

## PANTOGRAPHY APPLICATION WITH REAL-TIME PLC BASED ON IMAGE PROCESSING IN GANTRY ROBOT SYSTEM

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*Programmable Logic Controllers (PLC) is one of the indispensable products of automation industry. PLCs, which are widely used in many fields of programming, make our lives easier in daily life. In this study, after determining the coordinates of the image taken from the camera with the help of image processing algorithm, the servo drives of cartesian machine are controlled and processed in X-Y plane with Rexroth PLC in real time. In this application, it is aimed to obtain the image again by subtracting the boundary coordinates of the image taken with the camera in MatLab environment. To achieve this goal, the servo drives of the cartesian machine were controlled and the application was realized. Two different methods were applied for the image taken in Matlab environment. The skeleton of the image was taken for the first method and then the boundary coordinates were determined. For the second method, the contour of the image was first extracted. The coordinates of the contour image were not directly used. These coordinates have been tried to be optimized.*

*In this study, it is aimed to draw a desired image by drawing border coordinates in Matlab with Rexroth PLC on a cartesian machine. As a result of the test studies, it was seen that the drawing process was carried out properly (according to the coordinates received) as a result of the analysis and measurement processes (metric caliper and measurement methods).*

Key words: *Rexroth PLC, MatLab, Image Processing, Skeleton, Contour*

### 1. Introduction

A digital image is formed by the conversion of the light energy (analog signal) reflected by the objects into a digital signal by the sensor. The basic component of an image is pixels. A numerical image is expressed by a matrix of MxN sized pixels. For grayscale images, the image consists of different grayscale values. Gray value ranges are expressed as {0,1,2, ..., 255}.

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The acquisition of information from the images and interpretation of these information forms the basis of the image processing area by processing and analyzing the digitized images by means of developed methods such as video camera and scanner. Examples of image processing applications are industrial quality / production controls from factory automation applications, counting of blood cells from medical applications, character recognition from computing applications, face recognition from security applications, and production of intelligent weapons from military applications. In recent years, it has been seen in the literature that there are many different studies using image processing techniques for automation and production sectors.

Today, digital image processing and image recognition technology is used in many different fields. Another area of use of this technology is, of course, industry. Production is rapidly automated thanks to the robot and artificial intelligence technique developed especially in the assembly industry. The identification of the smooth shapes used in the industry and the definition of the positions and areas of rotation of these shapes will pave the way for new industrial applications.

The variety of applications with image processing is increasing day by day. Plate reading systems, face recognition applications, fingerprint recognition applications, iris recognition applications such as applications that are commonly used today are examples of image processing [1-3].

Another recent topic is the robots. When we talk about robot, the first thing that comes to mind is humanoid machines that think and decide like human beings. This shows that the design of robots is inspired by the structure of living things.

When robot is mentioned, humanoid robots come to mind first. The structure of Cartesian robots is different from that of humanoid robots. Cartesian robots consist of axes perpendicular to each other. Gantry robots are also a kind of cartesian robot. What distinguishes Gantry robots from cartesian robots is that they have two bearing axes. This robot configuration is the robot design with the most limited mobility.

In a cartesian coordinate system, the location of the coordinate system center is the center of the junction of the first two links. The center does not move except for the movements towards the center of the robot, ie the center of the robot is fixed. Cartesian robots consisting of three linear axes are widely used in industrial applications and for manufacturing purposes. Cartesian robots have applications such as packaging, logistics, milling, laser, plasma, oxy acetylene cutting machines, water jet cutting, electro erosion [4-10].

In this study, digital image processing and cartesian robot are combined in this system and real time processing (writing) application is realized with PLC control.

In the first stage of the application, the image taken with the camera was processed in Matlab environment. Two different methods were used to edit this image. For the first method, the image was converted to a black and white image. Then the skeleton of the image was taken and in this way boundary coordinates were obtained. In the second method, the image was passed through a threshold value and the contour of the black and white image obtained in this way was taken and the coordinates were obtained. Optimization process was performed for the obtained coordinates.

In the second stage of the application, the coordinate values were transferred to Rexroth PLC. A series was defined in the program and position information was obtained. The end information of the index was checked with 0. When the sequence is over, the sprung system connected to the relay goes up, ie the relay is deactivated. And the engines for the next series have taken position. Thanks to the

control of servo motors according to the specified coordinates (X and Y), real-time processing (writing operation) was performed on the cartesian robot.

