussions on theory and application of fuzzy logic. Early on, synergetic links with neural networks were included and the conference evolved gradually to embrace the full spectrum of what is now called Computational Intelligence (CI). Therefore, it seemed logical to launch the 4th Fuzzy Days in 1994 as a conference for CI—one of the world's first conferences featuring fuzzy logic, neural networks and evolutionary algorithms together in one event. Following this successful tradition, the 6th Fuzzy Days' aim is to provide an international forum for reporting significant results on the theory and application of CI-methods.

Once again, we have received a remarkable number of papers. I would like to express my gratitude to all who have been interested in presenting their work within the framework of this conference and to the members of the programme committee for their valuable work (in this edition each paper was reviewed by five referees). In particular, I wish to thank all keynote and tutorial speakers for their commitment. Last but not least, I am obliged to the Deutsche Forschungsgemeinschaft and Kommunalverband Ruhrgebiet for their financial support.

March 1999 Bernd Reusch

Control of Robot Arm Approach by Fuzzy Pattern Comparison Technique

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Abstract. The control of robot hand while reaching an object is a complex task involving the interaction of sensory inputs and motion commands. In this paper the system based on visual feedback is described. The whole system is shortly explained and the special emphasis is given to the target final approach control based on Fuzzy Pattern Comparison (FPC) technique.

1 Introduction

The real time control of the robot arm while reaching an object using visual feedback is quite a complex task which involves a lot of image processing and analysis [1,2,3].

The process of a robot arm approach can be divided into two phases:

- a target approach phase, and
- an executive phase (contact with target, for example inserting a pin into the hole or grasping)

The target approach phase is based entirely on the interpretation of visual inputs, whereas the execution phase relies usually on tactical sensing.

The target approach can be further divided into two phases:

- the rough target approach and
- the final (and fine) target approach, which usually includes precise positioning of the robot arm according to the target position.

The research described in this paper is a part of noncalibrated image based robot arm approach control system. The system consists of three cameras, two of them responsible for the rough target approach and the third one for the final target approach.

The rough target approach control is based on an expert system which does not need any information about camera position [4]. The third camera becomes active when the robot arm enters its visual field. The task of its control system is to precisely

position the robot arm depending on the target. This paper is concerned with the final target approach phase and describes both the main idea and its implementation on the Fuzzy Pattern Comparison (FPC) board.

2 Final target approach – problem description

The system is shown in Fig. 1.

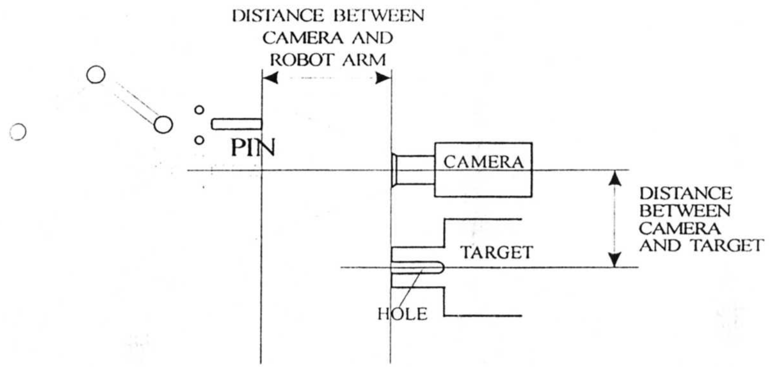


Fig. 1. Robot arm, camera for final position control and target

The final approach control system becomes active when the robot gripper enters camera visual field and reaches the predefined distance from the camera. Now the control task is to position the robot arm in the center of the camera visual field. After that, knowing the distance between the optical axe of the camera and the target, it is quite easy to finish the task and to reach the target. This control task could be interpreted as a 2D control of a robot arm around the image plane, as Fig. 2. shows.

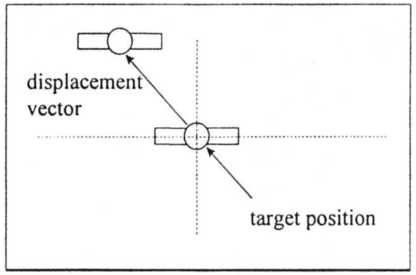


Fig. 2. The situation seen by the final approach camera

The most important part of this procedure is determination of the robot gripper displacement vector. It was calculated using the fuzzy set based algorithm and Fuzzy Pattern Comparator (FPC) board [5].

FPC is s specialized device particularly designed to provide very fast comparison of frames of data. The FPC utilizes fuzzy logic method of comparing data in order to determine the similarities or differences in groups of data. Its simplified block diagram is shown in Fig. 3.

