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PATTERN IDENTIFICATION METHOD FOR INDUSTRIAL ROBOTS BY EXTRACTING THE MAIN FEATURES OF OBJECTS

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A kiadásért felelős

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házi sokszorositójában
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ABSTRACT

Industrial robots controlled by minicomputer and equipped with visual inputs need not analyse and recognise a fully unfamiliar scene. It is supposed the robot should have previously been taught separately all the patterns that could possibly occur. The robot scanning the scene has to break it up into separate patterns in order to analyse them and after that to compare them with the pattern already learnt.

I wish to suggest a method of characterizing objects and stored models by their main features by means of the graph-vector method. Since the identification process is an interactive one, at first the easily obtainable characteristic vectors of lines and surfaces of two and three dimensional objects /denoted 2D,3D/, respectively, are evaluated. In many cases, an incomplete description of an object is enough to identify it, so that this method can be used even though the difference in brightness between two adjacent planes might be small or edges obscure. If the result of the first attempt of the identification is ambigous the program requires some further information for a second attempt. Result of simulation program is presented and some limitations of the present program and proposal for the future development are also described.

INTRODUCTION

It is well known that the production of industrial robots is increasing and their application is fanning out into various fields. To be more precise it could be said the devices now in use are rather programmable manipulators than robots. Since machines have to be equipped with suitable sensors for them to be used as industrial robots, the man-robot communication should be facilitated and finally they should be provided with basic decision-making ability. Although extensive research has been done in the above mentioned fields it has mainly been concerned with studying comprehensive questions of artifical intelligence. The results therefore could only be a useful quideline for industrial applications.

I wish to suggest a simple approach for pattern recognition for industrial robots. The aim has been to develop a very fast identification program which can be used effectively in an industrial hand-eye system. A period of ten minutes for the recognition of objects in full detail is too long for a material-handling or assembling robot. And this recognition in full detail is not essential either. In scanning the scene the objects need only be identified in terms of shape and size. This could be done by locating and identifying characteristic features of the objects. If and only if more than one object of the same type and size is present one should look for detailed differences but only characteristic ones in order to distinguish one from the other.

The whole program called BLEAR-EYED needs to obtain three dimensional data as input. In the course of this current research project I have done little in the field of previous image processing since many excellent works already exist. In referring to the related research at Prof. Hasegawa's lab. |1| I should also like to mention that the BLEAR-EYED can accept 3D data in canonical form from any kind of image processing methods |2|.

The output of BLEAR-EYED is transformed and abstracted information collected from the scene viewed. This information should correspond approximately to the description that a person working on the same job finds necessary to accomplish this task. It must contain at least the identity, location, orientation and approximate size of each object.

BLEAR-EYED was designed to evaluate all the possible data from imperfect 3D input. In the frame of the research reported here, BLEAR-EYED accepted imperfect line drawings as input. In many cases BLEAR-EYED succeded in identifiying considerably incomplete line drawings without having tried to complete them.

BASIC ASSUMPTIONS

To fulfill this aim the robot has to be previously taught all the patterns to be recognised. The industrial robot need not analyze a fully unfamiliar scene but it can be assumed that they will know separately every pattern that could possibly occur. The robot seeing the scene has to break it up into separate patterns in order to be able to analyze and later on to classify them according to the patterns already learnt.

The whole recognition process is an interactive one. In most cases the scene scanned by the robot is not complicated but sometimes it may happey to be. If a complete hierarchical program were developed applicable for every instance, then recognition processes would become rather sophisticated and require a lengthy running time to be able to cope with the most complicated scenes. In simple cases, which are in the overwhelming majority, full detail is unnecessary and a lengthy running time is inadmissible. The recognition process applied here may have more iterations /Fig.1./.