## 2. Test Setup

The mechanism used in the application consists of a cartesian robot that can move in two axes and a pneumatic vacuum holder that can move in the vertical axis. As a result of the processing and evaluation of the image taken from the camera by the computer, the letters are positioned in the horizontal and vertical coordinates. The movement of the robot in the X and Y axes is provided by two servo motors. Each motor is driven by its own drive. These drives are controlled by 1 Rexroth PLC. These PLCs can communicate with the computer via RS232 serial bus and receive commands related to the tasks of the robot and make restrictions on the current situation. Figure 1a shows a solid model showing the movement of the gantry robot in the X (vertical) - Y (horizontal) and Z (vertical) axes. The solid model of the test apparatus is shown in Figure 1b and the computer connection of the X and Y axes in Figure 2 is shown in the block diagram. Figure 3 and Figure 4 show the experimental setup.

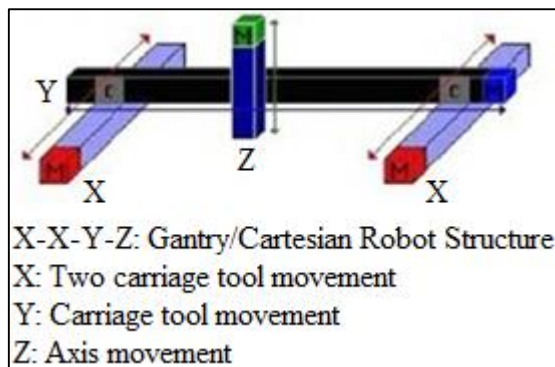


Figure 1a. Solid model of the gantry robot

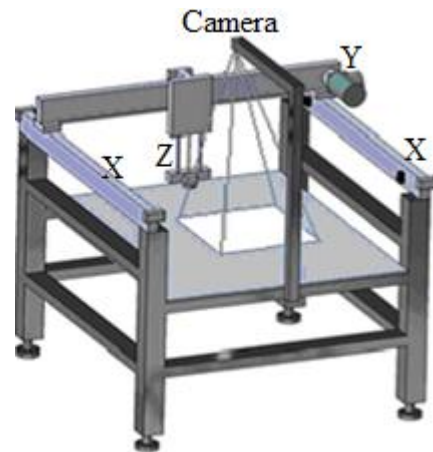


Figure 1b. Solid model of the experimental setup

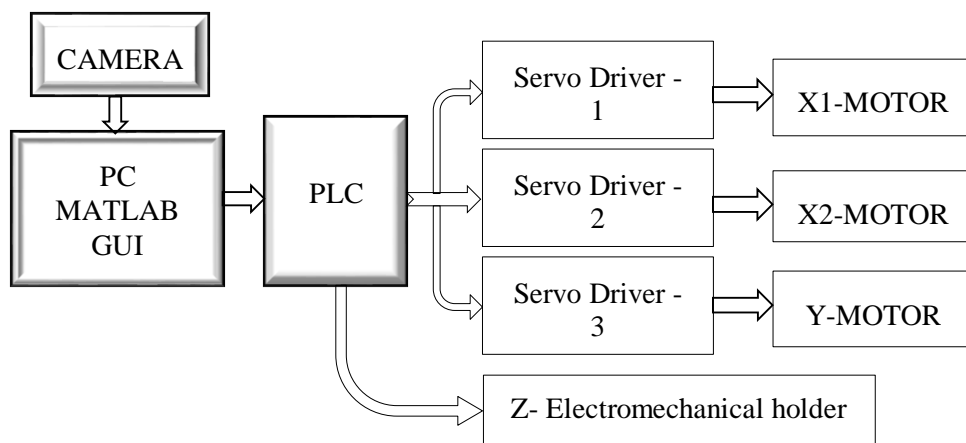
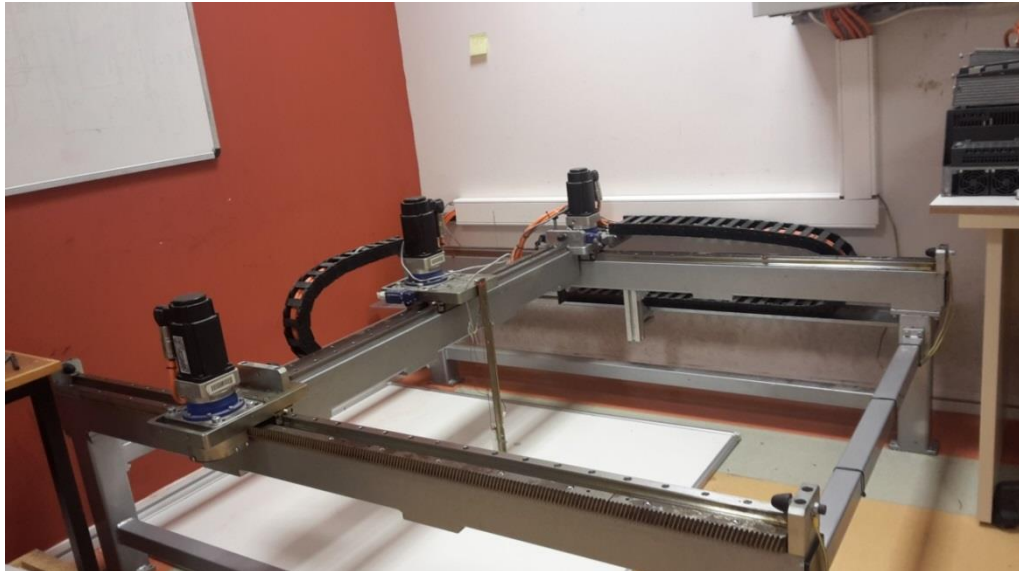


