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FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería Mecatrónica

Tesis

Simulation of an Automated Tahitian Lemon Grading System Based on Computer Vision

Yadhira Samhira Valenzuela Lino
Jhon Rodrigo Ortiz Zacarias
Yordan Cesar Sullca Mendoza
Sliver Ivan del Carpio Ramirez
Nabilt Jill Moggiano Aburto
Carlos Alberto Coaquira Rojo

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Yo: Jhon Rodrigo Ortiz Zacarias, con Documento nacional de identidad (DNI) N° 71689110; teléfono 918224147; estudiante de la Escuela Académico Profesional de Ingeniería Mecatrónica.

Yo: Yordan Cesar Sullca Mendoza, con Documento nacional de identidad (DNI) N° 75527660; teléfono 965838786; estudiante de la Escuela Académico Profesional de Ingeniería Mecatrónica.

Yo: Sliver Ivan Del Carpio Ramirez, con Documento nacional de identidad (DNI) N° 71902502; teléfono 955427976; estudiante de la Escuela Académico Profesional de Ingeniería Mecatrónica.

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Fecha: 20/02/2024
DNI: 73105932

Nombre: Jhon Rodrigo Ortiz Zacarias
Fecha: 20/02/2024
DNI: 71689110

Nombre: Sliver Ivan Del Carpio Ramirez
Fecha: 20/02/2024
DNI: 71902502

Nombre: Yordan Cesar Sullca Mendoza
Fecha: 20/02/2024
DNI: 71902502

Nombre: Nabilt Jill Moggiano Aburto
Fecha: 20/02/2024
DNI: 45103226

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Simulation of an Automated Tahitian lemon grading system based on computer vision

Jhon Rodrigo Ortiz Zacarias
Department of Mechatronics Engineering
Universidad Continental
Huancayo, Peru
71689110@continental.edu.pe

Yordan Cesar Sullca-Mendoza
Department of Mechatronics Engineering
Universidad Continental
Huancayo, Peru
75527660@continental.edu.pe

Yadhira S. Valenzuela-Lino
Department of Mechatronics Engineering
Universidad Continental
Huancayo, Peru
73105932@continental.edu.pe

Sliver Ivan Del Carpio-Ramirez
Department of Mechatronics Engineering
Universidad Continental
Huancayo, Peru
71902502@continental.edu.pe

Nabilt Moggiano
Engineering Research Unit
Faculty of Engineering
Universidad Continental
Huancayo, Peru
nmoggiano@continental.edu.pe

Carlos Coaquira-Rojo
Department of Mechatronics Engineering
Universidad Continental
Huancayo, Peru
ccoaquira@continental.edu.pe

Abstract- Lemon exports are of great influence in Peru, since there is a great demand from countries such as the USA, Belgium and Holland. For this reason, the agricultural sector is one of the essential factors for the economic development of the country, since it generates S/29,553 million annually throughout the national territory. On the other hand, Peru offers two types of lemons, for example: the Tahitian lemon and the subtle lemon; however, due to its characteristics, the Tahitian lemon is the one that is sent as an export product worldwide. Currently, the selection process of this fruit is done manually, since there are not enough industrial optimizations in its process. Therefore, the present study aims to carry out the simulation of an automated grading system for Tahitian lemon based on computer vision. The selection parameters for the image processing were established as the levels of ripeness of the lemon: early ripening, medium ripening, ripe and stale. This selection was implemented due to the need to comply with the quality standards required by the Free Trade Agreements (FTA). As a result, the selection simulation was obtained through a conveyor belt, where the fruit passed through the computer vision, which determined the route of the fruit. Finally, it was concluded that through automation it is possible to optimize the selection time of food products.

Keywords-Lemon, Selection, Ripening, Image processing, Simulation, Automation.

