Universidad Continental

FACULTAD DE INGENIERÍA

Escuela Académico Profesional de Ingeniería Mecatrónica

Tesis

Simulation of an Automated Sorting System for Peruvian Mangoes Based on Computer Vision

Michael Cristhian Rivera Rojas
Maydelson Valentin Yanarico Estrella
Jhon Rodrigo Ortiz Zacarias
Iraiz Lucero Quintanilla Mosquera
Yadhira Samhira Valenzuela Lino
Carlos Alberto Coaquira Rojo

Para optar el Título Profesional de
Ingeniero Mecatrónico

Huancayo, 2023

Universidad Continental

INFORME DE CONFORMIDAD DE ORIGINALIDAD DE TESIS: EN FORMATO ARTÍCULO CIENTÍFICO

A	**:**	Dr. Felipe Néstor Gutarra Meza Decano de la Facultad de Ingeniería
DE	**:**	Carlos Alberto Coaquira Rojo Asesor de tesis
ASUNTO	**:**	Remito resultado de evaluación de originalidad de tesis
FECHA	**:**	08 de diciembre del 2023

Con sumo agrado me dirijo a vuestro despacho para saludarlo y en vista de haber sido designado asesor de la tesis titulada: "Simulation of an Automated Sorting System for Peruvian mangoes based on computer vision", perteneciente al/la/los/las estudiante(s) Michael Cristhian Rivera Rojas y Maydelson Valentin Yanarico Estrella, de la E.A.P. de Ingeniería Mecatrónica; se procedió con la carga del documento a la plataforma "Turnitin" y se realizó la verificación completa de las coincidencias resaltadas por el software dando por resultado 19 % de similitud (informe adjunto) sin encontrarse hallazgos relacionados a plagio. Se utilizaron los siguientes filtros:

	SI	NO
• Filtro de exclusión de bibliografía		X
• Filtro de exclusión de grupos de palabras menores (Nº de palabras excluidas:)		X
• Exclusión de fuente por trabajo anterior del mismo estudiante	X	

En consecuencia, se determina que la tesis en formato artículo científico constituye un documento original al presentar similitud de otros autores (citas) por debajo del porcentaje establecido por la Universidad.

Recae toda responsabilidad del contenido la tesis en formato artículo científico sobre el autor y asesor, en concordancia a los principios de legalidad, presunción de veracidad y simplicidad, expresados en el Reglamento del Registro Nacional de Trabajos de Investigación para optar grados académicos y títulos profesionales – RENATI y en la Directiva 003-2016-R/UC.

Esperando la atención a la presente, me despido sin otro particular y sea propicia la ocasión para renovar las muestras de mi especial consideración.

Atentamente,

CCoaquiraR

Asesor de tesis
Carlos Alberto Coaquira Rojo

Cc.
Facultad
Oficina de Grados y Títulos
Interesado(a)

Universidad Continental

DECLARACIÓN JURADA DE AUTORÍA

El presente documento tiene por finalidad declarar adecuada y explícitamente el aporte de cada estudiante en la elaboración del artículo de investigación a ser utilizado para la sustentación de tesis: formato de artículo científico.

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: MICHAEL CRISTHIAN RIVERA ROJAS, con Documento nacional de identidad (DNI) N° 72723326; teléfono 902249959; estudiante de la Escuela Académico Profesional de Ingeniería Mecatrónica.

Yo: MAYDELSON VALENTIN YANARICO ESTRELLA, con Documento nacional de identidad (DNI) N° 72177264; teléfono 988260076; estudiante de la Escuela Académico Profesional de Ingeniería Mecatrónica.

Yo: IRAIZ LUCERO QUINTANILLA MOSQUERA, con Documento nacional de identidad (DNI) N° 70347500; teléfono 940730996; estudiante de la Escuela Académico Profesional de Ingeniería Mecatrónica.

Yo: YADHIRA SAMHIRA VALENZUELA LINO, con Documento nacional de identidad (DNI) N° 73105932; teléfono 917561384; estudiante de la Escuela Académico Profesional de Ingeniería Mecatrónica.

Yo: CARLOS ALBERTO COAQUIRA ROJO, con Documento nacional de identidad (DNI) N° 20049057; teléfono 94203799; Director de la Escuela Académico Profesional de Ingeniería Mecatrónica.

Ante Usted, con el debido respeto me presento y expongo:

Declaramos que hemos participado en la ideación del problema, recolección de datos, elaboración y aprobación final del artículo científico.

Nombre: JHON RODRIGO ORTIZ ZACARIAS

Fecha: 29/06/2023

DNI: 71689110

Nombre: MICHAEL CRISTHIAN RIVERA ROJAS

Fecha: 29/06/2023

DNI: 72723326

Nombre: MAYDELSON VALENTIN YANARICO ESTRELLA

Fecha: 29/06/2023

DNI: 72177264

Nombre: IRAIZ LUCERO QUINTANILLA MOSQUERA

Fecha: 12/12/2023

DNI: 70347500

Nombre: YADHIRA SAMHIRA VALENZUELA LINO

Fecha: 12/12/2023

DNI: 73105932

Nombre: CARLOS ALBERTO COAQUIRA ROJO

Fecha: 12/12/2023

DNI: 20049057

V.B. del asesor designado

Simulation of an Automated Sorting System for Peruvian mangoes based on computer vision

