

DESIGN OF AUTOMATIC MANGO CLASSIFICATION SYSTEM BASED ON EXTERNAL FEATURES AND WEIGHT

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DOI: <http://doi.org/10.57001/huih5804.2024.160>

ABSTRACT

In this paper, the concepts of designing the automatic classification system are described. This system classifies and evaluates based on parameters of external characteristics of mangoes as well as their weights. External features are mentioned such as the length, width, and height of each mango, the defect, and the color of the mango's exocarp. The recognition of parameters is based on vision machine and machine learning techniques to evaluate the appropriate quality of mangoes. The automatic mango classification system is designed for moving mangoes through grading systems, measuring, collecting image data, weighing, and combining the data for grading. The system classifying mangoes by color, size, and weight is designed in modular form to be convenient for moving, assembling, and operating. After the design, the system was developed and evaluated through an experimental process. The system meets the capacity requirement of classification 3 tons/hour. The results of the system classification are compared with the manual sorting and evaluation, which shows that the classification results by the system are more effective and efficient than the manual one. Besides, the system can also attach a labeling module to be able to participate in the blockchain to identify and enhance the value of local mangoes, namely Dong Thap province.

Keywords: *Classification, Mango, Agricultural machine.*

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Received: 18/8/2023

Revised: 18/10/2023

Accepted: 25/5/2024

1. INTRODUCTION

Applying technology to the goal of sustainable development is one of the trends in recent. In the agricultural sector, sustainable development is necessary to ensure that the goal of establishing an ecologically sustainable system, which can meet human needs without destroying land and polluting the environment, and ensure the interests of future generations. In agricultural development in Vietnam, it is necessary to solve the problem of reducing the labor force, especially in the stage of agricultural product classification, which is quite backward at present, so Vietnam's food classification

equipment productivity is low, lagging behind the overall situation of the world. Agricultural development not only focuses on improving the productivity and quantity of agricultural products but also must go hand in hand with the story of improving the quality of agricultural products. With the development of today's society, market demand is becoming more and more difficult, and the overall model has brought pressure to the agricultural sector. Therefore, one of the main priorities of agricultural production is to meet the needs of the export market and meet the current demand for a large number of high-quality agricultural products. To achieve this goal, the research of agricultural classification equipment has become the top priority of agricultural construction and development. Due to the impact of the covid pandemic, many agricultural products have been seriously affected. Mango is the second most consumed tropical fruit in the world after bananas [1-3]. According to data from the Ministry of Agriculture and Rural Development, Vietnam is the thirteenth country in the world in terms of mango production with an amount of about 893,000 tons (2020). The largest mango export market in our country is the Chinese market, which has experienced more or fewer fluctuations since the outbreak of the pandemic, leading to many economic losses. To avoid being dependent on one market, quality agricultural products need to improve to meet demanding markets like Europe, or America. The design process of sorting machines with the application of technology is urgent to solve the problem of increasing output and reducing costs for the mango industry in Vietnam.

The classification of agricultural products is one of the tasks that require high accuracy, however, this process is still completed manually [4]. Nowadays, mangoes are classified manually after being harvested and transported to the warehouse. This process requires a lot of labor, resulting in increased production costs and more problems related to the quality of agricultural products. Therefore, the use of an automatic classification system can reduce production costs, improve labor costs, and improve the automation level of production models, with unlimited working hours [5, 6]. Currently, domestically and abroad, there have been studies on the classification system of agricultural products