I. INTRODUCTION

The agricultural sector is fundamental for economic development in Peru, given that according to the Institute of Statistics and Informatics (INEI) in 2019 the agricultural sector generated S/ 29,553 million in total within the national territory in the January-September period; that is, 5.4% of the total GDP in that year [1]. On the other hand, lemon is a permanent crop in the country, since it is harvested and planted all year round. Harvesting takes place 4 years after the planting period; in addition, the economic life of the crop lasts 15 years. The most important export destinations are Chile, Panama, USA, Holland and Belgium [2].

On the other hand, lemon is one of the most widely used fruits in Peru because it is one of the cheapest sources of vitamin C and antioxidants, and compared to other citrus fruits, its ripening process is faster; therefore, there is a need for farmers to take different precautions so that their production does not rot. In addition, the ripening stages of lemons can be seen in their acidity level [3].

Peru offers particularly 2 varieties of lemons due to geographical conditions. In the first place, the Tahitian lemon is characterized by its larger than average size, has no seed and is less acidic. Secondly, there is the subtle lemon in which its acidity stands out, since it is more acidic than the Tahiti lemon, it is greenish in color and preserves a citric fragrance. Because of its properties, the Tahitian lemon is highly demanded in the international market, and therefore, this is the only variety of lemon exported [4].

On the other hand, according to free trade agreements, there are clauses and quality standards to which export foods are subject [5]. The quality presentation factors of fruits are mostly evaluated by their size, shape, existence of bruises; in other words, the external quality of the fruits is essential in their sales, for this reason the color of the fruits also has a fundamental value in their selection [6].

Given this problem, growers in the current scenario sort fruit manually, which generates many hours of work and slow production and even leads to errors in color analysis due to eye fatigue and tiredness [7]. However, a solution can be exercised by using advanced software, since the application of computer technology for process automation is of great relevance nowadays [8-9-10]. Similarly, image capturing systems for digital processing are considered important tools for obtaining relevant data and aiding decision making [11].

Recent research such as [8], developed an algorithm suitable for recognizing lemons in real time using the color index, range segmentation in the CieLAB color scheme, mathematical morphology and the Kuhn-Munkres tracking algorithm. The results obtained from these techniques showed an accuracy rate of over 95% with an average error of 4.45% between the visual fruit count and the algorithm count. Subsequently, it was concluded that conditions such as natural light, tracking speed, spatial and radiometric resolution of the image are variables to be taken into account and modified so that the algorithm has the capacity to generalize and obtain acceptable results.

The objective of this research is to develop the simulation of an Automated System for the classification of Tahiti lemons based on computer vision, because it is important to point out the efficiency of production and reduce human errors in the selection of lemons, therefore, four types of selection were established within the process according to the ripening cycle: early ripening, medium ripening, ripe and spoiled. Image processing was used to identify the parameters of these

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lemons; they were also moved along a conveyor belt. As a result, the immediate classification through the parameters was obtained, in addition to counting the number of lemons that go to each conveyor sub-belt. Finally, it was concluded that these parameters optimized the sorting time and accounted for the amount of lemons segregated per day through the Factory IO environment.

II. Materials and Methods

It is extremely important to automate the selection of Peruvian lemons because there are two varieties. However, according to the Ministry of Agriculture, Peru only exports one type of lemon called "Tahiti lemon", [12] which must be in perfect condition and free of diseases. Therefore, automation will not only control this, but also the degree of ripeness through the color of the fruit, since there is a degree of variety in the acidity of the fruit [3], so that the final consumer can choose according to his taste preference.

1) Lemon ripening

This fruit is able to reach a rapid ripening compared to other citrus fruits, where its degree of ripening can be identified through the acidity levels or its fruit color [3]. In the present study, the automation of the selection process is carried out through the physical appearance of the fruit, as detailed in the following Fig. 1.