INFORME DE ORIGINALIDAD

19%	13%	9%	6%
INDICE DE SIMILITUD	FUENTES DE INTERNET	PUBLICACIONES	TRABAJOS DEL ESTUDIANTE

FUENTES PRIMARIAS

1	www.researchsquare.com Fuente de Internet	1%
2	Julio Vera Sancho, Keyda De la Gala Quispe, Klinge Villalba Condori. "Chapter 25 Storytelling with Holograms for the Development of Reading Competence", Springer Science and Business Media LLC, 2019 Publicación	1%
3	Submitted to Universidad de Málaga - Tii Trabajo del estudiante	1%
4	Mar Ferrer-Ferrer, Javier Ruiz-Hidalgo, Eduard Gregorio, Verónica Vilaplana, Josep-Ramon Morros, Jordi Gené-Mola. "Simultaneous fruit detection and size estimation using multitask deep neural networks", Biosystems Engineering, 2023 Publicación	1%
5	www.ijstr.org Fuente de Internet	

1%

6	eurchembull.com Fuente de Internet	1%
7	thesai.org Fuente de Internet	1%
8	Faiz Ainur Razi, Alhadi Bustamam, Arnida L. Latifah. "Development of Efficient Brain Tumor Classification on MRI Image Results Using EfficientNet", 2023 International Seminar on Intelligent Technology and Its Applications (ISITIA), 2023 Publicación	1%
9	Submitted to University of East London Trabajo del estudiante	1%
10	www.researchgate.net Fuente de Internet	1%
11	i-scholar.in Fuente de Internet	1%
12	www.colpos.mx Fuente de Internet	1%
13	Submitted to University of the Philippines Los Banos Trabajo del estudiante	1%
14	eprints.uet.vnu.edu.vn Fuente de Internet	

1%

15	Submitted to Universidad Nacional Abierta y a Distancia, UNAD,UNAD Trabajo del estudiante	1%
16	icrepq.com Fuente de Internet	1%
17	computerresearch.org Fuente de Internet	1%
18	www.jurnalet.com Fuente de Internet	1%
19	Meer Hannan Dairath, M. Waqar Akram, M. Ahmad Mehmood, H. Umair Sarwar, M. Zuhaib Akram, M. Mubashar Omar, M. Faheem. "Computer vision-based prototype robotic picking cum grading system for fruits", Smart Agricultural Technology, 2023 Publicación	<1%
20	feeval.org Fuente de Internet	<1%
21	login.easychair.org Fuente de Internet	<1%
22	www.sidalc.net Fuente de Internet	<1%
23	dokumen.pub Fuente de Internet	

<1%

24	Submitted to University of New South Wales Trabajo del estudiante	<1%
25	"Table of Contents", 2021 6th International Conference on Robotics and Automation Engineering (ICRAE), 2021 Publicación	<1%
26	Submitted to Queen Mary and Westfield College Trabajo del estudiante	<1%
27	Krzysztof Baszczyński. "Effects of Safety Harnesses Protecting against Falls from a Height on the User’s Body in Suspension", International Journal of Environmental Research and Public Health, 2022 Publicación	<1%
28	www.ncbi.nlm.nih.gov Fuente de Internet	<1%
29	cdn.www.gob.pe Fuente de Internet	<1%
30	cybertesis.unmsm.edu.pe Fuente de Internet	<1%
31	documentop.com Fuente de Internet	<1%

32	indutwin.de Fuente de Internet	<1%

Excluir citas	Apagado	Excluir coincidencias	Apagado
Excluir bibliografía	Apagado		

Simulation of an Automated Sorting System for Peruvian mangoes based on computer vision

INFORME DE GRADEMARK

NOTA FINAL

/0

COMENTARIOS GENERALES

PÁGINA 1

PÁGINA 2

PÁGINA 3

PÁGINA 4

PÁGINA 5

PÁGINA 6

Simulation of an Automated Sorting System for Peruvian mangoes based on computer vision

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

Michael Cristhian Rivera-Rojas
Department of Mechatronics Engineering
Universidad Continental
Huancayo, Peru
72723326@continental.edu.pe

Maydelson Valentin Yanarico-Estrella
Department of Mechatronics Engineering
Universidad Continental
Huancayo, Peru
72177264@continental.edu.pe

Iraiz Lucero Quintanilla-Mosquera
Department of Mechatronics Engineering
Universidad Continental
Huancayo, Peru
70347500@continental.edu.pe

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

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

***Abstract*— Agriculture is one of the most important economic activities in Peru. Furthermore, the Peruvian mango is the most important fruit as an export product on the European market due to its good quality. Three varieties of mango are cultivated in Peru: Haden, Kent and Tommy Atkins, each of them presents different characteristics; however, the production of this fruit is affected because manual processes are still used for its production, which generates a delay in the process due to the inaccuracy of the labour. The present study aims to develop the simulation of an automated grading system for Peruvian mangoes based on computer vision. On the other hand, to establish the process development, the transfer learning principle was analysed and a flow diagram of the system was made. The simulation of the system environment was obtained through the Factory IO software, together with the image processing through the Matlab software, in which the characteristics of the three mango varieties were introduced; therefore, with this information, the system was able to carry out the mango selection. Finally, it was concluded that the presented design optimises the selection and storage time of the mangoes, as well as automating the labour in the process.**

Keywords*— *Agriculture, mango, production, automation, gray scale.

I. INTRODUCTION

Agriculture is a major economic activity in Peru, since according to figures from the National Institute of Statistics and Information (INEI), in 2019 it generated S/. 29,553 million with 5.4% of the total GDP in that year [1]. Additionally, mango is Peru's main export fruit, since it is recognised in international markets for its high quality, likewise the main export destinations for this fruit have been: The United States and the countries of the European Union in which the United Kingdom stands out [2].

On the other hand, mango is a perennial plant that is usually produced in the coastal areas of Peru; however, there is currently a great variety of mango cultivated in the world [3]. However, three varieties are produced in Peru, which are described below: firstly, the Haden mango, which has a bright red colour with green and yellow shades, and is usually round to oval in shape. Secondly, there is the Kent mango, which is recognised by its dark green colour and oval shape; it also has a juicy and tender flesh. Finally, the Tommy Atkins mango, which is characterised by being small and oval; due to its fibrous constitution, it has a firm flesh [4].