In the first recognition attempt BLEAR-EYED tries to identify the object on the scene on the basis of easily obtainable data even if the extracted features are incomplete. As can be seen later, this first attempt is very simple compared to other available methods and therefore much faster. If the object can not be identified, a special program will demand to obtain more detailed features of the scene scanned. To speed the process critical points are selected to answer the perceptive input. This is the starting point /Point B. in Fig.1./ in the second attempt of the recognition process. If the outcome of the second attempt is unsuccessful then there is a need for further completion of the extracted features.

PROBLEMS OF REPRESENTATION OF ENVIRONMENT

For the sake of fast identification a representation technique has been developed. Both the basic patterns learnt and the objects viewed are transformed inside the computer into the same kinds of format in order to be evaluated. The internal representation of objects in industrial robots poses similar problems as those on which researchers are working in Computer Aided Design face. Nevertheless some significant differences arise due to their dissimilar purposes, since for CAD the emphasis lies in the detailed and exact description of the object, while in robotics, rough description only is sufficient to characterize the object. Representation applied in BLEAR-EYED is as follows:

Pattern description

Graphs are used to describe both two and three dimensional objects. The idea was used by Falk |3| among others but it was applied here with some modifications. The graphs were used not only in mathematical terms but rather in the physical sense. The lines do not only indicate the connection between two nodes, but refer to the state of relation between the nodes. These graphs can be called the "state diagrams of the patterns". Inevitably, the redundancies of these state diagrams may later be useful when diagrams are incomplete. Invisible faces, obscure edges and vertices can be specified and the accuracy of the obtained geometrical data cross-checked.

For the implementation of state diagrams two kind of graphs are used: vertex and bound diagrams. The vertex diagram is actually a graph of the line drawing which has been divested of its geometric descriptiveness: the values of X and Y, X and Y and Z /2D,3D,respectively/ of each vertex of the pattern denoted as $\bar{P}_i$ are assigned to a node. The $\bar{v}_{ij}=a\bar{e}_{ij}$ vector between $\bar{P}_i$ and $\bar{P}_j$ is assigned to an edge in the graph.

The bound diagrams eventually contain the definition of the object. Their nodes represent the boundary elements: lines $\bar{V}_i=A\bar{e}_i$ or surfaces $\bar{N}_i=tA\bar{n}_i$ in 2D,3D, respectively; where $\bar{e}_i$ is unit vector, a is scalar contant, $\bar{n}_i$ is the normal vector of the surface and 't' is the scalar index indicating the shape of the surface. The edges of graphs represent rotation vectors ($\bar{Q}_{ij}=B\ \bar{G}_{ij}\alpha_{ij}$), which can transform the boundary elements represented in the starting nodes into the boundary elements of the end nodes. These transfer vectors are usually elliptical ones since their completition is not worthwhile. The most important parts of the vectors are: α_{ij}, which indicates the angle between two adjacent elements, and $\bar{G}_{ij}$ vector which means the axis of rotation. B is the scalar factor, usually missing.

Feature extraction

To conduct a rapid identification process, all characteristic features of the object should be extracted from the pattern description. They are, in the case of 3D fundamental geometrical objects, the number of faces, their shape, and the angle between them, etc., in short the facts from which one can make a classification tree /Fig.2./, and the objects viewed can be distinguished on the basis of them.

Depending on the simplicity or complication of the task at hand one or more classification trees can be used.

Internal representation

The internal representation of learnt models and viewed objects are the same as is shown in Fig.3. The record consists of head and tail. The head comprises all the features as follows: the number of faces, the definition of the shape of faces indicating the deterministic one/s/, if any; the angles between surfaces, the weight and volume of the body, the center of gravity, as well as the electrical, thermometric coefficients, the colour and roughness of the surfaces, the rigidity of the structure, as well as the pointers to the tail. The structure of the head is fixed and generalized for every possible object.

The tail contains detailed geometrical information of the object: the vertex and bound diagrams. They are stored in matrices. /The extent of the matrices are given in the head./ The vertex diagrams are stored for 3D bodies in two arrays for $\bar{P}_{ij}$ and $\bar{v}_{ij}$. Another SV array is reserved for the switching matrix which gives the connections between them. For bound diagram the two arrays are $\bar{N}_{ij}$, $\bar{Q}_{ij}$ and the switching matrix is SB.