Figure 2. Computer connection of X and Y



**Figure 3. The experimental setup**



**Figure 4. The experimental setup**

### **3. Image Processing Method**

In this section, it has been studied on the recognition of the coordinates of the center points in MATLAB by using digital image processing techniques independently of the rotation and size of the geometric shapes. Image processing techniques were used to extract the boundary coordinates of the image taken with the camera. Two methods are used to extract boundary coordinates. The first method is the skeletal extraction technique, which is a morphological procedure. In the second method, the contour of the image is taken and the coordinates are obtained after an optimized operation. In the Matlab environment, the x-y boundary coordinates of the object in the image obtained by processing and evaluating the image taken from the camera are sent to the PLC and the drawing of the object is realized.

### 3.1. Obtaining a Coordinate by Skeleton

Matlab contains many morphological functions. Skeleton retrieval from these morphological functions removes pixels from the boundaries of objects, but does not allow the object to break apart. The remaining pixels form the image skeleton [11-12]. The general steps of the algorithm of the proposed method are shown in Figure 5.

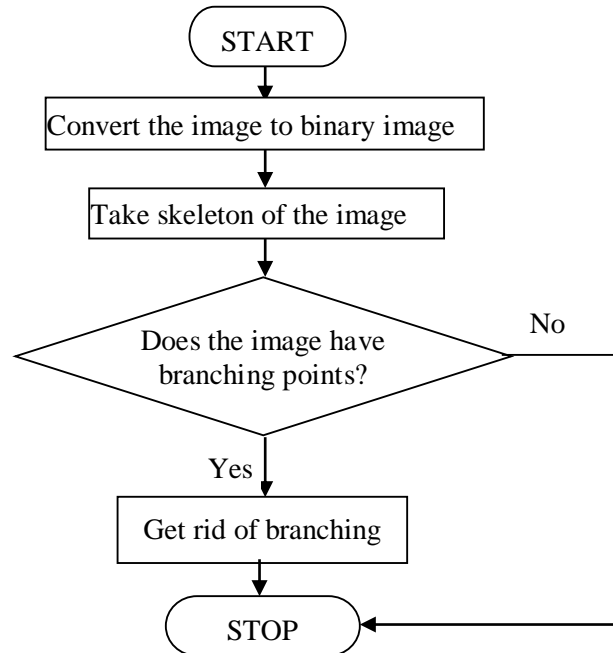


Figure 5. Algorithm of suggested method

The mathematical expression of the skeletal function can be explained as follows:

A's skeleton is defined by 'erosions ( $\ominus$ )' and 'openings ( $\circ$ )' operations [2].

$$S(A) = \bigcup_{k=0}^K S_k(A) \quad (1)$$

$$S_k(A) = (A \ominus kB) - (A \ominus kB) \circ B \quad (2)$$

B is the structuring element seen in Equation (2).  $(A \ominus kB)$  indicates the successive erosion of A.