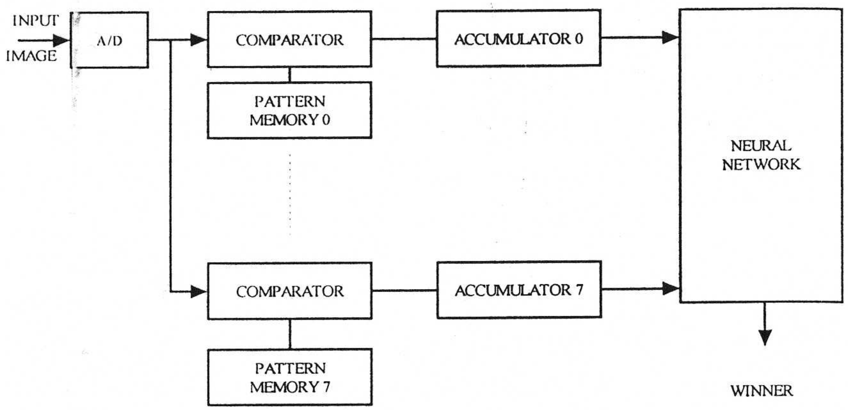


Fig. 3. The Fuzzy Pattern Comparator

Up to 8 patterns (referent images) could be stored in board pattern memories. Input image data enters serially into the device, where it is formatted into bit fields and in a parallel way compared with referent images in pattern memories. The results of the comparison are stored in registers associated to the pattern memories. The neural net gate is used to find which of the referent images is the most similar to the input image, and the accumulated errors in registers could be used as a similarity measure of the input image and referent images. This feature of the FPC board was used for displacement vector determination.

3 Robot gripper displacement vector determination

The procedure had two phases:

- the learning phase, and
- the working phase.

In the learning phase, the robot arm is moved manually in front of the camera and 6 characteristic positions were captured and stored in pattern memories: up, right-up, right-down, down, left-down, left-up.

Fig. 4. shows one of them.

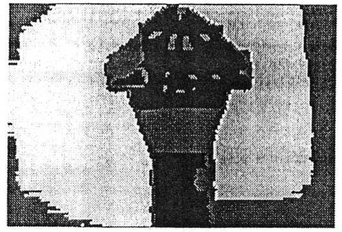


Fig. 4. The referent image *"up"* from the pattern memory

In the working phase the similarity measures (accumulated errors in registers) between the input and stored reference images were used for calculation of the 6-element vector of fulfillment

$$\vec{\lambda} = [\lambda_1\ \lambda_2\ \lambda_3\ \lambda_4\ \lambda_5\ \lambda_6],\ \lambda_i \in [0,1]$$

λ_i corespondents to the i-th referent image. The input image and the pattern images are identical if $\lambda_i=1$.

$\vec{\lambda}$ is used as an input to fuzzy algorithm shown in Fig. 5, which gives the direction and magnitude of the displacement vector.

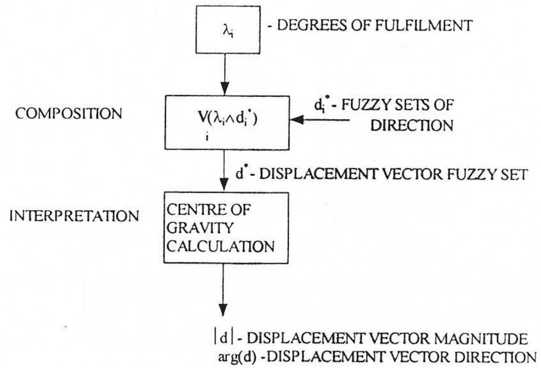
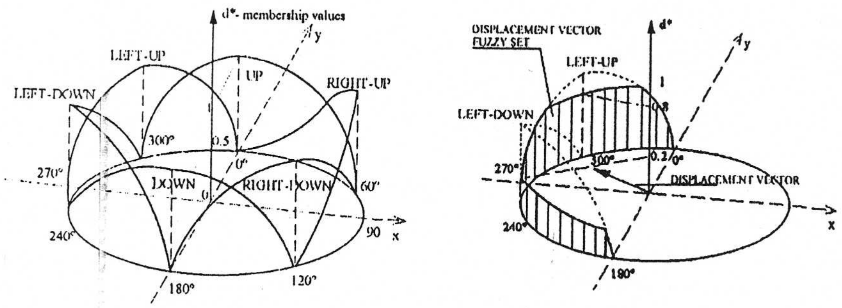


Fig. 5. Displacement vector calculation

Fig. 6. shows fuzzy sets of directions defined on the displacement vector circle. The shape of the displacement vector fuzzy set calculated by classical max-min composition carries information about relative position of the robot gripper according to

the optical axe of the camera. For example for the starting position of the robot gripper, seen



a) b)

Fig. 6. a) Fuzzy sets of direction defined on a circle
b) Example of the displacement vector fuzzy set

by the camera somewhere between left-down and left-up as Fig. 9a) shows, the vector of fulfillment will be

$$\vec{\lambda} = [0 \quad 0 \quad 0 \quad 0 \quad 0.2 \quad 0.8]$$

and its corresponding output displacement vector fuzzy set d* is shown in Fig. 6b. The displacement vector itself is defined on a circle as a vector from the center of the circle to the center of gravity of the output displacement fuzzy set d*.