RECOGNITION PROCEDURE

As was mentioned in the introduction BLEAR-EYED has three phases.

Memorization

During the memorization process the internal representation of models /patterns, which may possibly occur/ is assembled. These records are called Internal Models. At present Internal Models exist for the basic patterns shown in Fig.4. and were constructed in FORTRAN artificially.

Pattern Identification

This was the main point of this research. The skeleton of the flow chart is shown in Fig.5. Input of this program is a set of three dimensional data and the output is a proposal for the identity of the object viewed. The main steps of the identification are as follows;

The TRANSForm puts the input 3D line drawing into the vertex part of the tail of the Internal Record, from which the CONSTRuct assembles the bound diagram for the other half of the tail. The EXTRACt evaluates the necessary data for the head from the tail of the same record. The ANALYSe has two inputs, the head of the record and the classification tree, and it results in a hypothesis, and in certain ambiguous cases two or more possible objects can be indicated. The last step is the VERIFY which compares the head of the Internal Record in question to the head/s/ of the Internal Model/s/ assigned by ANALYSe. This point is the end of the first attempt of the identification /Point B.Fig.1./ which could result in a firm decision or a suggestion for another attempt.

Scene Specification

After having been identified, the object's specification should be evaluated and supplied to the execution routines of the hand system. The brief explanation of Fig.6. is as follows:

On the basis of the Internal Record the LOCATE calculates the position of the object in the coordinate system of the arm. The ORIENT searches for the main directions of the object in the posture viewed, then the SCALE investigates the proportion between the size of the model and that of the object. According to the result of the ORIENT, the ROTATE brings the Internal Model into the same posture as the object. On the other hand on the basis of the result of the SCALE the INFLATe blows up the Internal Model to the required degree. The MATCH shifts the Internal Model into the spatial position of the object. At this point attention should be paid to the fact that two internal descriptions of the same pattern with the same size and in the same spatial position and orientation emanating from two different sources have come into existence. The first one is the Internal Record made from the viewed object which is incomplete, and the other is the Modified Internal Model which is complete /Fig.7./. The Modified Internal Model contains besides the geometrical data easily obtained by visual sensors, the obscure parts of the viewed object and in addition the invisible /hidden/ parts of the body as well. The latter two are other great advantages of this method, since the arm controller routine can be supplied with all the details necessary for fast execution. That is the reason for robot manipulation purposes, the Modified Internal Model will be used as the definition of the viewed object.

Before abandoning the Internal Record entirely, some auxiliary comparision on visibility will be made in order to decide for the future which parts of the objects will be visible, which parts will be hidden in the given position, which parts have been seen and which obscured parts have been guessed. All the operations are carried out on the Modified Internal Models in comparison with the Internal Records.

The visibility process begins with the CURTAIn looking for the boundary lines of the body. Then the COLLATe marks the elements perceived. All the other elements lying before the curtain are declared as guessed by GUESS and behind the curtain as hidden by HIDE. This is the end of this program and an example is shown in Fig.8. Fig.8a. is the print of the incomplete vertex diagram, Fig.8b. is the identified Internal Model as it is stored, Fig.8c. shows the Modified Internal Model with visibility.

FUTURE DEVELOPMENT

The research reported here has been the first step toward semi-intelligent industrial robots. There are many problems to be solved before an experimental application can be realized.

First of all the memorization should be improved in order to make it easier to build up new internal models. The possible ways are: improved camera input or graphic languages. Also combined methods, like simple camera input supported by an artificial hand with recognition ability seem to offer some promising approaches.

Development of the higher iterations is also pressing. In the second or subsequent attempts the sensors of the hand |1| will be used to furnish data into the head of the Internal Record to help detect the identity of the object. Still lacking an unambigous result, additional routines will be needed to direct the sensors into a new position from which the critical data can be more easily obtained than it was from the original place.