$$(A \ominus kB) = (\dots((A \ominus B) \ominus B) \ominus \dots) \ominus B \quad (3)$$

The equation in equation (3) is repeated k times. K is the iterative step before A erodes to an empty cluster.

$$K = \max \{k \mid (A \ominus kB) \neq \emptyset\} \quad (4)$$

As a result, the skeleton of A is obtained by combining skeletal subsets. When the disadvantages of this method are evaluated, the skeleton is formed when more points are determined while selecting the points forming the skeleton. However, unnecessarily selected points create unwanted branching points in the image. When the steps in the given algorithm are followed, the creation of the skeletal points of the image is shown in Figure 6. After this step, the boundary

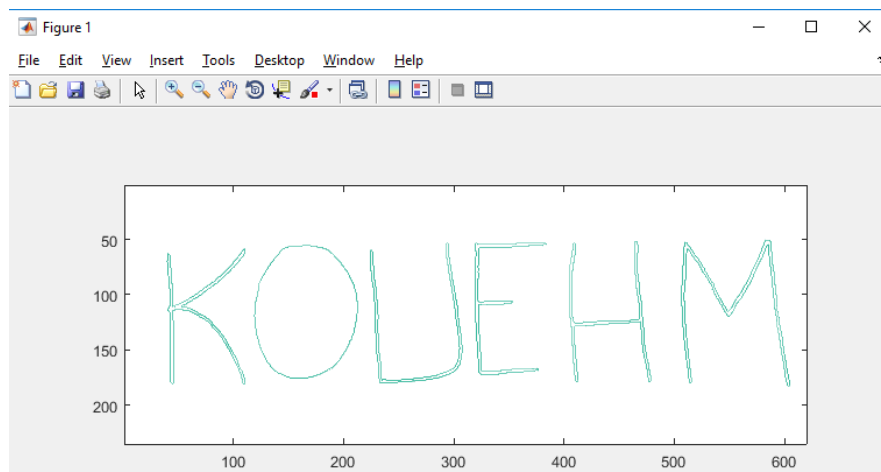
coordinates of the image are taken with the `bwboundaries` command. Creates 6 matrices within the variable. These matrices express each letter sequentially.



**Figure 6. Created skeleton points**

### 3.2. Obtaining a Coordinate by Contour

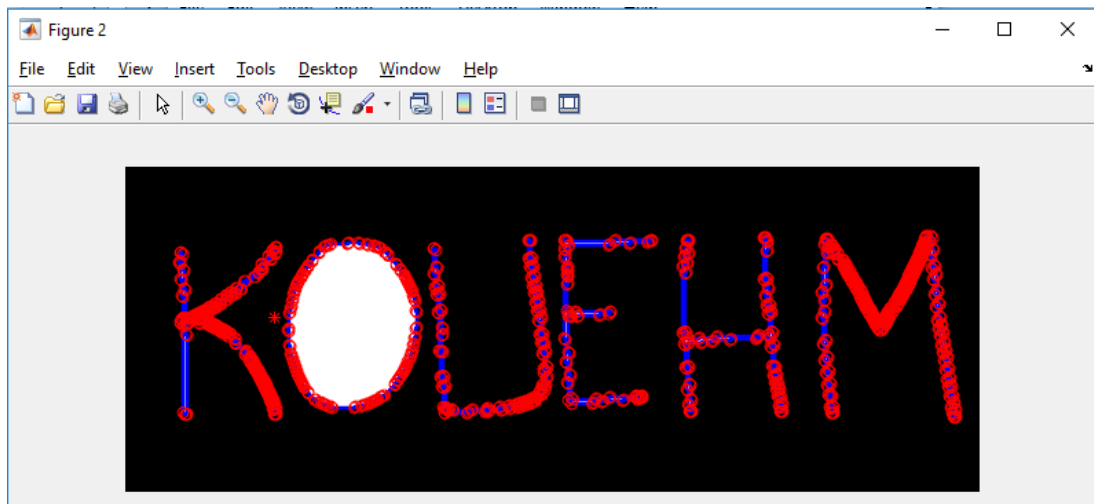
At this stage, the image is first passed through a threshold level. Then, the gaps in the image are filled with the morphological command `imfill`. In the next step, the contour of the image is taken. Figure 7 shows the contour of the original image.



