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Diverting and Sorting Mobile Robotic Table for Motion Control Testing

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Abstract. This article is about the design and construction of a Diverting and Sorting mobile robot table for testing motion control techniques, the robot consists of nine modules with two degrees of freedom each one in three times three matrix configuration; a table with dual rack gear track in bottom move between modules, combined control of each module allows the transport of objects. Computer vision techniques are employed in this case a Pinhole camera model for detection and location of the carry objects. Each of the characteristics of the design and construction of the parts that form the mechanical system are explained in detail. The table design includes high quality and low-cost materials. At finally, the robotic table is verified with different techniques of control, for example follower desired path. The result shows a difference between the real path and the desired path that will be calculated under the quadratic error function.

1. Introduction

The evolution of robotics to move forward in huge strides to achieve a new technologic age, through robotic system that is also reliable and meets the requirements of high capacity [1]. Different types and designs of the new technologic age of robotics have been introduced to industry of manufacture. In the industrial area, the robotic arms are multifunctional, programmed to perform a variety of tasks in environments of high risk to humans. [2][3][4].

Nowadays, there are multiple types of ordering systems with software and standard controllers, which operate in storage and distribution stations feeding operations in supply chains. The high product demands require software and high-speed hardware, this increases productivity, quality and performance. Manufacturing industries handle large warehouses of products in carton packs forced to stop the production line. Systems that divert the flow and classify reduce time and deliver products just in time. As well as artificial vision has allowed the generation of new techniques for data processing. [5] [6] [7] [8]

2. Design and construction

It includes different parts that provide data acquisition, drive and control motors. The camera is the primary data-acquisition device by collecting sequential images that will be previously measured using sophisticated machine vision algorithms. A diagram of the Diverting and Sorting robot table electronic system is illustrated in figure 1.

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A Logitech 960-C270 performs image acquisition. Captures successive images of the position of the object on the table, these data are interpreted by a computer, where artificial vision algorithms are performed. This data processing is directly linked to the processor speed of the computer. The computer used for this table complies with the following characteristics: Intel i7, 16 GB RAM and Windows operating system with MATLAB software that is responsible for the artificial vision algorithm and the tracking control for the movement of the motors.

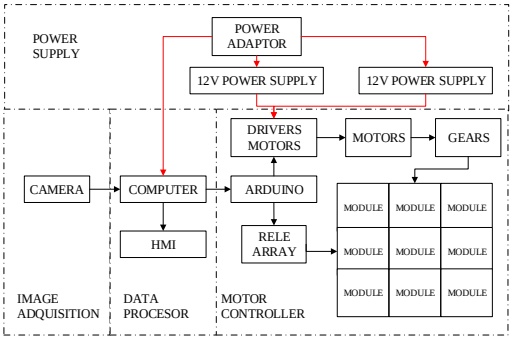


Figure 1. Configuration of the Electronic System.

2.1. Electronic Design

An Arduino Mega board is used to control the motors, sending data through a serial port with 2 information signals for each of the 18 motors in total. The signals represent the direction of rotation and the speed. In addition, a Cytron 10A-25V dual channel DC motor is used to drive and power the Polulo 25Dx54L motors. Finally, each channel to Cytron 10A-25V is connected to a motor controller for each module, two PC switching sources are used to power the entire system.

As actuators for the robotic system, 18 motors are used which are distributed two for each module, to give a total of 9 modules distributed in a 3x3 matrix, one motor for the X axis and the other for the Y axis, which receive their control signal from the Cytron boards. The same ones that manage the energy to drive the motors that will then move the table.

2.2. Image processing

Using the data obtained by means of the artificial vision system, the robot table is controlled, therefore for the process of obtaining images it is carried out by means of a projection of the plane of interest in the image plane where the sensor is located. As a consequence, the perspective is lost and a 2D image is obtained, which provides information on position and speed. In order to compute the coordinates of the object of interest, the pin hole camera model provides a simplified version of the information resulting in a shorter processing time and therefore relief of computational load [9], figure 2.

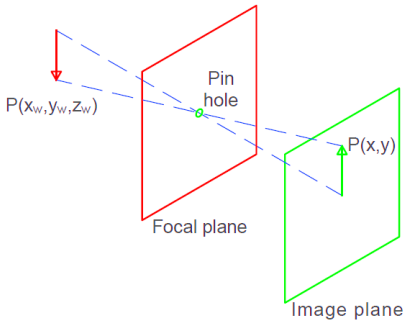


Figure 2. Pinhole Camera Model Illustration.

The pinhole camera model is used for the determination of mathematical equations describing a three-dimensional point $P(X_w, Y_w, Z_w)$ for the case of the image plane is based on figure 3. [10].
To determine the model, the analysis is carried out for each two-dimensional axis, as shown in figure 3. The 3D information of the world is projected onto the plane of the image located at an equal distance known as focal length.

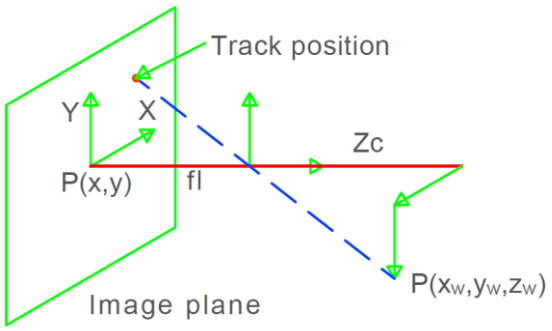


Figure 3. Track position analysis based on the Pinhole Camera Model.

