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SHAPE RECOGNITION OF VARIOUS PARTS PRODUCED WITHIN A MANUFACTURING PROCESS USING IMAGES FROM DIFFERENT ANGLES

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Abstract: An artificial vision system can be used in order to recognize the type of the parts from a conveyor. Sometimes, it is necessary to acquire images from different angles using more than one video camera. This approach is necessary if the parts can have any position on the conveyor. In this paper, a solution based on the usage of three video cameras is presented. It is considered the case in which the parts cannot be placed one above another and their projections from the taken images are not overlapping. The type recognition problem can be solved by recognizing the shape of the parts' projections from the acquired images. The analysis of these shapes is based on the properties of the projections' regions.These properties are obtained using the functions of MATLAB environment (and the Image Processing Toolbox). Also, the position and the orientation of the parts are determined using geometrical relations. All these information will be written in an output text file. This file can be read by a program implement in the language (RAPID) of RobotStudio environment. The details about the parts can be used to command an industrial robot to pick certain parts one by one and place them in a storage area.
Key words: shape, recognition, angles, video camera, manufacturing process, part.

1. INTRODUCTION

Consider the case of a manufacturing process where various machine-tools produce different parts. After processing, these parts are placed on a conveyor. Depending on the objects which must be constructed, some produced parts are required. Thus, the parts which are on the conveyor have to be recognized.

The task of picking a part from the conveyor can be performed by an industrial robot. In order to successfully pick a part, the robot's controller needs to know the dimension, the position and the orientation of that part.

Artificial vision methods can be used to recognize the parts which are on the conveyor. Using video cameras, images of a section of the conveyor from different angles are taken periodically. A processing and analysis algorithm uses these images and finds the required information about every part: type, position and orientation.

Having this information, a decision algorithm chooses the parts needed to assemble the final object (considering also the parts picked before).

In this paper it is proposed a simple method of recognizing the parts placed on the conveyor using images from different angles. The position and the orientation of the parts can be determined simultaneously. This solution is based on the theoretical knowledge about shape recognition [1, 2, 3, 4]. Even though more complex solutions can be found in specialized literature (for example [5]), the proposed method from this paper is focused on a specific type of applications and it is based on both simple geometrical relations and functions from *Image Processing* Toolbox of MATLAB environment. Details about the implementation of this solution in MATLAB environment will be gradually provided.

2. THE WORK DOMAIN

It is considered that the parts obtained from the machine-tools can have three shapes: square cuboid, cube and circular cylinder. The height of the circular cylinders is considered to be equal with height of the square cuboids. The diameter of the circular cylinders is considered to be equal with the sides of the cubes and also with the sides of the square face of the square cuboids. All part's dimensions are considered to be known.

Because the parts can be positioned anywhere on the conveyor, sometimes the parts cannot be differentiate from certain angles. Two such cases can be seen in figure 1. Thus, the solution detailed in this paper is based on the usage of three video cameras. One of this video cameras will be placed such that its axis to be perpendicular to the surface of the conveyor. The other two video cameras will be placed such that their axes to form a triorthogonal axis system (Fig.2.). The second camera will be placed such that its axis to be perpendicular to the side of the conveyor. The third camera will be placed such that its axis to be parallel with the side of the conveyor.

It is considered the case where the projections of the parts seen by the video cameras are not overlapping. One such case can be seen in figure 3. Moreover, in this paper it will not be considered the case where the parts are placed over other parts.

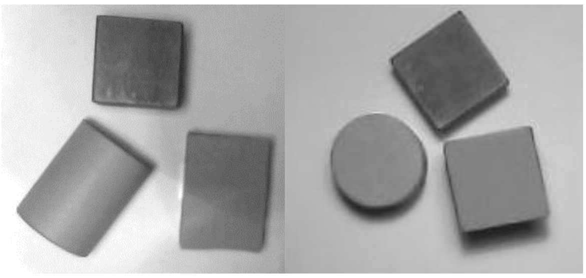


Fig. 1. Cases where different parts cannot be differentiate from a single image (left image: circular cylinder – square cuboid;right image: square cuboid – cube)