**Figure 7. Contour of original image**

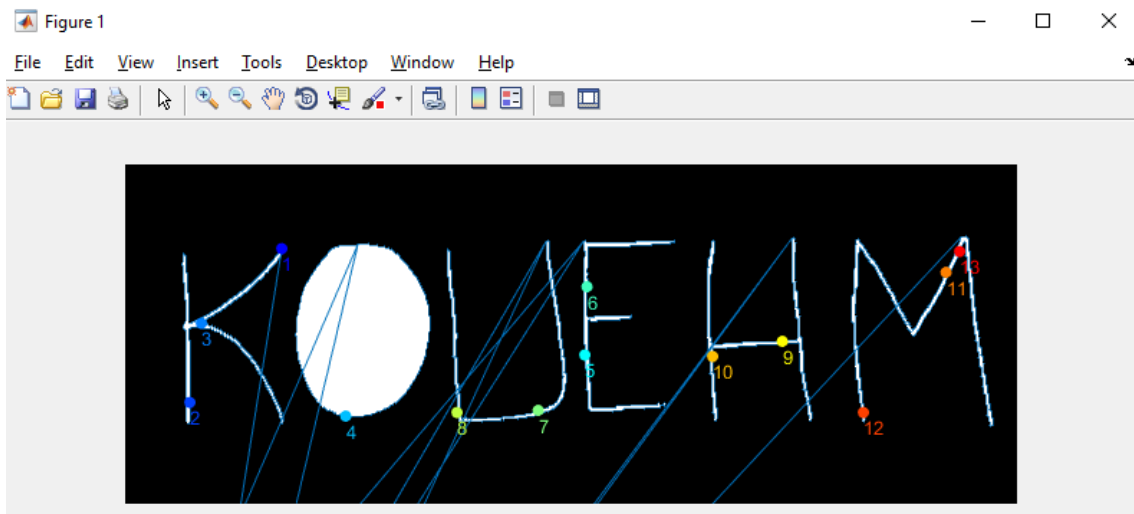
In the second stage of the application, “`polyarea`” function is used. This function returns the polygon fields defined by the X and Y columns if X and Y are matrices of the same size.

The contour obtained in the application was stored in variable C. This variable is divided into x and y coordinates. All rows and columns are transposed and the `polyarea` function is performed in a while loop. Figure 8 shows the “`polyarea`” function.



**Figure 8. Processed polyarea method of image**

In this application, another application was tried to be made in order to ensure the optimization of the coordinates received. Certain points are selected from the contour image. These dots are expected to form letters. The most important detail here, the need for too many points, the progress of the ranking is very important for the success of the application. Therefore, this process has been realized by optimizing the points on the image at hand. Figure 9 shows the optimized version of the image.



**Figure 9. Image optimized**

### 3.3. Obtaining Coordinates by Eliminating Overhang Pixels

The spur function, which is a morphological process in Matlab, processes the matrix values that are different from neighboring pixels, which may be protrusions, by resembling the neighboring pixel. After applying the spur to the matrix shown in Figure 10, the value different from the neighboring pixels was converted to the neighboring pixels. In this way, the protruding pixel value is removed. In addition, when this function is applied to small objects, the protrusion removes pixels and does not disturb the structure of the object [3]. Therefore, it is thought to be a suitable function for the image used.

0	0	0	0		0	0	0	0
0	0	0	0		0	0	0	0
0	0	1	0	becomes	0	0	0	0
0	1	0	0		0	1	0	0
1	1	0	0		1	1	0	0

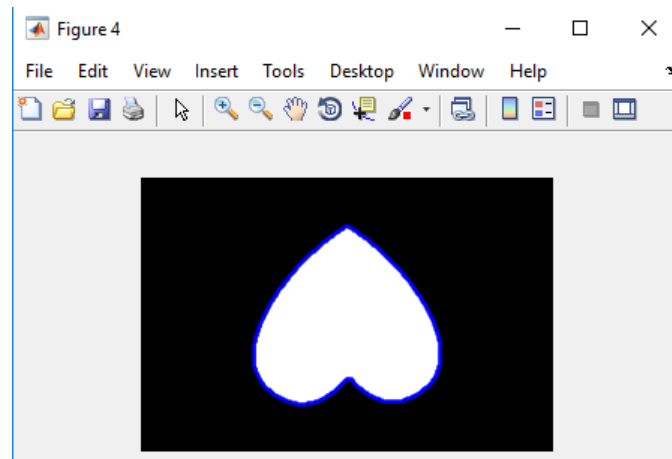
**Figure 10. Spur method**

Figure 11 shows the original image. After converting this image to black and white format, spur function was applied and boundary coordinates were taken by `bwboundaries` command.



