Omnidirectional Transport System for Classification and Quality Control using Artificial Vision

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ABSTRACT

Classification and transport of material is a crucial stage in the manufacture of parts and represents a large portion of the lead time in a production line, which is why optimization is crucial. This work deals with an omnidirectional transport mechanism for classification and quality control of parts coming from rapid prototyping processes. Said mechanism is constituted by an artificial vision system, which will be responsible for taking the necessary information to perform the classification and quality control using a neural network; and, a matrix of omnidirectional wheels that allows the movement of the piece on the XY plane. The purpose of this investigation was to demonstrate that omnidirectional mechanisms can also be used to transport and classify parts within industrial processes, being another alternative of use to conventional systems. The system is able to classify three types of pieces of different forms, sizes and perspectives with high reliability and speed; it also allows a better human-machine interaction due to a graphical interface where the performed processes are detailed.

CCS Concepts

• **Hardware→Electromechanical systems:**

Keywords

Artificial vision; conveyor; omnidirectional transport system.

1. INTRODUCTION

Conventional transport and classification systems use several resources including diverse types of sensors and actuators [1]. In the transfer of pieces a conveyor belt is generally used, while pneumatic systems are used for the differentiation between acceptable and defected objects [2], both of them consuming time and energy within the production system.

Other aspects to consider are the quality control in these systems. A widely used method is the manual method, but is subjected to failure, since the quality of the review depends directly on several aspects like visual ability to discriminate errors [3], mood and fatigue reflected by the operator due to the prolonged hours of work that is usual in an industrial environment, therefore an automated alternative is highly recommended. An omnidirectional transport and classification mechanism is an effective optimization alternative since it allows the product to be transferred while being classified, reducing lead time.

Parameters mentioned above streamline product classification and transport systems as they eliminate traditional methods, adopting new and high-level technologies, which are based on omnidirectional mechanisms for transport and classification, and artificial vision is implemented to classify and perform quality control [4].

This study shows the design and construction of the omnidirectional mechanism, and the software used to control the device. A scheme of the mechanism is shown in Figure 1, which consists of a conveyor belt that is activated when the motion sensor detects an object, in addition, an artificial vision system installed in the middle of the route is responsible for taking the necessary information to perform the classification and quality control through the omnidirectional system and placing the objects in the respective containers.

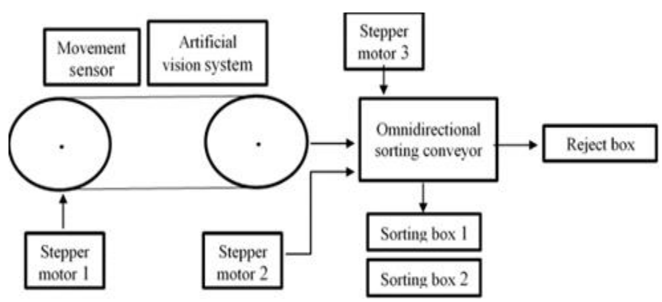

Figure 1. Outline of the system

2. DESIGN OF THE SYSTEM

2.1 Mechanical Structure Design and Control

Mechanism design was performed on a CAD software as shown in Figure 2 to determine all measures necessary for the construction of the machine.

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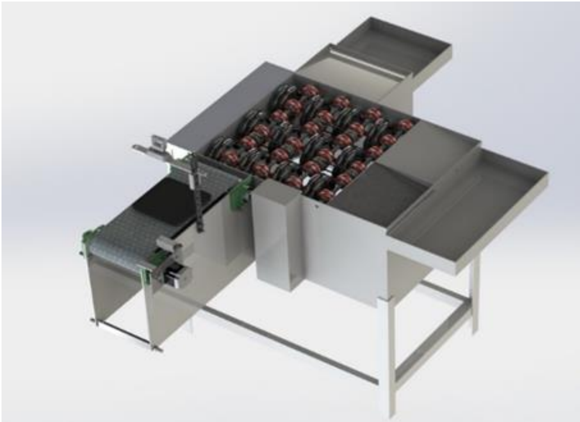

Figure 2. Mechanism model.

The machine consists of 10 main parts presented in Figure 3. The first part of the system consists of a stepper motor (1) which is responsible for moving the conveyor belt (2) when the movement sensor (3) detects an object at the beginning of the path. At the halfway point, there is the artificial vision system, which consists of a webcam (4), which allows taking information from the objects that are transported on a pallet (5). The omnidirectional mechanism formed by the stepper motors (6 & 7) which allow the movement of the omnidirectional wheels (8 & 9) [5] achieving that the piece mounted on the pallet is directed towards the corresponding container (10, 11 or 12) as the case may be.