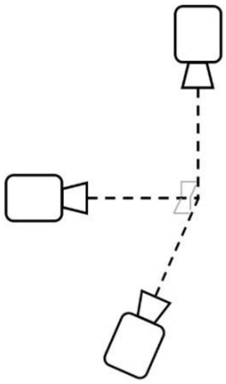


Fig. 2. Triorthogonal axis system formed with the axes of the video cameras

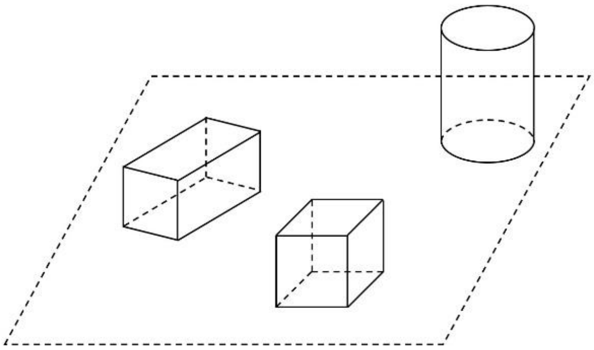


Fig. 3. An example of positioning which respects the condition of non-overlapping the part's projections taken by the video cameras

3. CALIBRATION OF THE VIDEO CAMERA

In order to have a match between the images taken by the video cameras (figure 4) an initial calibration is required. Referring to figure 4, the video cameras must be positioned such that:

- The sides of the images are parallel and perpendicular to the sides of the conveyor;
- Bottom-Left corner of the image taken by the camera 1 coincide with the Top-Left corner of the image taken by the camera 2 and the Top-Right corner of the image taken by the camera 3;
- Bottom-Left corner of the image taken by the camera 2 coincide with the Bottom-Right corner of the image taken by the camera 3.

4. DETERMINING THE TYPE OF THE PARTS

The type of the parts from the conveyor can be determined by finding the shapes of the projections

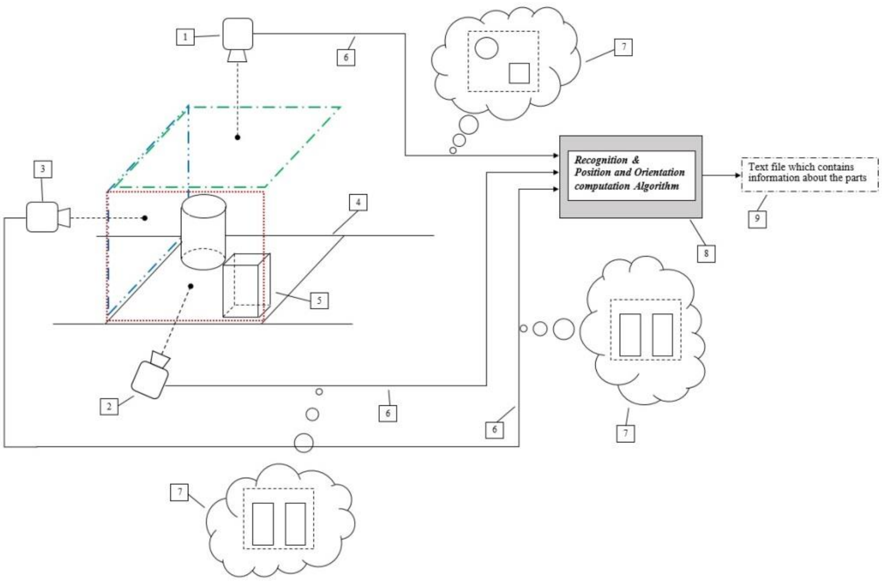


Fig. 4. The ensemble of the system in which the recognition algorithm works (1, 2, 3 – Video cameras, 4 – Conveyor, 5 – Part, 6 – Images' transmission channels, 7 – Images taken by the video cameras, 8 – Shape recognition and position computation algorithm, 9 – Output of the algorithm)

seen by the video cameras. If a square or a rectangle is identified in an image, this information is not enough to decide which the type of that part is. However, by analyzing the shapes of the projections of that part from the other images, the type of the part can be determined.

Preliminary stages of image processing (acquisition, enhancement, and segmentation) are presented in the specialized literature [6, 7]. Only the recognition stage is the objective of this paper. It is considered that after preliminary stages, binary images are obtained (figure 5). These types of images will be used in the method detailed below.

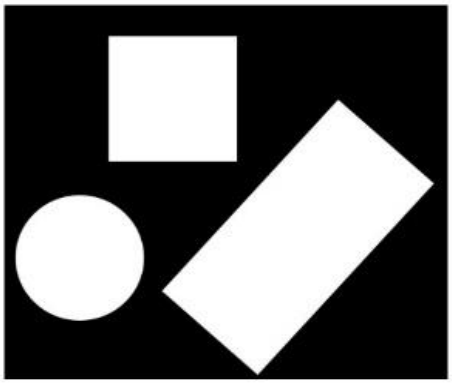


Fig. 5. Binary image

5. DETERMINING THE PROJECTION OF A SPECIFIED PART FROM THE TAKEN IMAGES

Assume that a region which represents the projection of a part in the image taken by the camera 1 (figure 4) is chosen. The middles of the intervals in which the pixel's coordinates on X axis and Y axis respectively varies have to be determined. In order to determine these intervals, the extreme points returned by Extrema property from the regionprops function is used.