such as mango, apple, and tomato, by applying image processing technology [7]. However, it is necessary to use a distinct classification system for each type of agricultural product, particularly with mango because the groups are evaluated based on many factors. The rapid development of science and technology to design, calculate, model, and simulate systems operating on specialized software has accelerated the process of designing and manufacturing classification and classification systems. Although classification systems have appeared for a long time in the agricultural field, up to now there is no specialized system for the classification of mangoes [8-10]. The news that Cao Lanh mango (Dong Thap province, Vietnam) is impersonated with the planting area code, causing the markets to ban the import, which is a wake-up call about the problem of origin confusion not only for mango products but also for the agricultural product industry. Recently, the EVFTA agreement officially took effect, creating great opportunities for Vietnam's agricultural products to grow in exports to the EU, especially commodity groups such as vegetables, coffee, pepper, rice, and seafood with a tax rate of 0%. The EU will protect 39 geographical indications of Vietnam. The geographical indications of Vietnam are related to agricultural products and foodstuffs, creating favorable conditions for some types of Vietnamese agricultural products to build and affirm their brands in the EU market. However, if the mandatory requirements on traceability, labeling, safety, and hygiene are not met, Vietnamese agricultural products not only lose these opportunities but also affect the reputation of the brand in the EU and world markets. This shows that in the coming time, the implementation of traceability of agricultural products in the domestic market as well as for export is an urgent task. Because even in the domestic market, the problem of mixing the origin of agricultural products is also very complicated.

2. MANGO GRADING SYSTEM

An automatic mango grading system is designed to move mangoes through grading systems, measuring, collecting image data, weighing, and combining the data for classification. With the requirement of classifying mangoes by color, size, and weight, the structure is designed in a modular form, which is convenient for moving, assembling, and operating. Fig. 1 shows the mango classification scheme according to color, size, and weight. The system consists of a feeder, a camera sorting module to measure mango size, a mango weight module, and a sorting conveyor. The pace of the modules is computed synchronously to ensure the continuous and stable operation of the system. The mango grading structure is designed to grade three mango lines at an adjustable grading speed to satisfy the system's productivity. The mangoes are put into the feeder after it has been cleaned. Then, the mangoes are transported to the next part by the conveyor and the suitable speed for both the image acquisition process and the speed of the weighing system. The feed conveyor speed and size are

calculated based on the system capacity requirement of 3 tons/hour. The mango is taken from the mango hopper, moved, and photographed from every angle by the image processing system. There are numerous methods for photographing the entire surface of the mango, such as rolling, rotating, or using multiple cameras. The chosen option was to use a plastic roller conveyor capable of moving and rolling the mango at the same time, allowing the camera to capture the entire mango without pausing, which is important for synchronization with other modules and ensuring design productivity. The mango is rotated 360 degrees around its center to detect surface flaws like dark brown spots, bruises, and withering, as well as to gauge the mango's volume. The mangoes are transferred from the mango feeder conveyor to the roller conveyor, which is designed to both move the mango through the photographic area and rotate the mango vertically due to the ability of the rollers to rotate around the axis. The image processing chamber is made of appropriate materials and equipped with lights to prevent errors caused by ambient light interference. After the image processing stage, the mangoes are transferred to a separate tray to be weighed by a dynamic weighing system using loadcell to determine the weight of the mango, combined with the size parameter from the processing center, thereby determining the quality and sweetness of the mango. Then, the mangoes are assigned to each sorting conveyor.

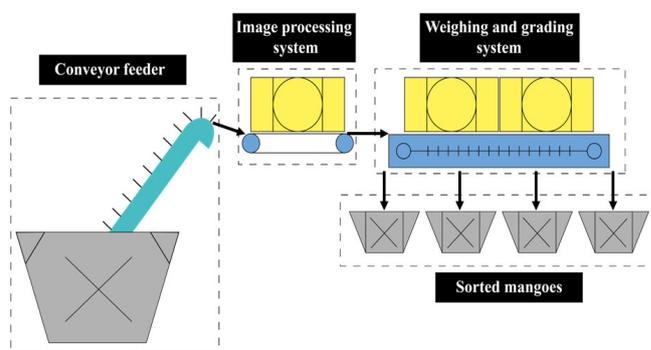


Fig. 1. Structure of the mango classification system

Mangoes are divided into four grades, with Grade 1 being the highest quality and grade 4 representing a product rejected due to poor quality. The structure of the chain conveyor consists of four chains carrying three rows of mango-weighing trays corresponding to 3 mango streams from the image processing system. The mango is carried by the loadcells to weigh by tray convey. When the mangoes reach the sorting areas, the sensor signal triggers the securing latch, causing the mango tray to fall onto the sorting conveyor. The tray is made of 304 stainless steel and 1mm thick. The bottom of the tray is spherical, so the mango always tends to roll to the tray's center.