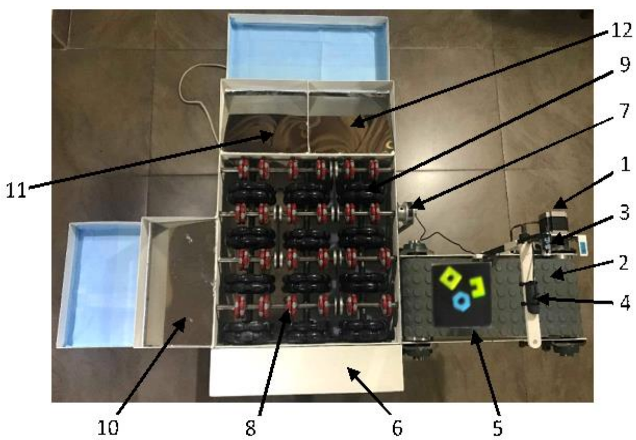

Figure 3. System components

The omnidirectional mechanism consists of a matrix of omnidirectional wheels that guide the product to its destination, placed in a configuration that allows movement on the horizontal axis X as well as on the vertical axis Y. To guarantee that the system does not present collisions the wheels that will move to the Y-axis as well as those of the X-axis were of different sizes and located according to Figure 4. Omnidirectional wheels of 48 mm were used, distributed 6 in each of the 4 horizontal axes, and omnidirectional wheels of 125 mm distributed 4 for each of the 3 vertical axes

The control of the mechanism is achieved by and Arduino UNO controller, the motion sensor and the drivers with for the motors, one for the conveyor and two for the omnidirectional mechanism, as shown in Figure 5.

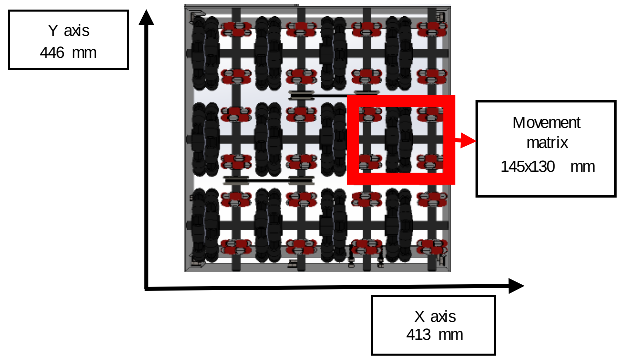

Figure 4. Omnidirectional mechanism.

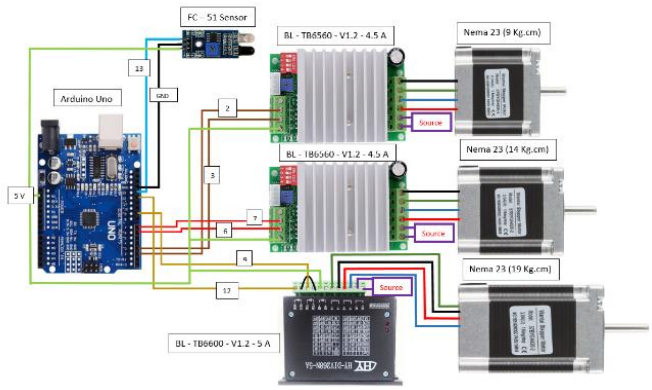

Figure 5. Electronic components.

2.2 Programming

The system requires a software that allows the control of the motors, depending on the piece that is identified by the artificial vision system and a neural network. A webcam acquires the image while a routine programmed using OpenCV and Qt Creator processed it through the use of neural networks [6] comparing the image captured with those of the database and classify it correctly. The operation of the software is shown in the flow diagram of Figure 6.

2.2.1 Image processing and neural network

Different algorithms are used to filter the images, which help reduce the noise so that the information obtained is as clear as possible as shown in Figure 7.

The operations used helped to detect the edges of the printed pieces, detect edges in the objects captured by the camera, eliminate the noises that inside and outside the region of interest, binarize and eliminate "salt and pepper" effect left in the image.

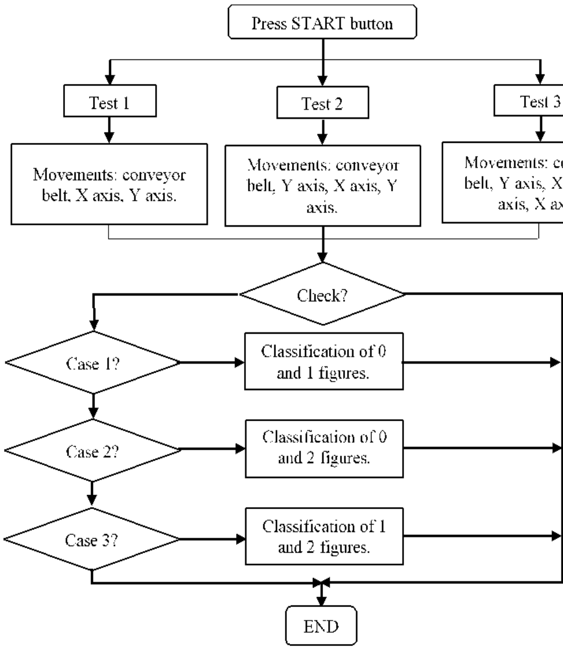

Figure 6. Flow diagram of the system software.