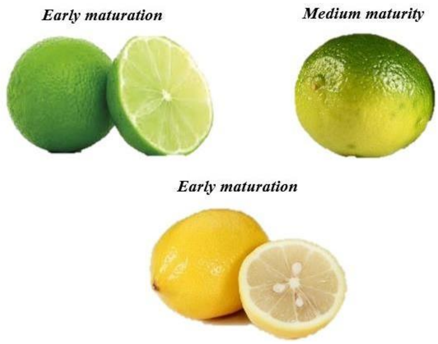

Fig. 1. Lemon ripening stages.

As shown in Fig. 1, the early stage of lemon ripening is where it achieves a dark green color, high acidity level and a rough texture. In the middle stage, it tends to a greenish-yellow color, reduced acidity level and smooth texture. The final ripening stage acquires an intense yellow color with very low acidity with a smooth and shiny texture [3]. By means of these selection parameters, the final customer will be able to choose the degree of acidity he wants or requires to use.

B. Phytopathology

It is important to take into account the external quality of the fruit, since this intervenes with the eventual sales, this factor influences the income when the consumer chooses to buy, and it is also one of the main factors that determine and evaluate the quality of the product [7].

It was detected that several pests affected lemon and citrus leaves with very serious diseases in temperate climate areas of Southeast Asian countries, with efficient grading can reduce a large loss of fruits with diseases [13]. Research has been carried out for decades due to the increasing supply and demand that the product has and in the detection of lemon diseases, one of the draconian effect diseases in lemon production is canker [14].

For this purpose, in Fig. 2, an investigation of the diseases or pests that lemons acquire was carried out to identify and be able to carry out an immediate separation, thus preventing other lemons from acquiring this disease.

Fig. 2. Lemon diseases.

C. Design of selection system

There is a serious problem in the classification of lemon color when an individual performs this function because the vision system generates errors due to stress and fatigue. Therefore, the development of technologies to perform detection by color image processing has arisen [7]. A main tool used for fruit classification is machine vision, which is composed of algorithms to mimic the functioning of the brain because it uses neural networks [15], but in the current scenario in which we live, vendors retain the approach of classifying the fruit manually through the colors of the fruit, which requires many hours of work and leads to errors in the analysis [7].

This automation is intended to prevent workers from constant fatigue and stress, since the classification will be implemented through images, with the conversion of the fruit to grayscales to create a representation in binary form, generating a great advantage because it has a threshold to assign a value from 255 to 0, giving whether the value is higher or lower for each pixel.

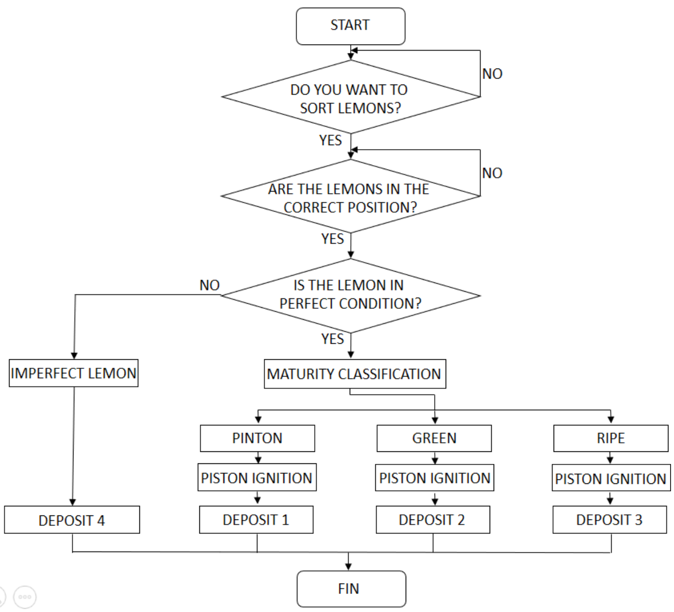

Fig. 3. Flowchart of the automated process

For an optimal automation process, the flow control was developed based on the ANSI structural standard [16-17], starting when the user wants to make the selection of lemon ripening, once approved, the correct validation of the position of the fruit is performed to evaluate the state of the fruit through images, if it is not in perfect condition, a piston is activated to separate the product in good quality, otherwise the degree of ripeness is evaluated and according to this it is placed in the early, medium or final ripening section, as shown in Fig. 3.