Despite the high demand for mangoes on the international market, Peruvian farmers have problems with the mango grading system, since this process is carried out manually, which causes a delay in production and increases costs [5]. Of equal importance, another substantial problem are the known mango diseases; for example, anthracnose, which causes the fruit to rot from the end of the stem due to diplodia. Similarly, insect pests such as weevils, leafhoppers and capsid bugs cause diseases that lead to fruit losses, as farmers fail to identify them in time, thus reducing production efficiency [6]-[7].

Although there are several systems and applications that help the agricultural industry to produce more crops today, an automated system capable of classifying mangoes through image processing has not yet been developed in Peru [8]. Additionally, there is a need to develop fast and simple classification models with the intention that they can be implemented on embedded computers with limited constraints [9].

Recent research has proposed methodologies to classify various types of fruits according to their internal and external characteristics and do not employ destructive techniques [10]. For example, the study [11], which presented an algorithm based on neural networks and statistical approaches, which was in charge of classifying mango and other fruits through a simple camera; in addition, they considered parameters such as weight, size, ripeness and colour of the fruit. So they concluded to establish a speed of 40 rpm for the motor of the belts taking into account that this speed allowed an optimal precision in the classification of the fruits.

On the other hand, the present research differs in that it aims to develop the simulation of an automated mango sorting system based on computer vision, where mainly through various parameters, good quality mangoes of the three varieties existing in Peru described above were selected; consequently, after going through image processing, they were directed through conveyor belts to be stored or discarded, depending on the conditions of the fruit. Finally, such action minimises human interaction and optimises production time.

II. Materials and Methods

The automated design is aimed at grading mangoes efficiently and with an innovative selection system, which uses artificial vision for a fruit that is produced in Peru on a large scale, the mango, since manual detection of diseases is not a feasible option due to the lack of availability of experts in the area [12]-[13]-[15], for this selection must take into account the varieties of this fruit in the country: Mango Haden, Kent and Tommy Atkins [13].

It is important to note the definition of the classification, as shown in Table 2 [5]. The values represented are weight in relation to size and in the next column a margin of error of 10% is taken into account.

TABLE 1. Weight in relation to handle size.

Size Code	Standard Range (Grams)	10% Allowed
A	From 200 to 350	From 180 to 425
B	From 351 to 550	From 251 to 650
C	From 551 to 800	From 426 to 925

Just as humans use our eyes and brains to understand the world around us, computer vision tries to produce the same effect so that computers can perceive and understand an image or sequence of images and act as appropriate in a given situation. Within the field of computer vision are artificial intelligence and machine learning. With the intervention of these two elements, the selection of mangoes for further production will be carried out.

A. Plant pathology

As mentioned above, fruit selection in the country is done through manual inspection; therefore, the main problem is the time spent in this action, which causes deterioration of the mangoes and thus loss of income [14]-[15]. In addition, all problems or diseases (pests) in mangoes are not detected manually, and in this context it is crucial to detect the disease and separate the bad fruits in an automated way, as this makes the separation faster and more accurate, as there are not enough specialists to do the manual sorting themselves.

The various diseases can be caused by fungi, bacteria, viral problems or environmental conditions. The two main diseases are anthracnose and mango scab, which will be considered in the image recognition algorithm [14].

On the other hand, environmental conditions such as humidity and temperature ranging from 24° C to 32°C make it easy for these diseases to develop [5]-[14].

TABLE 2. Main mango diseases.

	
Mango Anthracnose	Mango scab

B. Design of the selection system

Machine vision is the main tool for sorting mangoes, as it uses neural networks and algorithms to mimic the functioning of the brain [8]. This technology can achieve a high degree of flexibility and repeatability without compromising accuracy; moreover, for better resolution, the use of a monochrome camera is indispensable compared to a colour camera [16]-[18].

Greyscale conversion is used to create a binary representation of the image [19], in order to emphasise each specific area. One of its advantages is the classification of each pixel by considering a threshold to assign a value from 0 to 255 if the value is lower or higher than the threshold.

The schematic diagram of the transfer learning principle is shown in Fig. 1 [17].

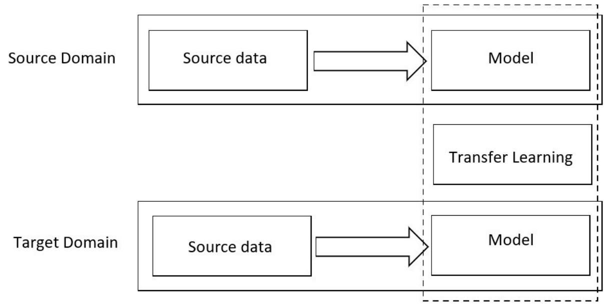

Fig. 1. Transfer learning.

With regard to the sequence of the processes, the development of each parameter of the system was established. Initially, it is essential to start up the system by evaluating the position of the mangoes, as the operation of the conveyor belts depends on this action, and if anomalies are detected in the censused mango, the pistons will be switched on to store the defective mangoes in the waste, if no anomalies are detected, the robotic arms will be activated, selecting the fruit in three different places depending on its size. In this way, when the selection is finished, the system will reach the end of the process and we will obtain as a result the packaged and selected mangoes, taking care of the quality of the fruit. In this way, the process ends as shown in Fig. 2, which is based on the ANSI standard structure [20].