The geometrical relations allow the choice of the position value of each of the pixels as in equation (2) for x axis and equation (3) for y axis.

$$\frac{X}{f} = \frac{x_c}{Z_c} \tag{2}$$

$$\frac{Y}{f} = \frac{Y_c}{Z_c} \tag{3}$$

The following matrix is used to obtain the real value of carry object for this the position of the shown in equation (4).

$$\begin{bmatrix} nx \\ ny \\ n \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & f^{-1} & 0 \end{bmatrix} \begin{bmatrix} x_c \\ y_c \\ z_c \\ 1 \end{bmatrix} \tag{4}$$

3. Tracking Control

The robotic table is verified with different techniques of control, based in follower desired path Error calculation is being calculated under the quadratic error function see figure 4.

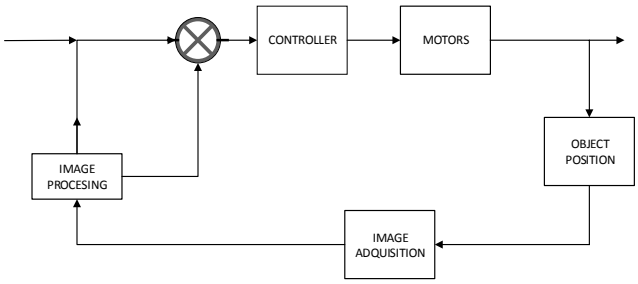


Figure 4. Control System Diagram.

4. Result and Analysis

The tests identify the path of the table and even a red object on it, which is intended to estimate its distance, a situation that will depend on the segmentation and discretion of the colors. The evaluations of the obtained results are specifically the location starting from a real path and another one that references the images acquired in reference points, estimating the position with the algorithm. Both

paths are contrasted on the basis of an error criterion, the actual path has 4 points in the plane whose positions are displayed in the figure 5.

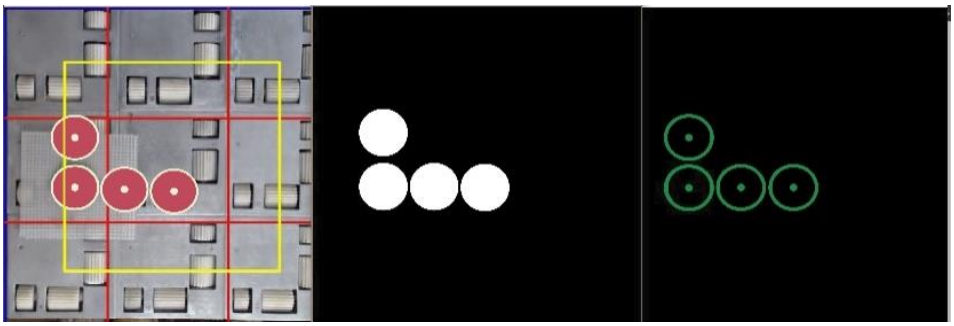


Figure 5. Displays the implemented route control.

Table 1. Real tracking position based in data acquisition.

No. points	xr	yr	Object
P1	220	60	Table – Red Object
P2	138	56	Table – Red Object
P3	130	130	Table – Red Object
P4	200	120	Table – Red Object

A figure. 6 shows the image of the real Path with defined criteria of identification, location, there are not two objects in the same image and its acquisition was made clockwise.

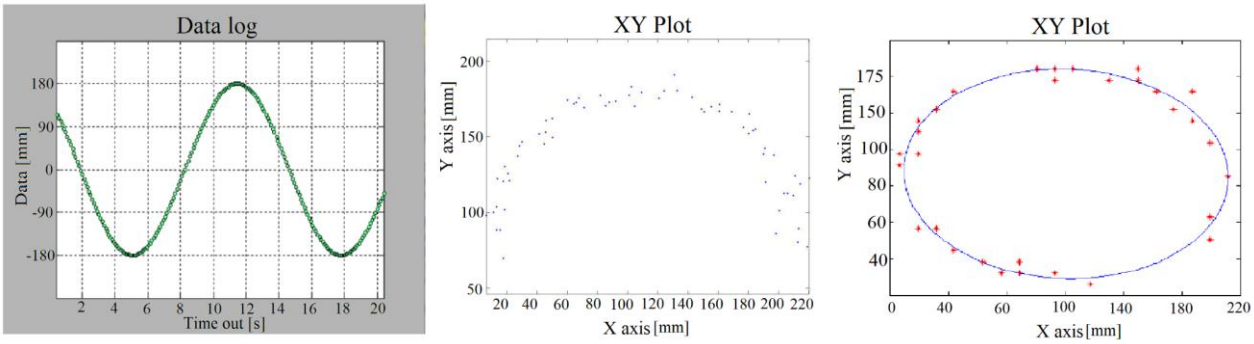


Figure 6. Trajectory data acquisition.

4.1. Error Verification

The result shows a difference between the real path and the desired path that will be calculated under the quadratic error function is show in equation (5).

$$E = \frac{1}{N}\sum_{k=1}^{N}[(x_r\,(k) - x_d\,(k))^2 + (y_r\,(k) - y_d\,(k))^2]^{1/2} \quad (5)$$

where:
$[x_r\,(k), y_r\,(k)]$=real position
$[x_d\,(k), y_d\,(k)]$= position is deducted by the mobile robotic table
k = instant where the distance measurement is taken in the field
N= total number of points where a distance measurement was made.

5. Conclusions

After the analysis of the quadratic error, it was found that the table has enough capacity to follow the desired path through the control algorithm with artificial vision, the combined control of each of the motors has been necessary to ensure a smooth movement for the transfer of the double rack on each of the modules.

In addition, the selected materials comply with the requirement which ensures a long service life. The path analysis is observed through the artificial vision system, which efficiently follows the proposed path using the singularity to have an abstraction of the system that facilitates the control algorithm with an error of ±2.4 mm.

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