Based on the initial calibration of video cameras, the projection of the selected part from the image taken by the camera 2 (figure 4) has the same coordinates on the X axis as the first projection. Using the middle of the interval of pixel's variation on X axis previously determined, the projection of the part from the second image can be determined. On this column of pixels, the projection's region is searched from bottom to top (from high values to low values on Y axis).

Based on the initial calibration of video cameras, the projection of the selected part from the image taken by the camera 3 (figure 4) has the same coordinates on the X axis as the coordinates of the first projection on Y axis. Using the middle of the interval of pixel's variation on Y axis previously determined, the projection of the part from the third image can be determined. On this column of pixels, the projection's region is searched from bottom to top (from high values to low values on Y axis).

6. PART'S SHAPE RECOGNITION ALGORITHM

The regionprops function available in the Image Processing Toolbox from the MATLAB environment will be used many times in order to determine both the type and the position of the parts placed on the conveyor. This function determines various properties of regions from an image.

The image taken by the video camera positioned perpendicular to the surface of the conveyor (camera 1 from figure 4) is used firstly. Because on the conveyor are not any parts placed one above another, all the parts can be seen in this image. In order to determine the type of the parts, the shapes of their projections have to be determined. There are three shapes which can appear in this image (according to the types of the parts produced by the machine-tools):

- Circle – for a circular cylinder part which is positioned with its height perpendicular to the surface of the conveyor;
- Rectangle – for a square cuboid partwhich is positioned with its height parallel with the surface of the conveyor or for a circular cylinder part which is positioned also with its height parallel with the surface;
- Square – for a cube part in any position or for a square cuboid partwhich is positioned with its height perpendicular to the surface of the conveyor.

In order to determine whether a specific shape is a circle or a square, the compactness value for that shape will be tested. The value of compactness is computed using the relation (1). The value of the compactness for a circle is given by the relation (2) and for a square is given by the relation (3). The values of the Area and Perimeter parameters are taken from the regionprops function. Due to the approximations which may occur (because ofspatial discretization) the compactness value will be tested using the inequality (4) (where ε is a parameter chosen experimentally). If the inequality is not fulfilled by any of these two values it means that the shape is a rectangle.

$$Compactness = \frac{Perimeter^2}{Area} \quad (1)$$

$$Compactness_{Circle} = 4\pi \quad (2)$$

$$Compactness_{Square} = 16 \quad (3)$$

$$|Compactness - Value| \leq \varepsilon \quad (4)$$

1) If a region is identified as being a circle then it is sure that the part which has that projection is a circular cylinder.
2) If the region is identified as being a rectangle then the image taken by the second video camera (camera 2 from figure 4) has to be analyzed. The projection from this image of the considered part is examined.
Due to the initial calibration of the video camera, the projection of a square cuboid part in this image has the sides parallel with the margins of the image. Using the Extrema property from the regionprops function, the extreme points of the projection's region are determined. Left-Top and Left-Bottom extreme points have to be selected among these points. The distance between these points is computed. Using the relation (5), the value obtained is tested if it is smaller than a threshold value ε(chosen experimentally) which is close tozero. If this condition is fulfilled then the part with that projection is a circular cylinder. The reason is given by the method of drawing a round section using pixels (figure 6). Otherwise, the type of the part cannot be specified exactly (the part can be a circular cylinder or a square cuboid).In this case, the image taken by the third video camera (camera 3 from figure 4) has to be analyzed.

$$\text{Distance} \leq \varepsilon \qquad (5)$$

The shape of the projection of the considered part from this image will surely be decisive in determining the part's type. The same test as before it is used. The part is a circular cylinder if the inequality (5) is fulfilled. Otherwise, the part is a square cuboid.
3). If the region is identified as being a squarethan the image taken by the second video camera (camera 2 from figure 4) has to be analyzed. The shape of the projection from this image will surely be decisive in determining the part's type.
The Left-Top and Left-Bottom extreme points are selected using the Extrema property taken from regionprops function. The inequality (6) is used to test if the distance between these two points is close to the length of the major side of a square cuboid. The parameter ε from this inequality has to be experimentally chosen. Its value has to take into account two elements. The first element is the approximation due to the spatial discretization. The second one is the variance of the perceived length by a video camera of a segment which is moving rearward or forward to the camera. This variance is small for a conveyor which has a relatively small width. If the conveyor is bigger or the length of the cube's side and the major length of the square cuboid are close then another condition to distinguish these parts has to be applied.The considered part is a square cuboid if the condition is fulfilled (figure 7). Otherwise, the part is a cube. Distance
The diagram of this shape recognition algorithm can be seen in figure 8.

