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CONTROL SYSTEM FOR MECHANIC BAND CONVEYORS BASED ON PATTERN RECOGNITION TECHNIQUES

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Abstract: *The paper presents an experimental control system for band conveyors manipulation. The control system is composed by a robot, supervising TV camera, control monitor and an image frame grabber card. A software system has been developed in order to assure the linking between the arm of the robot and the TV camera. Based on the image analysis, the computer synthesises the commands for the robot. The theoretical aspects and the practical problems solved in image processing and robot command syntheses are presented.*
Key Words: ***control system, image processing, pattern recognition***

1. INTRODUCTION

The experimental system is composed by one robot, having a polar controlled structure in 5 axes, with 6 liberty degrees, one image processing station and an automate system, all linked to a computer (see figure 1). The automate system, named Robot Control Unit (RCU), works as a computer interface, a special protocol providing the reception of the computer commands and the transmission of the robot state.

The image processing station includes a CCD monochrome TV camera, an image frame grabber card, and assures the acquisition and the storage of a higher resolution image in a 256 gray levels scale. A monochrome monitor may be connected to this acquisition card too. The monochrome image is grabbed and digitised by the computers. The results of the image analysis are used in the elaboration of the commands for the robot in order to manipulate the objects placed on a light coloured table. The area surveyed by the camera is artificially illuminated with constant parameters.

2. IMAGE PRE-PROCESSING RELATED ASPECTS

During the acquisition of monochrome images different noise sources may diminish the quality of digitised image. It may be distinguished two main types of noise sources: deterministic (e.g. optical system imperfections) and stochastic. The image detection is based on an OOP ass in [1] and therestoration of a monochrome digitised image [2] is based on the following model of the image degradation and image restoration processes.

We assume that the degradation was done by a filter with the transfer function *H(u, v)* and an additive noise *z(x, y)*. For the restoration is responsible a filter with the transfer function *R(u, v)*. The restored image function, *f(x, y)*, must approximate the function ***o****(x, y)* representing the original image. The degraded image function *d(x, y)* is assumed that is a sum of the result of a space invariant convolution operator *h( )* and the noise function *z(x, y)*

$$d(x, y) = \int_{-c}^{c}\int_{-c}^{c} \mathrm{h}(x, y; a, b)\, \mathrm{o}(a, b)\, \mathrm{d}a\, \mathrm{d}b + \mathrm{z}(x, y) \qquad (1)$$

where *c* is the window size. This relation may be re-wrote based on space invariant properties as follows

$$d(i, j) = \sum_{k=-c}^{c}\sum_{l=-c}^{c} \mathrm{o}(i - k, j - l)\,\mathrm{h}(k, l) + z(i, j) \qquad (2)$$

We consider a monochrome image digitised in *G* grey levels and $N = x_{max} . y_{max}$ pixels. A neural networks having *N.G* neurones is used to restore degradated images. The grey level of each pixel *r(i, j)* is obtained by the sum of the outputs of all the neurones in the assigned group.

$$r(i, j) = \sum_{k=1}^{G} v_{ij}^{k} \qquad (3)$$

where v_{ij}^{k} is the output of *k*-th neurone in the group of *G* neurones assigned to the pixel *(i, j)*. This output is obtained by applying a threshold function *g(u)* to the total input of the neurone. All the neurones are assumed to be interconnected by symmetric links. After the image enhancement follows the binarisation stage. The further treatments are applied on the binarised image.

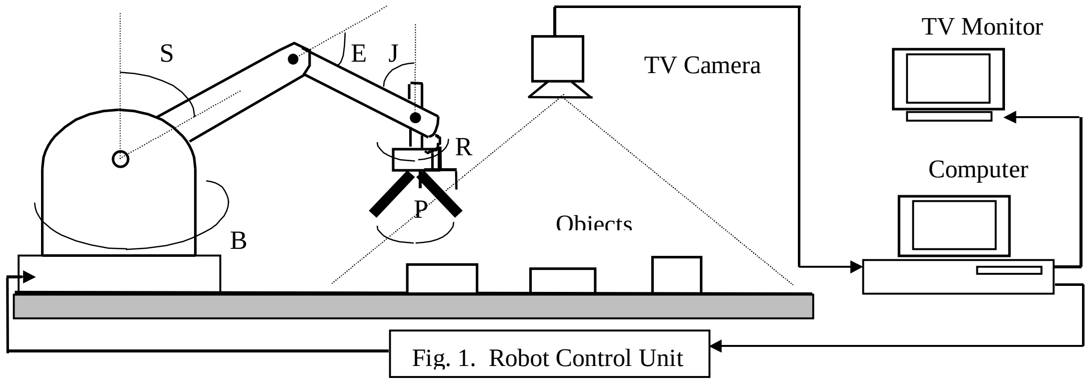

Fig. 1. Robot Control Unit

3. OBJECTS DETECTING

The objects isolation is based on a convex compounds labeling method. It must be underlined that every connecting area of pixel is interpreted as an object marked by the same label.