The following Fig. 4 covers the implementation of the system in a simulated approach, where the drivers used in the Factory IO software are shown, as well as the sensors and actuators such as fuzzy sensor, Vision sensor, conveyor belts, electric pistons, control box and boxes that simulate the different degrees of ripening of the lemons, which will be used for the connections through the OPC server; besides including the TIA Portal software for the automation of the system as the HMI (Human-Machine Interface) with this will have an optimal supervision of counting lemons.

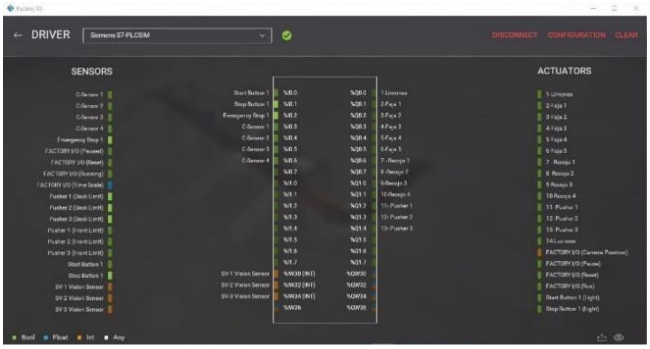

Fig. 4. Factory IO environment input and output controllers.

In Fig. 5 shows the Ladder programming which is composed of counters where the HMI environment is in charge of displaying the final quantity of the different ranges of ripeness of the lemons during a set time.

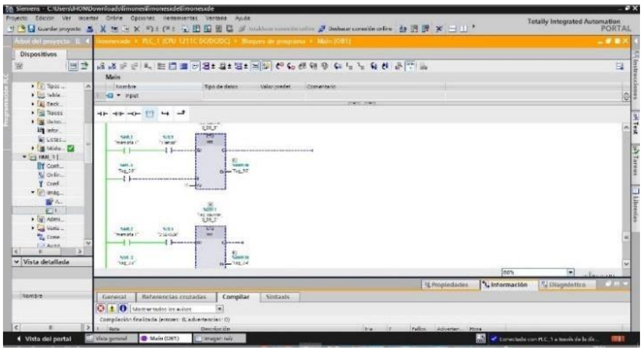

Fig. 5. Ladder programming of meters in TIA Portal software.

III. RESULT

In Fig. 6 shows the Ladder programming, where the function of the vision sensor is to detect the colors, in this case it detects the light blue box, activates an electric piston that moves these lemons to a tank so we can say that it classifies them by their ripening ranges and each process is similar so we have 4 different tanks.

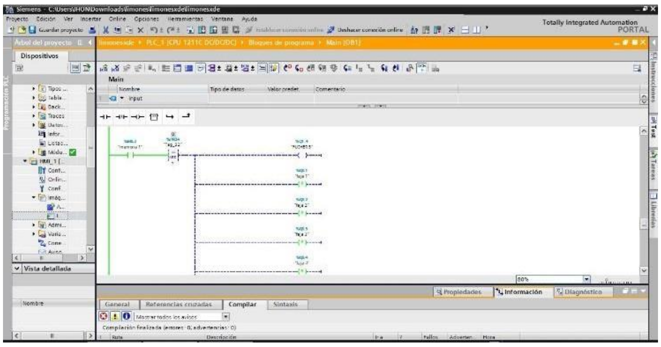

Fig. 6. Ladder programming of Vision sensor detection in TIA Portal software.

In Fig. 7 shows an alarm, which simulates the response obtained from the vision sensor, where, according to what is detected, it is classified by the lemon's ripeness ranges and sent to 4 different bins. These ranges are: early ripening, medium ripening, ripe and spoiled lemon.