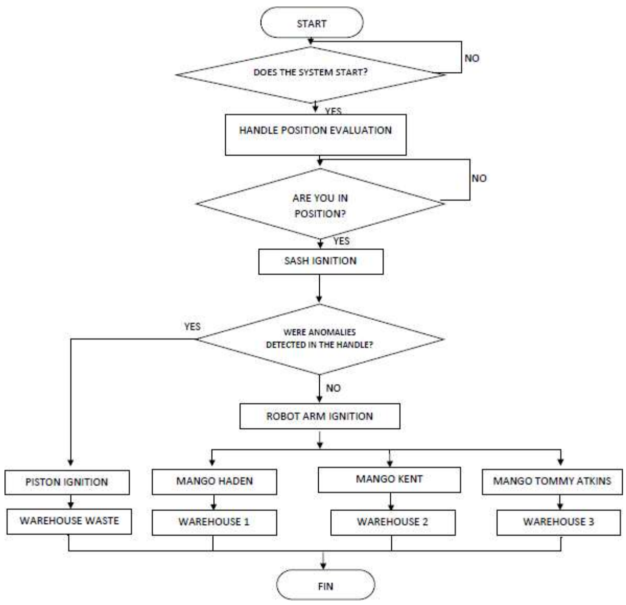

Fig. 2. System flow diagram.

The next aspect covers the implementation of the system in a simulated environment, where Fig. 3 shows the drivers used in the Factory IO software, which will be used for the connection through the OPC server; in addition to including the TIA Portal software for the automation of the system, which consists of 6 conveyor belts, fuzzy sensors, two 2 GDL arms, Vision sensor, which simulates the selection of handles, electric piston and an HMI (Human-Machine Interface).

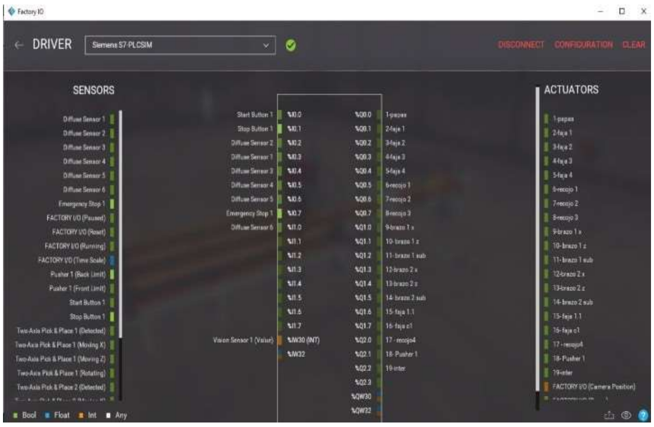

Fig. 3. Forming controllers in Factory IO software.

Fig. 4 shows the joint times of the two robotic arms, which must be kept in constant coordination in order to pick up the different boxes (mangoes). These are sent to 2 conveyor belts, thus ensuring optimal sorting of each mango variety.

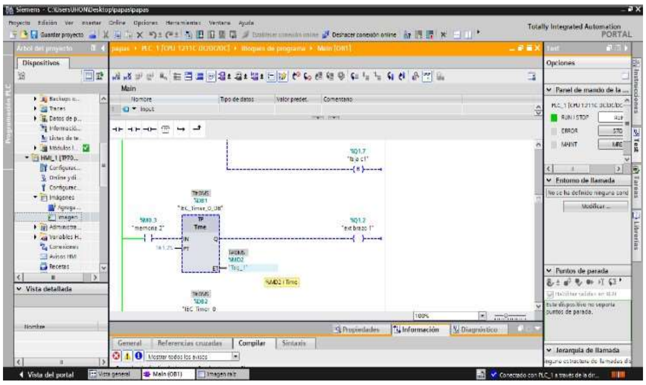

Fig.4. Programming of timers for the PLC robot arm.

Fig. 5 shows the Ladder programming which is composed of counters; in addition, the HMI environment will be in charge of showing the final quantity of mangoes selected during the established day.

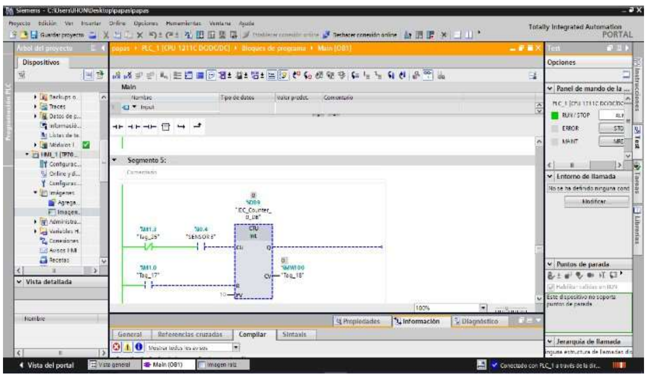

Fig. 5. Meter programming in TIA Portal software

III. Results

According to the results obtained from the process, Fig. 6 shows the programming generated to classify the defective mangoes. In such a way that, if the Visor sensor detects the green box, an electric pistol is activated, which moves these fruits to a separate area and does not contaminate the fruits in good condition.

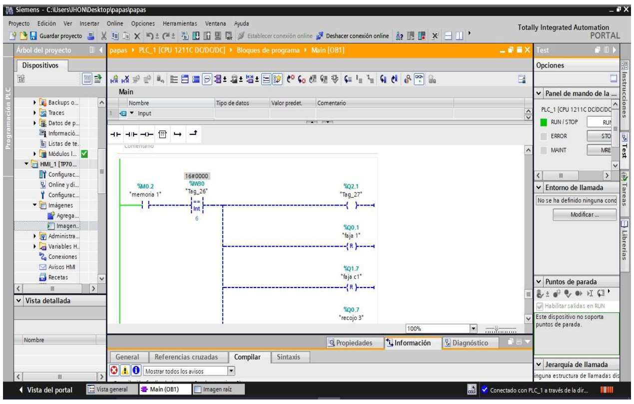

Fig. 6. Programming of TIA Portal Viewer Sensor Detection.

Fig. 7 shows an alarm, which simulates the response obtained from the system through image processing, where, according to what is detected, the handles that are in optimal conditions will be classified from those that are damaged or have some kind of malfunction.