Linking the recognition process to the hand system, the execution of hand movement could be speeded up if the hand control routine can be supplied with data of the easily grippable surfaces, prohibited areas or the unstable, indifferent status of the body. For this purpose a program for guidance in handling will be developed.

All the results based upon the basic set shown in Fig.4. have certainly little practical value, so the real intention is to transfer these solutions to the basic set of the workpieces and to real applications.

On the other hand the basic geometrical set will be increased and a complex scene with the objects partially overlapped will be processed.

CONCLUSION

The BLEAR-EYED program was developed for pattern identification for industrial robots. Emphasis was put on fast processing rather than recognition of a complicated scene. The distinguishing features of BLEAR-EYED are the acceptance of an imperfect description of the scene and its tolerance of inaccuracies in input data. Instead of trying to perceive the missing data BLEAR-EYED will analyse the easily obtainable incomplete description of the scene, to identify it. The stored complete model will then be positioned and orientated to get a perfect description of the scene. Although BLEAR-EYED appeared to be less sensitive to pre-processing errors a real test will show how well it performs when integrated as a part of a complete hand-eye system. Study of the complete system will undoubtedly suggest modifications and improvements to the approaches I have taken.

ACKNOWLEDGEMENTS

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ILLUSTRATIONS

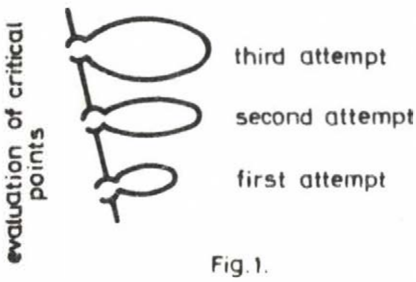

Fig. 1.

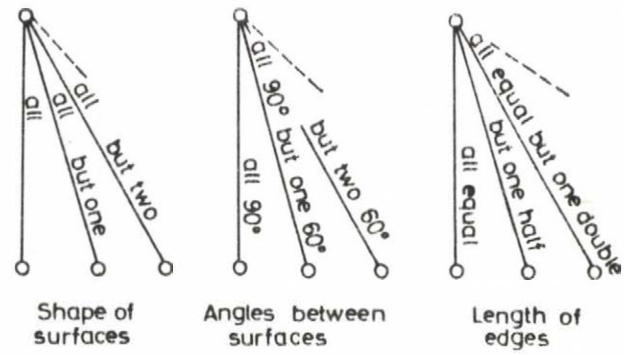

Fig 2.

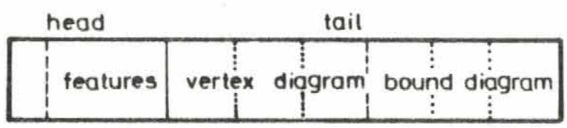

Fig. 3.

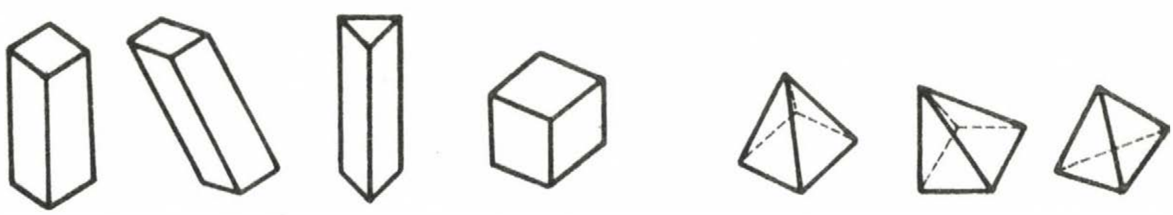

Fig. 4.