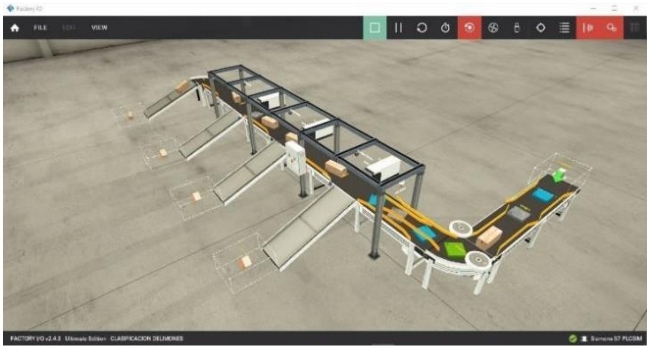

Fig. 7. Simulation of lemon ripening ranges in the Factory IO environment.

In Fig. 8 shows the first classification of the Pintón lemon ripeness range, where it is simulated with the light blue boxes, where the vision sensor detects this color and activates the first electric piston and sends it to the first tank.

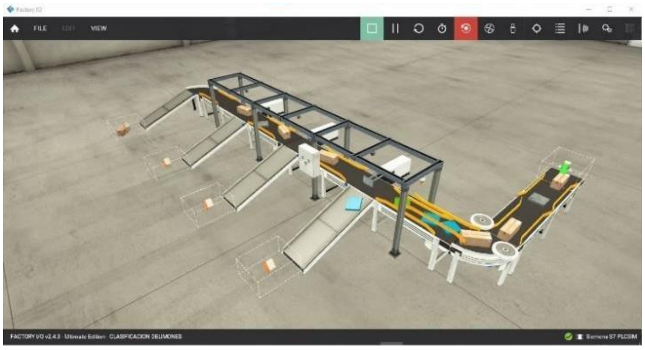

Fig. 8. Detection of light blue boxes (Limon Pinton).

In Fig. 9 shows the second classification of the Green lemon ripeness range, where it is simulated with the green boxes, where the vision sensor detects this color and activates the second electric piston and sends it to the second tank.

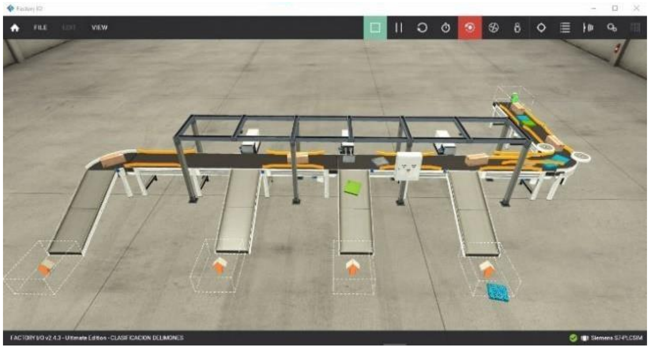

Fig. 9. Detection of green boxes (Green Lemon).

In Fig. 10 shows the third classification of the ripeness range of Ripe lemon, where it is simulated with the lead box, where the vision sensor detects this color and activates the third electric piston and sends it to the third tank.

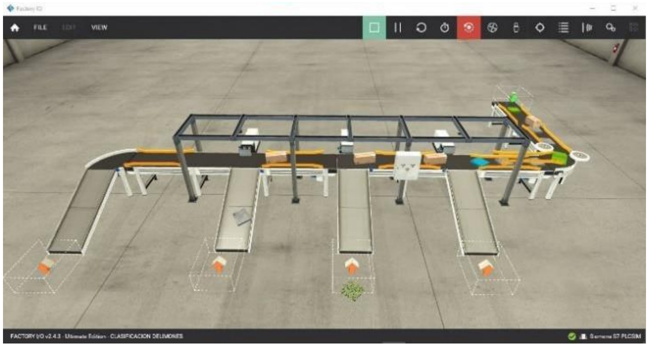

Fig. 10. Lead box detection (Ripe Lemon).