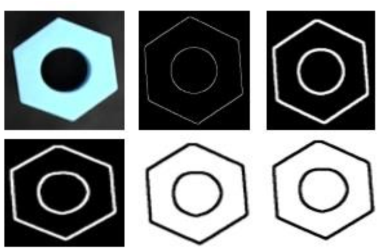

Figure 7. Stages of the image processing.

The classification and quality control were performed using a neural network that depends on the number of samples to guarantee reliable results, therefore several tests were carried out to define the error in the network when loading a certain number of images, obtaining the results shown in Table 1.

Table 1. Success rate with different amount of samples

Sample	Success rate
500	32%
1000	42%
1500	100%

According to the results of those tests, it was considered a neural network training with learning stage using 1500 samples for the training, 250 samples of each valid piece, one for noisy images and the last set with wrong samples. The architecture of the network is shown in Table 2

To verify the shape recognition, tests were performed with pieces of different dimensions as seen in Figure 8 and for quality control pieces with slight variations in their characteristics were used, as seen in Figure 9.

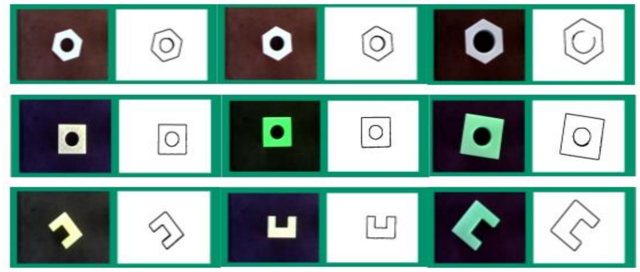

Figure 8. Pieces of different sizes used in tests.

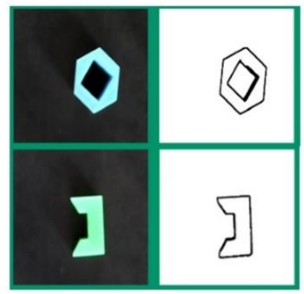

Figure 9. Pieces with different characteristics used in tests.

Table 2. Neural network architecture

Layer	Neurons
Input	256
Hidden	32
Output	5

2.2.2 Human-machine interface

In order to verify the status of each of the variables that govern the behavior of the system, the HMI shown in Figure 10 was implemented, in which the original and filtered images captured by the camera can be observed, as well as buttons and indicators to control and monitor the state of the device and a configuration test, which is mandatory to perform before using the system, ensuring that there are no malfunctions in the control software.

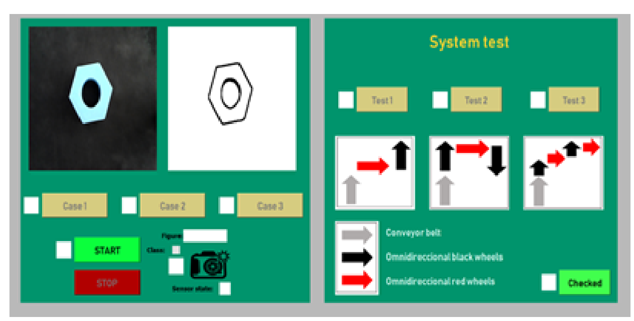

Figure 10. Graphic interface.

3. RESULTS

The artificial vision system is oriented to identify the part in different positions and orientations on the pallet, keeping the camera in the same position as seen in Figure 11. Also, the artificial vision system is not affected by changes in size as the field view of the camera is the entire area of the pallet, as shown in Figure 8.

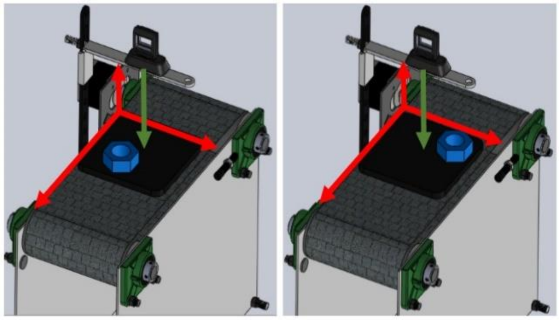

Figure 11. Different positions and orientation of the piece on the pallet.

The system is able to classify three different pieces: a hexagon with a hole, a square and a letter C shaped piece. During the tests, combinations of these were used to check the precise classification and transfer to the respective containers. Wrong pieces or those that do not belong to the selected combination were sent to container 3, as shown in Figures 12 to 14.