$$|Distance - Length_{SquareCuboidMajorSide}| \leq \varepsilon \qquad (6)$$

7. POSITION AND ORIENTATION DETERMINATION

Besides the type, an industrial robot has to know the position and the orientation of the part which has to be picked. The position and the orientation can be determined from the image taken by the video camera

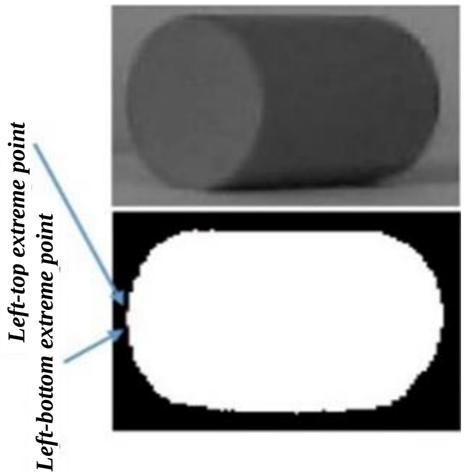


Fig. 6. Left-Top and Left-Bottom extreme points of a circular cylinder's projection

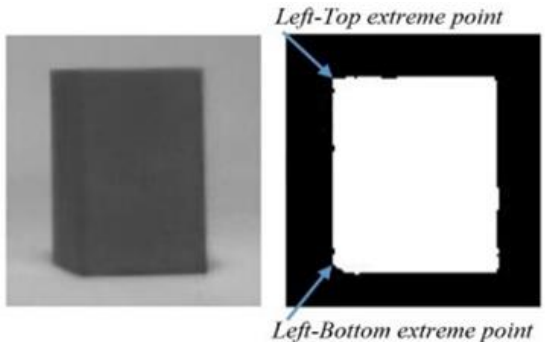


Fig. 7. Left-Top and Left-Bottomextreme points of a square cuboid's projection

positioned perpendicular to the surface of the conveyor (video camera 1 from figure 4). This information is exactly the same with the position and the orientation of the part's projection (which can be a circle, a rectangle or a square) from this image.
The position of a shape is the center of its region (the intersection of the diagonals for a square or a rectangle). This point is the center of the image returned by the property Image of the regionprops functions.
The orientation determination is not necessary for a circle. For squares and rectangles, the vertexes' positions have to be determined firstly. This

operation is done by choosing four out of eight extreme points returned by Extrema property of a region (the vertexes are those extreme points which have the distances to the other vertexes already chosen equal with the length of the sides or of the diagonals of the known shape). The orientation of a rectangle is given by the angle between a minor side and the horizontal axis (X axis). The orientation of a square is given by the angle between any side and the horizontal axis (X axis).

8. EXPERIMENTAL RESULTS

The required information about the parts placed on the conveyor has to be written in an output file. Thus, the industrial robot's program can read this file and command the movement in order to pick the desired parts.

When the industrial robots will want to pick a part, its Tool Center Point (TCP) has to be moved to the position of the part previously determined. However, these coordinates have to be expressed in millimeters and not in pixels. Thus, the relation (7) represents the required transformation which has to be made. In this relation, $length_{mm}$ and $length_{px}$ represents the same length expressed in two different measurement units. These values can be determined experimentally.

$$Size_{mm} = Size_{px} * \frac{length_{mm}}{length_{px}} \quad (7)$$

Also, the origin and the orientation of the axes has to be taken into account. For the case of images, the origin is placed in the upper-left corner. The X axis varies from left to right. The Y axis varies from top to bottom.

In the left column of Table 1 the images taken from the video cameras are shown (first image is from camera 1, second image is from camera 2 and the third image is from camera 3). In the right column, the outputs are show. The first value in each row represents the code of the part's type (A – square cuboid, B – cube, C – circular cylinder). The following two values represent the coordinates of the upper part's projection. The last value is the orientation of the same projection.