In Fig. 11 the last classification of lemons is observed, in this case it was considered lemon in bad condition (rotten), where it is simulated with brown boxes, as can be seen in the last classification it no longer uses the vision sensor because the first 3 sensors separate the different degrees of ripeness of the lemons and this is sent to the fourth deposit.

Fig. 11. Detection of brown boxes (rotten lemon).

In Fig. 12 shows the HMI environment, which will maintain direct communication with the user, where a counter system was implemented to monitor the amount of sorting of the different ranges of lemons.

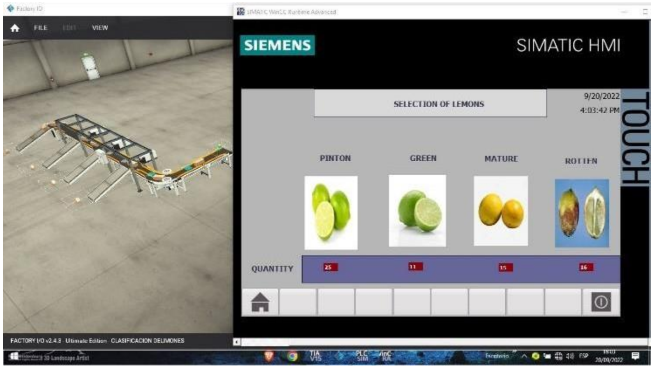

Fig. 12. HMI environment connection between TIA Portal software and Factory IO.

In Fig. 13 shows the execution of the system programming; where the system starts and stop control is presented, as well as the emergency control; in addition, the first row of the programming shows the communication between the TIA Portal software and Factory IO.

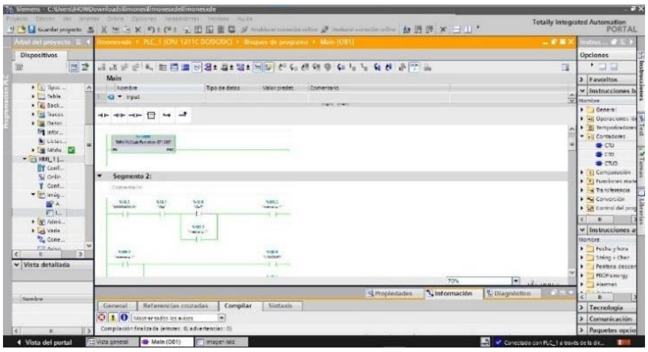

Fig. 13. Compilation of PLC programming in TIA Portal software.

In Fig. 14 shows the Factory IO environment, where a control box can be visualized in case of unforeseen accumulations or failures, the process is stopped, which is installed in a control box with an on/off push button for the whole system; in addition, to ensure any system failure, an emergency stop button is available.

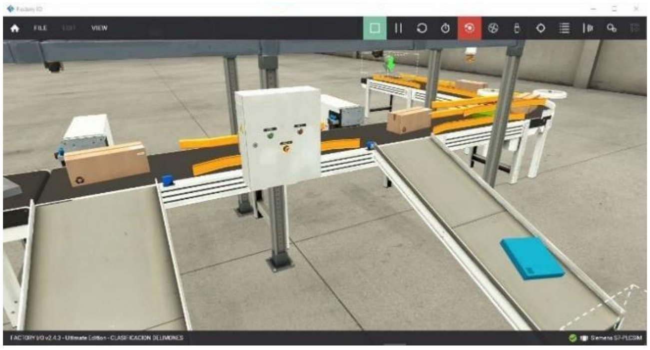

Fig. 14. Control box design.

The algorithm starts by entering an image of a lemon, converts it into a grayscale RGB image, obtaining a threshold value scaled between 0.0 where most values are close to a distribution, shape and scale (gamma), which projects 3 images at the same time and sends a result already validated by MATLAB software.