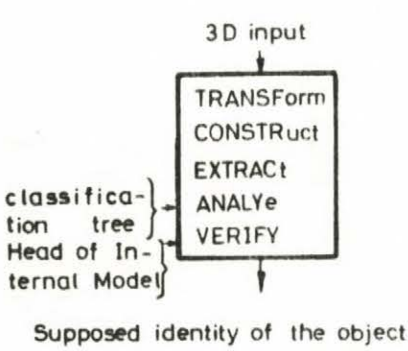

Fig 5.

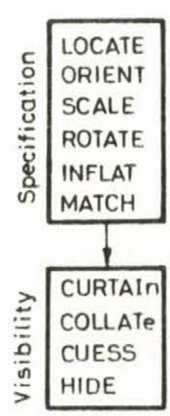

Fig 6.

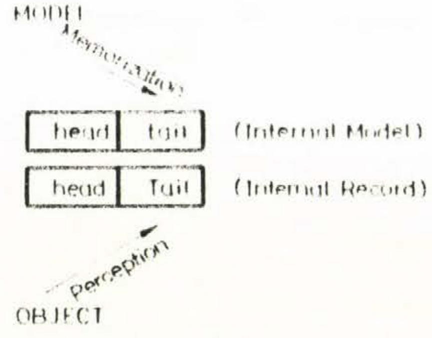

Fig 7

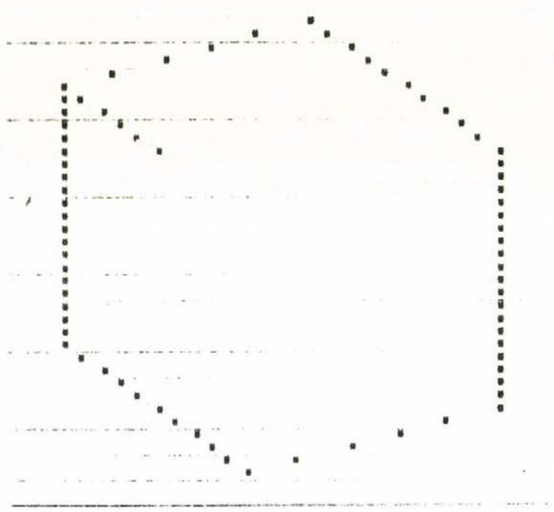

Fig.8a.

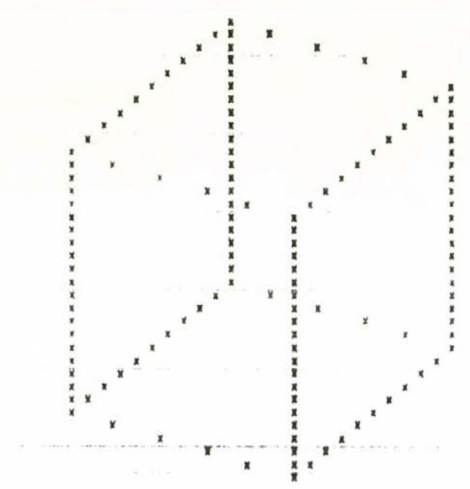

Fig.8b.

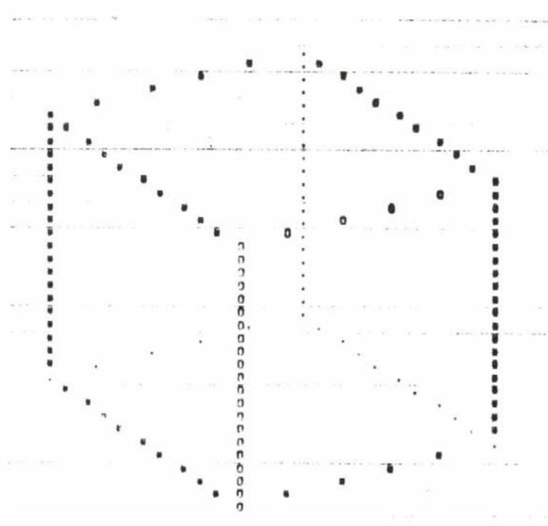

Fig.8c.

A TANULMÁNYOK sorozatban eddig megjelentek:

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