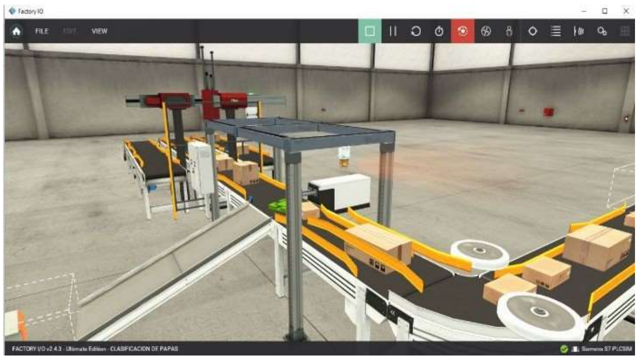

Fig. 7. Simulation of handle selection in Factory IO environment.

In Fig. 8, the Visor sensor is shown in operation, as it detects the defective or damaged handle, which is represented by the green box, and the electric piston directs it towards a store or warehouse. The aim of this process is to separate the good handles from the damaged ones.

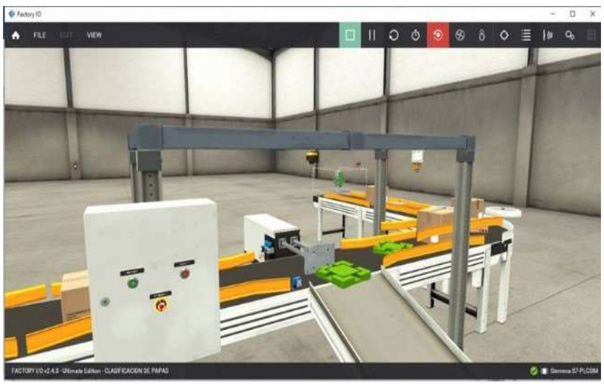

Fig. 8. Detection of green boxes (defective handles).

Fig. 9 shows that there are 2 robotic arms (2 GDL), which are in charge of classifying the varieties of mangoes, these work by means of the size of the box that refer to the three varieties of mangoes proposed in this research, which are: Haden, Kent and Tommy Atkins respectively.

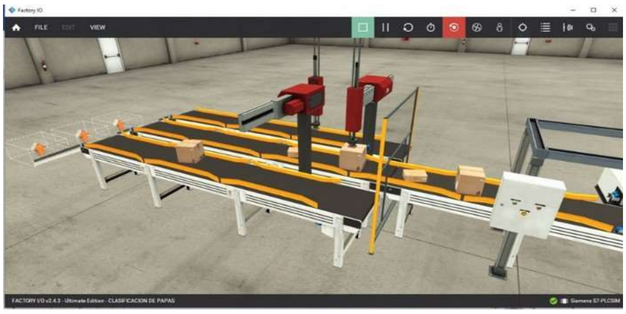

Fig. 9. Factory IO environment handle selection.

Fig. 10 shows the fuzzy sensors, which have the function of detecting the handles and by means of programming count each handle (which are represented by boxes).

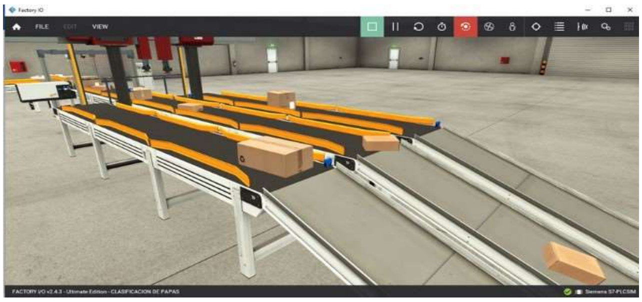

Fig. 10. Factory IO environment Handle counter system.

Fig. 11 shows the HMI environment, which will maintain a direct communication with the user, also a counter system was implemented in order to monitor the amount of sorted and ready to be exported mangoes and the number of unwanted mangoes.

Fig. 11. HMI environment.

Fig. 12 shows the execution of the system programming; where the system start-up control and the emergency control are presented; in addition, a similar interface was used for each gear.

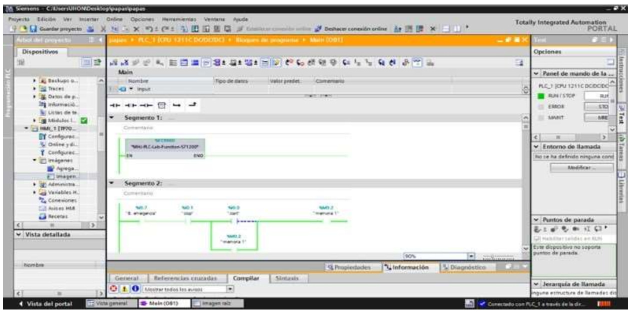

Fig. 12. Compiling PLC programming in TIA Portal software.

In case of accumulations or unforeseen breakdowns, there is a control panel that stops the process, which is set in a control box with a push-button on/off switch for the whole system; in addition, to ensure any system failure, there is an emergency shutdown button as shown in Fig. 13.

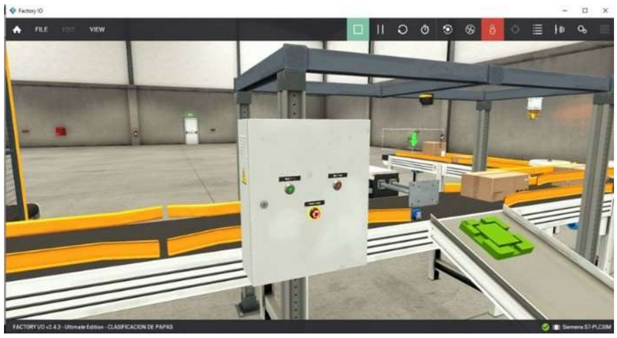

Fig. 13. Control panel design.