The problem consists in the setting of labels associated to the objects pixels from a binarised image. The regions representing objects are convex ones. All the pixels from a convex region must be labeled with the same value. Pixels from different objects image regions must be differently labeled. The labels should he integer numbers from 1 to the number of the objects, the background will be labeled with 0.

The algorithm achieves the labeling of objects in ***O(n)*** where *n* is the number of the image pixels. The main idea [3], [4] is to label the current pixel with the minimum of the predecessors pixels labels and finally to arrange these labels in a convenient way.

The labeling of the objects is a crucial phase because it permits the system to individualize the objects.

Based on these labels one may proceed to compute the surface, perimeter, the center of the gravity, and the rectangle that surrounds every object in the image. A special filtering procedure is implemented in order to eliminate the objects with small surface that are treated like isolated pixels. At the end of this stage all the geometrical parameters are computed in pixel units.

4. THE METRIC CONVERSION

This module must convert the pixel coordinates into metric coordinates according to the table coordinates system in the conditions of the variable angle and distance between the TV camera and the table. For solving the problem under these restrictions, a rectangular shape, with fixed dimensions, was drawn in the origin of the table reference system. The image of this drawing is seen as an object placed closer to the top left corner of the image. The scale factor necessary in the conversion from pixels to millimeters is computed from the values established for the surface and perimeter (*Spixel, Ppixel*) of the shape image and the values of the known surface and perimeter in millimeters of the drawing. because the image coordinates system may be translated with a segment ***d*** and/or rotated by an angle *a* relative to the table coordinate system, it must compute ***d*** and *a*. It has been assumed that there may be errors in representing the rectangular shape of the standard drawing when a rotation is performed. In order to eliminate the errors we used the Least Square Method for establishing the equation (in the image system) of the axis Ox from the table system.

The symmetry axis of the standard object has the equation: $y = ax + b$. We also considered that the standard object is composed of a set of ***m*** points and we try to find the values of ***a*** and ***b*** in order to minimize the following functional:

$$F(a,b) = \sum_{i=1}^{m} (y_i - ax_i - b)^2 \qquad (4)$$

For this aim it must be solved the system

$$\begin{cases} \frac{\partial F}{\partial a} = 0 \\ \frac{\partial F}{\partial b} = 0 \end{cases} \qquad (5)$$

and the values a and b results.

This algorithm is applied also for establishing the orientation of the object main axis.

In figure 3 is shown the principle the metric conversion is based on. The conversion algorithm specifies the coordinates of the principal points of the objects in the fixed coordinates system of the table. These coordinates are invariant to the position and the distance between TV camera and the table.

5. COMPOUNDS PARTS OF AN EIHM WITH BILATERAL TOROIDAL INDUCTORS

The EIHM has its primary winding on the toroidal inductors placed bilateral from the disc - made of conductive material - together with the activating drummer of the conveying band, this disk is also the inducted with the secondary winding of the hybrid motor as in [5].

In fig.2 is presented an activating system with EIHM for conveying bands used in constructions, mining exploitations, in quarries, in the metallurgical enterprises, in port fitting outs, for cereals and food business, for rolling stairs or other systems of transport a 1 drummer on which the rolling band of the conveyer is held, by using the elastic couple 2, there are linked on the lateral sides two disks made of electric secondary winding of the hybrid motors.

On both sides of every disk 3, there are two fixed toroidal inductors 4, on which is placed the distributed primary winding 5, or in the form of a ring.

In order to improve the performances of this electric machine, the disk of conductive material can be played of the middle, a sandwich-like structure [6], by using super magnetic material (silicosis sheet iron or other iron -magnetically material).

The toroidal inductor of the EIHM may have an opening segment as a semi-toroidal (semicircle), the construction of the primary magnetic core without winding. or as a complete semicircle opened at 360^0, case in which the engine becomes an asynchronous one with a rolling disc.

6. ROBOT CONTROL SYSTEM

The robot system is composed by one robot with 6 liberty degrees, two monochrome TV camera and an automate system, all linked to a computer system (see figure 1).

The function of the camera A is to survey the band and the objects transported. The program computer digitised the image and locates the blocks on the band, determines their orientations and synthesises the commands that will be transmitted to the robot.

The automate system centralises the information about power feeding, photo sensors placed in the horizontal plan and has a special device to control the electric motor. The binary information, especially from photo-sensor are redirected to the computer.

The B camera surveys the stack made by the robots. The monochrome image is grabbed and digitised by the computers. The results of the image analysis are used in the elaboration of the commands for the robot in order to build a right stack of blocks.

Acquisition and analysis of the band surface images

The surface of the band is surveyed by the monochrome TV camera named A in the figure 1. It is assumed that exists a sufficient contrast between the blocks and the surface of the band. The area surveyed by the camera is artificially illuminated with constant parameters. For these reasons, the use of a monochrome camera is perfectly justified, but this is not an imperative requirement. In order to have a certain robustness face to the variations of band colours or blocks, illumination conditions, the binarisation is made with an algorithm based on pattern recognition technique [2]. The aim of the object recognition is the selection of the stack where the object will be stored.