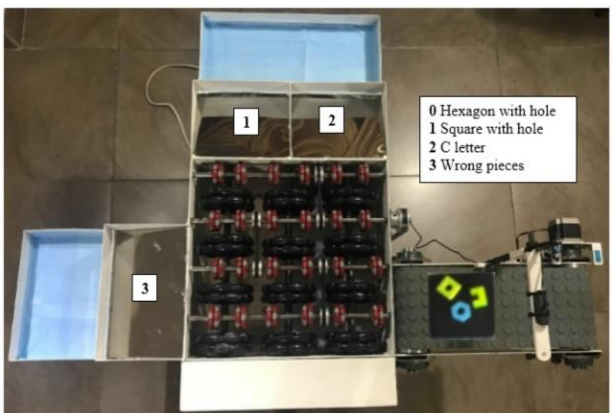

Figure 12. Combination 1 used for tests.

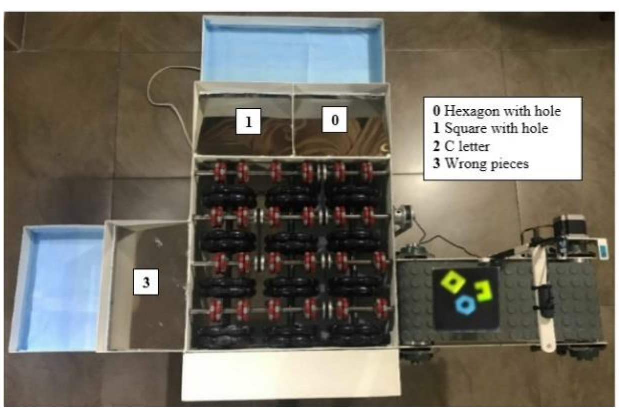

Figure 13. Combination 2 used for tests.

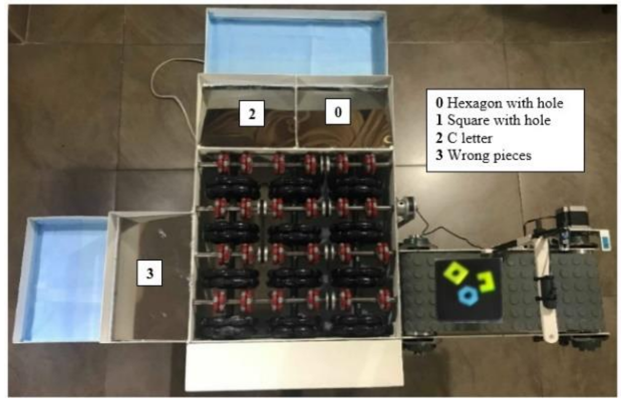

Figure 14. Combination 3 used for tests.

According to the tests conducted, it was possible to determine that the system is able to discretize between the pieces that have specific characteristics such as a hexagon with a circular hole to one with a square hole, detecting the second one as erroneous and locating it in its respective container. General results are shown in Table 3.

Table 3. General results of the system.

Test	Success rate
Classification and quality control	89%
Transfer	100%

The tests were performed in the system using three different pieces, although new pieces can be added by including a new class with the same number of samples as the previous classes, training the neural network again and setting the destiny of the new part.

Being the processing speed an important factor in this type of applications, it is important to distinguish two stages of the process: classification and transport. Classification stage can process three pieces per second, while the transportation system is capable to deliver 12 pieces to their respective deposits per minute. It should be noted that the system is governed by the first in-first out method, as it analyses one piece at a time.

4. CONCLUSIONS

The omnidirectional system achieved an optimization in the processes of transport and classification of pieces through the integration of a system of artificial vision and neural networks that allows the simultaneous development of these two activities. According to the results obtained, the system is capable of adequately performing and transmitting the destination information of the piece, achieving a global reliability of 89%.

In comparison with other systems, the present work has the advantages of being able to transport an object in multiple directions and thanks to the fact that it has artificial vision algorithms based on RNA it allows to detect several types of figures within the admitted range, its disadvantages are that it needs a high computational cost to function and presents problems with changes in lighting.

Regarding the transfer system, using an omnidirectional mechanism optimized space with respect to traditional systems like conventional conveyors by successfully guiding three different pieces in a short distance. On the other hand, the system will require a large number of actuators depending on the number of individual simultaneous movements required for each piece. While in this project, only two direction-movements were supported within the entire transfer area, to produce different simultaneous movements, a greater number of actuators will be expected, increasing the investment necessary for their implementation.

For these reasons, according to the results found with the implementation of this system, its application is efficient in systems that transport a piece sequentially, while in case of parallel inflow of products, a greater investment would be necessary to obtain the result wanted.

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