The algorithm starts by inputting an image of a handle and then converting it to a grayscale RGB image, obtaining a threshold value scaled between 0.0 and finally, the MATLAB software projects 3 images at the same time and sends a result already validated by MATLAB.

A simulated model was developed to determine the quality control in the selection of handles, since they have to meet certain criteria of shape and colour; for this reason a programming was developed where the system sends a message, which indicates various characteristics of the handle, for example: if the handle has some black spots, if it is not consumable, if it is deformed, if the handle is in good condition, if it is consumable or if it has the correct shape.

Therefore, Fig. 14 shows that an image of a HADEN handle has been entered, where the system indicates to the user at the bottom centre of the software that the handle looks correct and that it is in good condition and can be consumable.

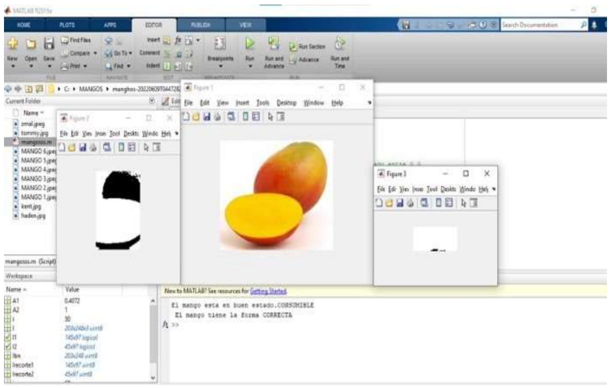

Fig. 14. Image processing of the HADEN handle.

On the other hand, Fig. 15 shows that an image of a KENT handle was entered, and the system indicates in the bottom centre of the software that the handle looks correct, is in good condition and can be consumable.

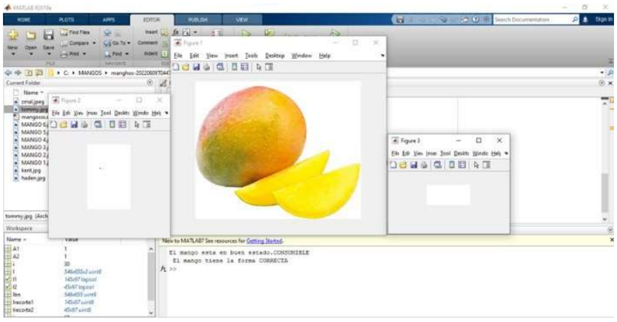

Fig. 15. Image processing of the KENT handle.

Consecutively in Fig. 16 it can be seen that an image of a TOMMY ATKINS handle was introduced, which the system indicates in the lower central part of the software to the user establishes that the handle has a correct appearance, moreover, it is in good condition and can be consumable.

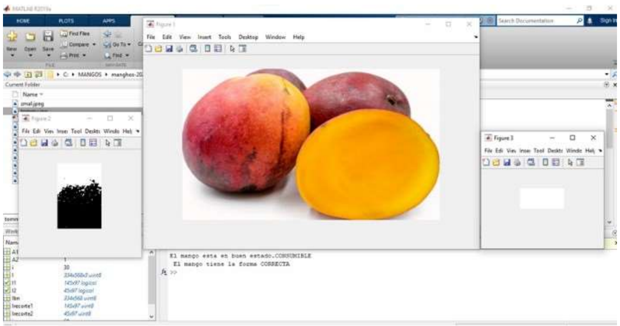

Fig. 16. Image processing of the TOMMY ATKINS handle.

However, in Fig. 17 it can be seen that an image of a MALOGRAPHED mango was introduced, consequently, the system indicates in the lower central part of the software to the user that the mango has a correct appearance, however, it has black spots on the skin with a percentage higher than 50%; therefore, this mango is not consumable and shows signs of fermentation.

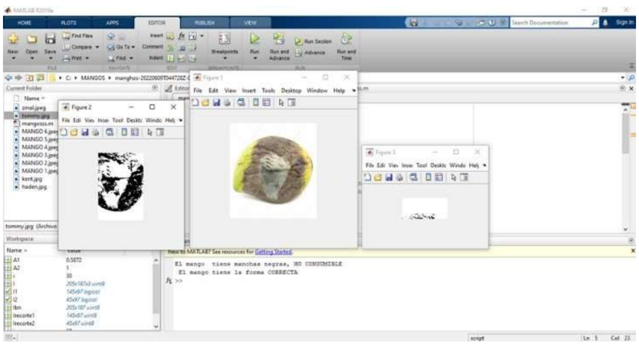

Fig. 17. Image processing of the DAMAGED handle.

IV. Discussions

According to the research [21] the authors employed image processing in order to distinguish between different image features in order to detect pests through the leaves and spots on the orange peel, for which they used machine vision and the Support Vector Machine (SVM), which is a statistical learning method that presents a rigorous mathematical basis, which is built through the structural risk minimisation criterion. Finally, they managed to reduce the dimension of the image feature matrices through principal component analysis.

According to the study [22] mango is considered as an economic fruit due to its dense nutrients, that is why in the classification stage a machine learning approach was established for the classification of ripening stages through Matlab based implementation, where it was observed that Ensemble classifier outperforms the discriminant classifier of its counterparts. Therefore, mango maturity index classification plays a very important role in knowing the shelf life of mangoes through machine learning.

Regarding the simulation of an automated Peruvian mango grading system based on grey scale image processing, the design of this system is focused on recognising the three varieties of mangoes produced in Peru, as well as grading them in order to optimise production times and costs. In addition, the mangoes are moved and stored on conveyor belts and then transported. Finally, an HMI interface was established to facilitate communication between the user and the system, as the latter counts in real time the amount of mangoes sorted per day, allowing farmers to have accurate records of their production levels.