**Figure 11. Original image**

Boundary coordinates of the image are given in Figure 12.



**Figure 12. Boundaries of image**

#### 4. Pantograph Application Based on Recommended Techniques

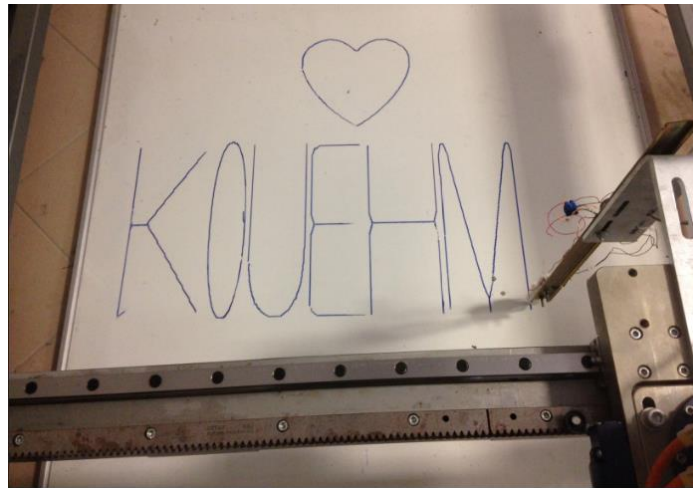
Pantograph application is performed using Rexroth PLC. Rexroth PLC consists of Rexroth servo drives and servo motors. Works on two axes. Communication of the drivers is provided via ethernet. For this purpose, IP scan is performed via ethernet cable connected to the computer. IndraWorks software is used for Rexroth PLCs. IndraLogic provides visualizations for viewing project variables. Geometric elements can be created with the help of visualization. Movement can be provided when used in online mode. Various color and text forms can be applied according to the specified variable values [13-20].



In this section, programming is controlled by the buttons added and the direction of movement of the motor is observed. To add a button to the program, select the appropriate icon from the software interface.

7 objects were used for this programming. It is compared with "k" 8 to see the end of the program. Other commands are used to move position information. When the system is started and "roll-up" is not provided, the roll-up increments the position information for x and y and moves them to the axes with the "move" command. In this way, the letter coordinates are taken. Relay and a spring system are used for the z axis in the scope of operation. The output of the 24 V DC relay is connected to the output of the PLC and the QX0.9 output of the PLC is connected to the input of the relay. When the relay is activated, the spring is pushed and the pen drops down. The relay is deactivated when switching to the other array. The pen comes up. When the position information is received, that is, when the position is started, the pen is turned on and if the AUTO\_START button is pressed, the z axis is activated. The object starts to be drawn.

The result of the programming in this study is shown in Figure 13..



**Figure 13. Result of programming**

## 5. Conclusions and recommendations

It has become a necessity to acquire some images within the developing technology and to arrange these images according to the needs. Various image processing techniques are used in military field, automation, remote sensing. When these techniques and PLC program are used together, the working areas of the PLC are increased and the cost is reduced. For this reason, the technology of the systems made using PLC is increasingly trying to use various artificial intelligence algorithms and image processing techniques instead of manpower.

In this study, it is aimed to draw a desired image by drawing border coordinates in Matlab with Rexroth PLC on a cartesian machine. For this, two methods were used in Matlab. These are skeleton subtraction and subtraction of boundary coordinates using the spur function. After this process, the coordinates received were loaded into Rexroth PLC as position information in sequence with a certain scaling.

As a result of the caliper measurement tests performed on the processing outputs performed on the experimental setup, it was observed that the machining took place almost in an error-free manner

(in coordinates). In the comparisons and evaluations, it is concluded that theoretical results and practical results are in great agreement.

In addition to this, it has been seen that with an image taken from the camera, it is possible to perform operations in image processing area on Matlab and parts processing can be performed in cartesian robots. It has been seen that these processes are developing and can be developed and working in collaboration with electronic devices where image processing can be added to most applications today.

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