A simulated model was developed to determine the control of the ripening range of lemons, since they have to meet certain criteria of shape and color; for this reason a programming was developed where the system sends a message, which indicates several characteristics of the lemons, for example: if the lemon has black spots, if it is not consumable, if it is deformed, if the lemon is in good condition, if it is consumable or if it has the correct shape.

Therefore, Fig. 15 shows that an image of a PINTON LEMON has been entered, where the system tells the user at the bottom center of the MATLAB software that citrus Aurantifolia of class "Pinton", the lemon is in good condition, CONSUMABLE and has the CORRECT shape.

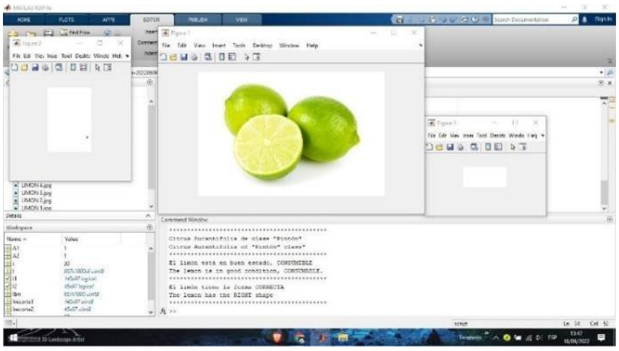

Fig. 15. Image processing of the PINTON lemon.

Therefore, Fig. 16 shows that an image of a BAD (Rotten) LEMON has been entered, where the system tells the user at the bottom center of the MATLAB software that Lemon in bad condition, the lemon has black spots, NOT CONSUMABLE and the lemon has the CORRECT shape.

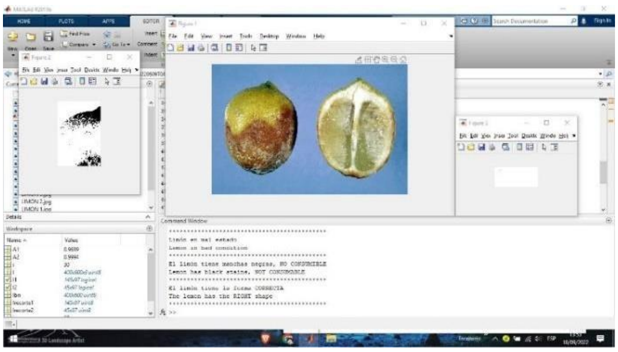

Fig. 16. Image processing of the PODRIDO lemon.

Therefore, Fig. 17 shows that an image of a RIPENED LEMON has been entered, where the system tells the user at the bottom center of the MATLAB software that citrus Aurantifolia of class "Ripe", the lemon is in good condition, CONSUMABLE and has the CORRECT shape.

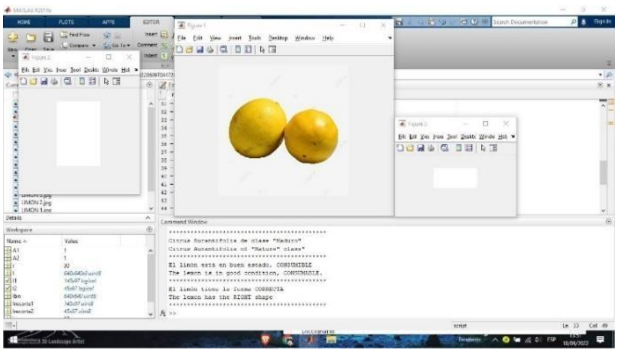

Fig. 17. Image processing of the MADURO lemon.

Therefore, Fig. 18 shows that an image of a Green LEMON has been entered, where the system tells the user at the bottom center of the MATLAB software that citrus Aurantifolia of class "Green", the lemon is in good condition, CONSUMABLE and has the CORRECT shape.