V. Conclusions

In the present research, the results obtained showed a control system focused on the classification of mangoes produced in Peru, which contributes to significantly improve the efficiency of the fruit classification processes, as well as optimising the time in which the mangoes are selected and stored. The study also presents an HMI environment that makes it reliable and useful for users, as a count of mangoes selected in the evaluation process is carried out in real time. Additionally, the system is able to identify a problem or error in general. On the other hand, the Factory IO and TIA Portal software was used to simulate the process, which begins with the positioning of the mangoes to be moved along a conveyor belt, in order to reach the census process and once anomalies are detected in any fruit, the pistons will be activated, which will cause this defective mango to remain in a scrap store, then the robotic arms will be responsible for the selection by size and variety. Finally, the mangoes will continue their journey with the help of a conveyor belt to an exit control where they will be stored.

The presented design optimises the sorting and storage time of mangoes and automates the manpower in the process, as experts to identify if a mango is in good condition are not abundant and more manpower is needed for large-scale selections, thus avoiding losses for producers and minimising costs.

The motivation for the design presented was to support people who produce mangoes in large quantities, as it is a fruit with great nutritional value. The objective of this study is to optimise the selection time and guarantee the precision of the selection of mangoes produced in Peru and therefore reduce economic losses, which is why a collection and storage system was developed based on the problems of mango producers.

Appendixes

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

REFERENCES

[1] "ComexPerú - Sociedad de Comercio Exterior del Perú," COMEXPERÚ, 2020. https://www.comexperu.org.pe/articulo/sector-agro-genero-un-48-de-ingresos-tributarios-adicionales-en-el-periodo-enero-setiembre-de-2020-vs-el-mismo-periodo-de-2019 (accessed Jun. 10, 2022).J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.

[2] Ministerio de Desarrollo Agrario y Riego, "Mangos," Ministerio de Desarro Agrario y Riego, 2015. https://www.midagri.gob.pe/portal/186-exportaciones/evolucion-de-las-exportaciones-de-los-principales/606-mangos (accessed Jun. 10, 2022).

[3] C. Trongtorkid and P. Pramokchon, "Expert system for diagnosis mango diseases using leaf symptoms analysis," *3rd International Conference on Digital Arts, Media and Technology, ICDAMT 2018*, pp. 59–64, Jun. 2018, doi: 10.1109/ICDAMT.2018.8376496.

[4] INDECOPI, "COMISIÓN NACIONAL CONTRA LA BIOPIRATERÍA," Lima, 2018. [Online]. Available: https://www.frutasverdurasymas.com/wp-

[5] N. D. Thong, N. Truong Thinh, and H. T. Cong, "Mango Sorting Mechanical System Combines Image Processing," *2019 IEEE 7th International Conference on Control, Mechatronics and Automation, ICCMA 2019*, pp. 333–341, Nov. 2019, doi: 10.1109/ICCMA46720.2019.8988714.

[6] G. S. Tumang, "Pests and diseases identification in mango using MATLAB," *Proceeding - 5th International Conference on Engineering, Applied Sciences and Technology, ICEAST 2019*, Jul. 2019, doi: 10.1109/ICEAST.2019.8802579.

[7] M. Sardogan, A. Tuncer, and Y. Ozen, "Plant Leaf Disease Detection and Classification Based on CNN with LVQ Algorithm," *UBMK 2018 - 3rd International Conference on Computer Science and Engineering*, pp. 382–385, Dec. 2018, doi: 10.1109/UBMK.2018.8566635.

[8] N. T. Thinh, N. Duc Thong, H. T. Cong, and N. T. Thanh Phong, "Mango Classification System Based on Machine Vision and Artificial Intelligence," *2019 IEEE 7th International Conference on Control, Mechatronics and Automation, ICCMA 2019*, pp. 475–482, Nov. 2019, doi: 10.1109/ICCMA46720.2019.8988603.

[9] M. T. Vo, T. Duc Nguyen, and N. T. Dang, "Embedded machine learning for mango classification using image processing and support vector machine," *Proceedings - 2019 6th NAFOSTED Conference on Information and Computer Science, NICS 2019*, pp. 279–284, Dec. 2019, doi: 10.1109/NICS48868.2019.9023803.

[10] E. Arendse, O. A. Fawole, L. S. Magwaza, and U. L. Opara, "Non-destructive prediction of internal and external quality attributes of fruit with thick rind: A review," *Journal of Food Engineering*, vol. 217, pp. 11–23, Jan. 2018, doi: 10.1016/J.JFOODENG.2017.08.009.

[11] J. D. Rojas-Cid, W. Perez-Bailon, L. Rosas-Arias, D. B. Roman-Ocampo, and J. A. Lopez-Tello, "Design of a size sorting machine based on machine vision for mexican exportation mangoes," *2018 IEEE International Autumn Meeting on Power, Electronics and Computing, ROPEC 2018*, Mar. 2019, doi: 10.1109/ROPEC.2018.8661378.

[12] K. Mrudula, H. R. Jain, J. Bhansali, and S. N. Sejal, "Plant-Wise Comparison of Various CNN Algorithms for Detection of Pest Infestation," *2021 IEEE Pune Section International Conference, PuneCon 2021*, 2021, doi: 10.1109/PUNECON52575.2021.9686499.

[13] "Enfermedades en el mango: diagnóstico y monitoreo oportuno - Redagrícola Perú," Redagrícola, Oct. 21, 2021. https://www.redagricola.com/pe/enfermedades-en-el-mango-diagnostico-y-monitoreo-oportuno/ (accessed Jun. 11, 2022).