The electrical system designed for the sorter is very important and is the key factor for the automatic operation of the machine. Three-phase current is defined as a current with three hot wires and one cold wire, which is similar to a

single-phase current with three parallel operations and a neutral wire. Three-phase voltage is larger than single-phase voltage, and the transmission process consumes less energy. The main power supply is provided to the electrical equipment and control equipment through the distribution cabinet. The power distribution cabinet is powered by the main power supply, from which the power is distributed to the equipment of the whole system. The electrical control system in the mango classification system is shown in including the power line and control signal line. The central controller plays an important role in interacting with the user's system through the control panel. The central control unit includes a signal control CPU and central control circuit. The signal control CPU works with a voltage of 220VAC-50Hz with the characteristic of stable operation under continuous conditions. The central control circuit works to provide and collect control signals of actuators, and sensors. To transmit the data information from the sensor to the computer for analysis, we use the circuit that communicates with the computer. The type of communication depends on the characteristics of the signal. Once the communication circuit is introduced, we must select the circuit with the required range, resolution, linearity, and speed.

3. MANGO QUALITY CLASSIFICATION

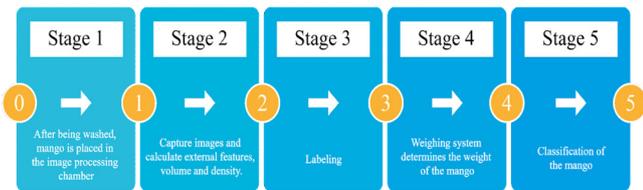


Fig. 2. Mango evaluation and classification system

The classification system works according to the control flow (Fig. 2) to evaluate the mango quality. Then, the mango is transported to the tray driven by the conveyor. When the sensor detects the mango, the system weighs the quality of each mango and the results are stored for classification. Mangoes are classified according to the quality extracted from the mass data array of the weighing system, and the signals controlling the corresponding grading structure are output when the mango tray reaches the grading position. The quality standard can be set through the classification parameter setting interface according to the requirements of each mango. Repeat this process until the system stops.

The grading mode is selected according to size and shape, the mango is fed to the image chamber, and the roller conveyor moves and rotates the mango. When the sensor detects a mango, each mango collects images from different angles, and then the data of mango size and shape are extracted. The standard size and classification shape can be set according to the requirements of each mango through the interface of setting classification parameters according to the shape and size. The system algorithm diagram of mango classification by size, volume, and defect. Here, the mango moves forward and rotates so that the camera can take pictures of the whole surface to extract key parameters

such as size, shape, and defects. Next, the mango weighs the mass through the chain conveyor. The weighing data is combined with the data extracted by the camera stored in the data array to synthesize the classification signal, and then it is compared with the preset classification parameters to control the mango classification structure according to the required level.

The mangoes weight and density are strongly influenced by their shape, which varies from region to region and country to country. Mangoes interior quality is impacted by density. The quality also be excellent if the density is above normal. Two-dimensional image processing techniques, namely statistical analysis based on height or width. To create the finished dataset, the mango's weight was also computed. The density of the mango is finally calculated using a predictive algorithm based on its width and height. Machine vision system has many advantages, such as saving time, reducing labor costs, and quickly and accurately evaluating fruit quality. Color is used to estimate the maturity, fruit size, and defect part size of plant fruit. Extracting data from digital photos and understanding them is essential for using this system.

4. EXPERIMENTAL AND DISCUSSIONS



Fig.3. The display of the mango classification system

The mango evaluation and classification process is divided into five stages. Before being moved to the feed conveyor, where they are successively provided to the image processing chamber mounted on a roller conveyor, mangoes are washed and sprayed as necessary. Next, the mango enters the image processing chamber in stage 2, it is continuously rolled on the conveyor belt so that the camera can capture all sides of the mango, while the captured color images are processed to determine the defects in the fruit surface (blemish, bruise, black spot, wilting) and mango fruit size (length, width, volume, density). Mangoes that meet the shape and size requirements are continued to enter stage 3 to label. To save accurate information for each mango at the end of the cycle, the mango can be dropped on the corresponding conveyor, then when passing through the image processing chamber, the system marks the number for each mango, each number corresponds to a QR code, which is printed on the label of the mango, and this label is affixed to the corresponding mango. The tray containing the mango is brought to the load cell as the process advances to stage 4. The load cell is used to determine the actual weight of the mango and transmit a signal to the controller. At stage

5, upon receiving information, the controller compares the existing data with the data on the established classification standards (VietGAP, GlobalGAP) before transmitting signals to the classification structure. Mangoes are divided into four groups (maximum of five categories): type 1 is the highest quality, type 4 is a rejected product due to unsatisfactory quality, and type 5 is a supplement that can be used for a variety of other agricultural products or other classification standards.