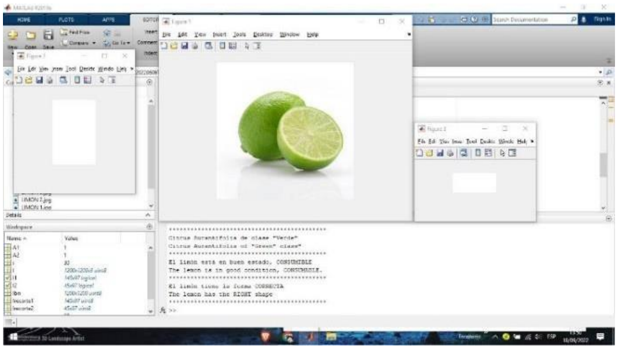

Fig. 18. Image processing of the GREEN lemon.

DISCUSSION

According to the research [18] the authors proposed a tomato sorting machine, whose objective was to provide quality tomatoes, which meet the market standards. The variables chosen for their selection were the ripening stage, i.e. ripe tomato and unripe tomato according to their color; they also added TCS3200 RGB color sensors. The overall frame accuracy of 93.33% was obtained as a result, where 1500 tomatoes per hour were evaluated with an expandable channel. Finally, it was concluded that in the proposed system the tomatoes pass in a straight line on a slope up to the characterization point.

The present research on the simulation of an automated grading system for Tahiti lemons based on computer vision focused on the design of the selection of the ripening stage of the lemons, since, due to their exportation, they must comply with various Free Trade Agreements (FTA) that consider the quality of the food product. However, it was also important to prioritize production selection times, since these must be reduced in order to optimize costs. For this reason, counters were installed in each lemon selection belt, which allow us to know the quantity of lemons selected per day, which will be stored. Finally, through the HMI interface there will be an effective communication between man and machine, since it will be through the machine that the amount of production selected per day will be visible.

APPENDIXES

In this section you can see Fig. 15-18, where you can see the results of the image processing of the different types of lemons such as PINTON, RIPEN, GREEN and PODRIDO.

https://drive.google.com/file/d/1otBDU32LIz4A8GbGRT4qhL0zoXUvKx5M/view?usp=sharing

CONCLUSIONS

To conclude with the research, the results obtained from the simulation of the control system that is focused on the degree of maturity of Tahiti lemons produced in Peru, this contributes to significantly improve the efficiency of the processes of classification of ripeness ranges of lemons for excellent exportation. The study also presents an HMI (human-machine interface) environment that makes it reliable and useful for users, since a lemon sorting counter system was implemented in the evaluation process in real time for easy supervision of users. On the other hand, the system is able to identify a problem or error in general, also the TIA Portal and Factory IO software was used to simulate the process, which starts with the positioning of the lemons to be moved along a conveyor belt, to reach the census process and once detected the color (degree of maturity) of each lemon, the pistons will be activated according to each color, As can be seen in the simulation, when the vision sensor detects the light blue box (lemon pinto) it goes to deposit 1, on the other hand, if the green box (green lemon) is detected it goes to deposit 2, the lead box (ripe lemon) is also detected it goes to deposit 3 and finally, as the vision sensor detects the 3 ranges of maturity, the lemon in bad condition (rotten lemon) is discarded and it goes to deposit 4.

The export of Peruvian lemons is a fundamental factor in the Peruvian economic sector. Thanks to this automation, traders will be able to select the lemons according to their degree of ripeness by means of computer vision, preventing employees from being exposed to labor-intensive work and producing errors in the process. In addition, this system will discard fruit with diseases or malformations in order to obtain optimum quality for the end consumer. This design will optimize time in the classification and storage of lemons to be exported due to their great supply and demand in several countries.

With this automated process it will be possible to distribute to the market a greater production of lemon, considered one of the cheapest sources of vitamin C, achieving a greater reach to people to strengthen their immune system and its great consumption in food. With the objective to reduce the time in the process and to be able to separate the infected fruits to avoid the contagion of the diseases. Being a very important subject of research for its great supply and demand at international level, besides being a fruit with great nutritional value.

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