[14] Ameghino Bautista Jessica Giannina, "Competitividad de la cadena de valor del mango (Mangifera indica L.) en la región Lambayeque," Universidad Nacional Agraria La Molina, Lima, 2008. Accessed: Jun. 11, 2022. [Online]. Available: http://repositorio.lamolina.edu.pe/handle/20.500.12996/2463

[15] E. García-López, D. Téliz-Ortiz, Á. Villegas-Monter, E. Hernández-Castro, G. Valdovinos-Ponce, and J. A. Mora-Aguilera, "Tolerance of five mango cultivars to malformation disease in Mexico," *J. Plant Pathol.*, vol. 102, no. 4, pp. 1145–1151, 2020, doi: 10.1007/s42161-020-00592-5.

[16] S. L. Wu, H. Y. Tung, and Y. L. Hsu, "Deep Learning for Automatic Quality Grading of Mangoes: Methods and Insights," Proc. - 19th *IEEE Int. Conf. Mach. Learn. Appl. ICMLA* 2020, pp. 446–453, 2020, doi: 10.1109/ICMLA51294.2020.00076.

[17] J. Liu, M. Wang, L. Bao, and X. Li, "EfficientNet based recognition of maize diseases by leaf image classification," *J. Phys. Conf. Ser.*, vol. 1693, no. 1, 2020, doi: 10.1088/1742-6596/1693/1/012148.

[18] K. K. Patel, A. Kar, and M. A. Khan, "Rapid Assessment of Some Physical Parameters of Mangoes Using Monochrome Computer Vision," *Agric. Res.*, vol. 10, no. 3, pp. 468–482, 2021, doi: 10.1007/s40003-020-00517-9.

[19] R. Saleem, J. H. Shah, M. Sharif, M. Yasmin, H. S. Yong, and J. Cha, "Mango leaf disease recognition and classification using novel segmentation and vein pattern technique*," Appl. Sci.*, vol. 11, no. 24, 2021, doi: 10.3390/app112411901.

[20] Y. S. Valenzuela-Lino, Y. Rojas-Tapara, J. R. Ortiz-Zacarias, S. Ivan Del Carpio-Ramirez, F. W. Zarate-Peña and C. Coaquira-Rojo, "Automated design of a cleaning machine and an environmental temperature controller for guinea pig houses," 2022 IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS), 2022, pp. 1-5, doi: 10.1109/IEMTRONICS55184.2022.9795767.

[21] C. H. Qian, H. Q. Qiang, and S. R. Gong, "An Image Classification Algorithm Based on SVM," *Applied Mechanics and Materials*, vol. 738–739, pp. 542–545, Mar. 2015, doi: 10.4028/WWW.SCIENTIFIC.NET/AMM.738-739.542.

[22] M. Baig Mohammad, L. N. Thalluri, R. Devireddy, C. Priyanka, and R. Sulthana, "An Image Processing Approach for Grading of Mangoes based on Maturity," *2020 International Conference on Computational Performance Evaluation, ComPE 2020*, pp. 512–516, Jul. 2020, doi: 10.1109/COMPE49325.2020.9200

[23] D. Huamanchahua, J. Ortiz-Zacarias, Y. Rojas-Tapara, Y. Taza-Aquino, and J. Quispe-Quispe, "Human Cinematic Capture and Movement System Through Kinect: A Detailed and Innovative Review," pp. 1–7, Jun. 2022, doi: 10.1109/IEMTRONICS55184.2022.9795801.

[24] I. L. Quintanilla-Mosquera *et al.*, "Design of an automated manure collection system for the production of biogas through biodigesters," pp. 1–6, Jun. 2022, doi: 10.1109/IEMTRONICS55184.2022.9795763.

[25] Y. S. Valenzuela-Lino, J. Eduardo Rosales-Fierro, J. R. Ortiz-Zacarias, N. Moggiano, C. A. Coaquira-Rojo, and D. Huamanchahua, "Design of an Automated Feeding and Drinking System for Turkeys in Different Stages of Development," pp. 1–6, Jun. 2022, doi: 10.1109/IEMTRONICS55184.2022.9795849.

[26] S. I. del Carpio Ramirez, J. R. O. Zacarias, J. B. M. Vazquez, S. A. C. Quijano, and D. Huamanchahua, "Comparison Analysis of FIR, ARX, ARMAX by Least-Squares Estimation of the Temperature Variations of a Pasteurization Process," *2021 IEEE 12th Annual Ubiquitous Computing, Electronics and Mobile Communication Conference, UEMCON 2021*, pp. 699–704, 2021, doi: 10.1109/UEMCON53757.2021.9666649.

[27] D. Huamanchahua, J. Ortiz-Zacarias, J. Asto-Evangelista, and I. Quintanilla-Mosquera, "Types of Lower-Limb Orthoses for Rehabilitation and Assistance: A Systematic Review," *2021 IEEE 12th Annual Ubiquitous Computing, Electronics and Mobile Communication Conference, UEMCON 2021*, pp. 705–711, 2021, doi: 10.1109/UEMCON53757.2021.9666710.

[28] I. L. Q. Mosquera, J. E. R. Fierro, J. R. O. Zacarias, J. B. Montero, S. A. C. Quijano, and D. Huamanchahua, "Design of an Automated System for Cattle-Feed Dispensing in Cattle-Cows," *2021 IEEE 12th Annual Ubiquitous Computing, Electronics and Mobile Communication Conference, UEMCON 2021*, pp. 671–675, 2021, doi: 10.1109/UEMCON53757.2021.9666491.

[29] J. R. Ortiz-Zacarias, Y. S. Valenzuela-Lino, J. Asto-Evangelista, and D. Huamanchahua, "Kinematic Position and Orientation Analysis of a 4 DoF Orthosis for Knee and Ankle Rehabilitation," *2021 6th International Conference on Robotics and Automation Engineering, ICRAE 2021*, pp. 141–146, 2021, doi: 10.1109/ICRAE53653.2021.9657817.