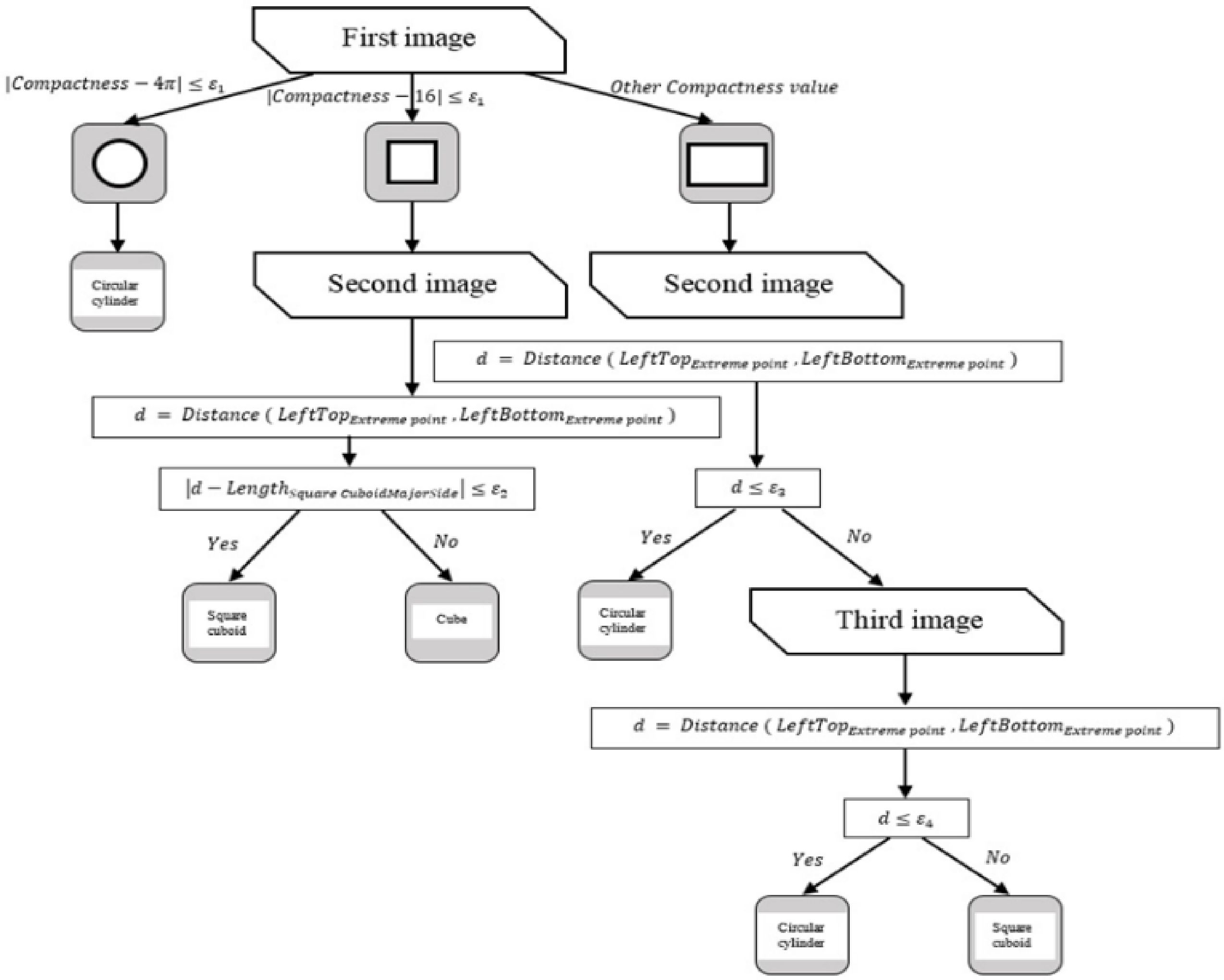
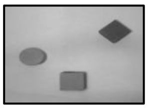
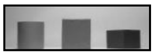
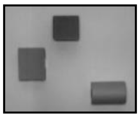
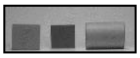


Fig.8. The diagram of the Shape recognition algorithm

Table 1. Results obtained after applying the described algorithm

Input images			Output data
			C 29.68 62.16 0 B 101.36 30.8 137 A 71.68 101.36 89
			B 73.92 28.56 91 A 31.92 75.6 0 C 123.76 112.56 92

9. CONCLUSIONS

In this paper, a method for type recognition of various parts obtained after a manufacturing process was presented. Also, the position and the orientation of these parts were determined. This method is based on an artificial vison algorithm which uses part's images taken from three different angles. The results obtained prove both the correctness and the efficiency of the algorithm.

Using this information, an industrial robot can be controlled to pick and place in a storage area the desired parts. The position in which the Tool Center Point of the robot has to be fixed can be easily computed knowing that the speed of the conveyor is constant. Thus, the parts needed to build various objects can be provided as soon as the manufacturing process is finished.

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