4 Robot Arm Control

Displacement vector magnitude |d| and direction arg(d) are input information to the control algorithm which moves the robot arm. The algorithm is quite simple one, defined by 8 crisp if-then rules for direction of the robot movement and 3 rules for the control action magnitude. Typical direction rule is:

"If displacement vector MAGNITUDE is *left-up*, then move robot segment BODY to *right*, and robot segment ELBOW to *down*."

And control action magnitude rules were:

"If MAGNITUDE is *central*, then STOP, else
If MAGNITUDE is *middle*, then STEP is 1, else
If MAGNITUDE is *big*, then STEP is 4."

Algorithm is adapted for RRR robot configuration as Fig. 8 shows, so terms like BODY and ELBOW for robot segments were used. Fig. 7 shows the definition of linguistic terms *left-up, down, central* ... In our experiments boundaries were crisp and the results were quite satisfactory, but fuzzy boundaries and fuzzy control algorithm could be applied, too.

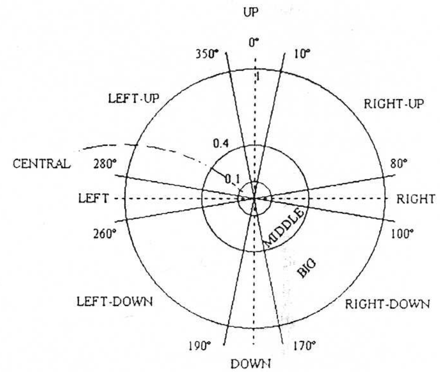


Fig. 7. Definition of linguistic terms used for robot arm control

For displacement vector shown in Fig. 6b) the robot BODY will be moved to the right 4 steps (looking from the camera side) and ELBOW down 4 steps. The value of one step was determined experimentally according to the robot speed.

5 Experiments

In experiments the educational robot MICROROBOT TechMower shown in Fig. 8. was used .

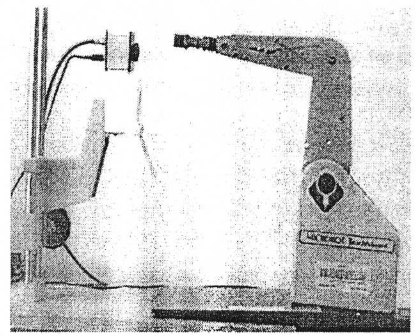
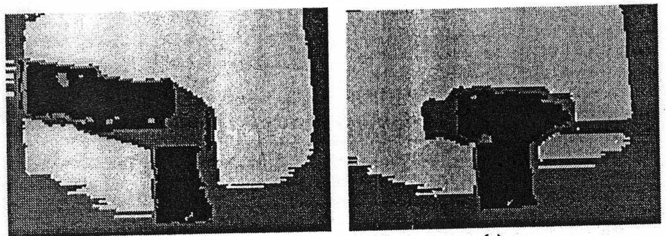


Fig. 8. Photo of the experimental system

The control algorithm was implemented on standard PC/486 computer and the real time robot movement control was achieved. Fig. 9 shows the starting and ending positions of the robot gripper seen by final approach camera. The processed image was 192x132 pixels digitalised in 4 bits.



a) b)

Fig. 9. The starting and the ending robot gripper image

6 Conclusion

The simplicity is an advantage, specially in technical systems. Experiment described in this paper shows that a rather complicated control task could be solved using quite inexpensive equipment and fuzzy control principles.

Future work will be oriented toward 3D vector displacement determination and inclusion of gripper orientation control.

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A Fuzzy Shapes Characterization for Robotics

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Abstract We proposed [9] an original membership function building for fuzzy pattern recognition. This method uses only one shape feature – the compactness – leading to a simple and fast determination of membership function. We improved this method adding the possibility of control for the slopes of functions and unifying their representation [10,11]. We implemented this method in machine vision area, where for the robot's eye it must process a continuos image data series in real time. In the reason to reduce the need of preliminary human inspection, we proposed to add a new feature – the elongatedness – to be used in conjunction with the membership function built from compactness [12]. In this paper we propose a unified membership function, built by using the compactness and the elongatedness features of shapes together.

1 Introduction

An important application of pattern recognition is in the machine vision area. A robot, with various sensors and other features that allow them to have sensory functions for perceiving the circumstances and the environment around them, with intelligent information processing function became an "intelligent robot". Machine vision capability – the robot eye – is one of the most important sensory function of an intelligent robot. To obtain this function we need a camera (or more) together with an image processing and a pattern recognition method embedded in the robot controller. In general, the amount of data to be processed for pattern (shape) recognition is large scale. Since the computer that can be used with robots are in general small ones centered on microprocessors, the amount of memory is also small in most cases. However, if it is wanted to use image processing and pattern (shape) recognition for a robot's eye, it must process a continuous image data series in *real time* [8].

In the last decades, the scientific community agrees the idea that ambiguity, the uncertainty is a property of real world. We try to build some examples to support the position that *fuzziness* is an alternative to *randomness* in describing uncertainty.