The software for geometrical parameters estimation and the object recognition need a learning stage with standard objects and the output is the calibration of the image analysis module. This learning stage is executed off-line and is supervised by an operator.

The main actions that the robot must do are: positioning of the arm above the expected object on the band, catching the object, moving the object above the right position into the target stack, releasing the object.

The computer elaborates the commands and transmits them by a serial link to the robot. The fields of a robot command must contain polar co-ordinates in the robot's own co-ordinating system. In the frame of the whole control system of the robot, including TV camera, there may be distinguished 7 co-ordinates systems:

n object surveying system (S1) - measuring units: cm

n graphic system for the A TV camera (SA) - measuring units: pixels

n object catching area system (S2) - measuring units: cm

n robot co-ordinates system - polar co-ordinate for each arm (S3), measuring units CAN

n stacks systems (S4) and (S5) - measuring units: cm (one for the stack with standard objects and one for the non-standard ones)

n graphic system for the B TV camera (SB) - measuring units: pixels

These systems assure the flexibility of the operation. The co-ordinates transformation relations is based on coefficients computed during the learning stages (calibration). For example, in order to have a correct transformation between the co-ordinates in S2 and S3, the arm of the robot is moved, by a manual command of the operator, in the origin of the S2 and in a point placed on the Ox axis of the S2. As answer to a special command emitted by the computer the robot transmits the co-ordinates (in S3) of its arms.

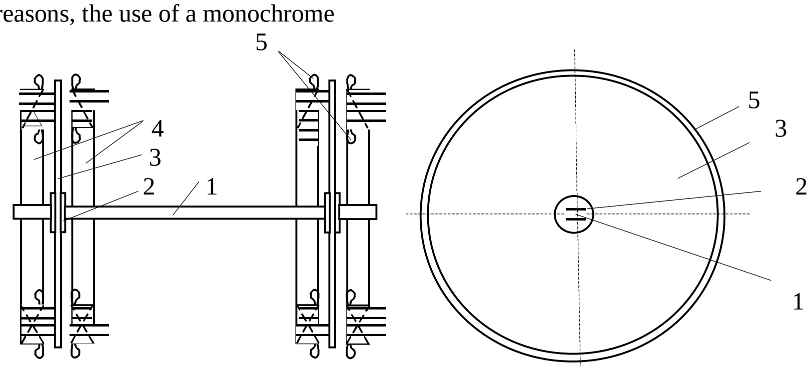

Figure 2

7. PATTERN RECOGNITION

A general pattern recognition scheme supposes that an object of the real world may be represented by a pattern *x*, where *x* is the vector:

$$\boldsymbol{x} = (x_1 , ... , x_n) \qquad (1)$$

and $x_1 ,.., x_n$ are features which values are obtained from different measurements or by employing a features selection techniques. Each pattern can be considered as a point in an *n*-dimensional space called pattern space. The similar patterns can be grouped into a finite number of sets. We suppose that these sets are disjoints and we name them classes; their representation in the pattern space consists in a number of regions that may be separable or not..

The significant objects identified on the conveyor band may be standard object (whole blocks), pieces of a fragmented block etc. the standard objects recognition is necessary to send to the robot the order that will move the objects in the standard objects stack, and the other objects in the other stack. The recognition process is based on a the concept of parallel separated patterns [4].

A pattern is described by an array of features or a pattern may be viewed as a point in a n-dimensional space. The similar patterns can be grouped into a finite number of sets.

We suppose that these sets are disjoints and we name them classes; their representation in the pattern space consists in a number of regions that may be separable or not. For example a class contains

To recognize a pattern is to classify them into a class, according to the region that contains the pattern point.

A control algorithm

We have applied the deterministic grammars to the design of two control algorithms designated to be integrated in a Power Network Control System like are in function at the Branch of RENEL Suceava. The proposed algorithm uses some syntactic pattern recognition techniques for decision making. The general form of the designed algorithms is as in following procedure:

```
 procedure  control
begin
  while automation is permitted do
     *) scan the process variables
     *) codify the acquits values into string
        it results a syntactical pattern;
     *) analyze  bottom - up, this pattern and
        determine the class which the pattern
        is belonging to
      if the pattern was rejected then
           *) no actions is performed
      else
           *) execute all the actions
              associated with that class;
      end
      *) wait a period of time
   end
end
```

For the syntactical analysis we have used one grammar for every automation.

8. CONCLUSIONS

The installation presents the following advantages:

- the direct transmission of the movement between bilateral toroidal inductors which represent the main fitting of the action motor and the inducting solidary disk by mechanically coupling with the action motor and the inducting solidary disc by mechanically coupling with the activating drummer of the conveying band;
- the expulsion of the reduction gears of revolution which diminishes the global efficiency of the equipment;
- easy and cheaper maintenance;
- protection against shock and trepidations of the mechanic reduction gears of revolution;

The system assured also the increase of the reliability and liability.

For the cases that the system works in real conditions, an algorithm for processing incomplete patterns developed in [1] was adapted to this special case.

These kind of situations may arise for default transducers or temporally interruption of data communication with the conveyor band system.

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