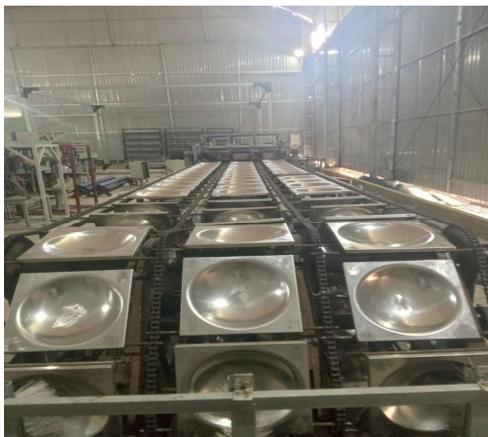


Fig. 4. Mango weighing and grading system

The automatic mango classification system is divided into two parts including image processing and classification part. The image processing system is used to capture the image by the camera and extract three mango characteristics such as length, width, and defects. A roller conveyor system transports the mango to the image processing chamber in this section. The mango is rotated during the motion, and the captured image shows every angle of the mango. The images generated are sent to the central processing for analysis and data storage. The mango's characteristics are represented by the corresponding quantities. After washing, the mango is transferred to the conveyor system for photography. During this process, the fruit is rotated to obtain the length, width, defects, and color of the whole mango (Fig. 3). This phase consists of three steps. First, through a roller conveyor system, images are removed from the image processing

room. In the processing room, the images were sealed, and exposed to radiation, and the mango images were recorded and saved. The captured image is processed in a second step using various techniques, such as fps (frames per second) enhancement, image noise filtering, edge detection, and boundary tracking. The length, width, and defect are extracted and combined into a tuple in the final step. Previous studies have offered a neutral evaluation of the threshold method's accuracy. The color image is transformed into a binary image using the threshold method, which is then processed by the morphological image processing chain. image processing on a frame-by-frame basis. Noise, edge detection, and boundary tracking are removed from the frames before the mango features are extracted. The moving mango stream must be continuously processed during the classification process because the hardware structure and the image processing chamber were both designed based on the power needed for the system. The signal is always noisy during processing when estimating weight with a load cell, so the results of the measurement are less accurate. All load cell signals are consequently run through a Kalman noise filter, which eliminates too-large variations. The actual weight of the mango will be determined by decoding and estimating the weight signal from the load cell. The placement of the mango on the tray has an impact on the overall result, so the camera checks its placement.

The sorting machine was completed and met the initial specifications, it can sort following the color, size, and weight. When test phases, functions such as weight classification accomplish high precision following each standard, and the mango's placement in the center of the tray improves the precision of weighing (Fig. 4). Measurements of the width, length, height, weight, and volume of each mango sample compare and calculate the error between the actual measurement and the measurement on the machine system. In image processing, it has determined the number of mangoes and assigned a size to each mango, as well as identified the defect positions of the mangoes based on the previous requirements, but there are still minor errors in the results. The defect rate of mango is calculated on the machine, it is not feasible to compare and evaluate the accuracy of defects due to the lack of data on defects; however, the area of defective parts has been identified and calculated. The error parameters between the machine and the real thing are growing better and better, taking samples at the time of testing, the errors are generally above 97%, and the small error has no effect on the classification quality of mangoes. Calculating the yield per rotation of 123 trays (corresponding to about 123 mangoes) takes about 1.2 minutes and can be increased by 20% of the original speed. Putting the machine learning algorithm into the system helps the sorting machine to be smarter, able to self-learn errors, and correct errors in the defect handling part of mango. With a machine capable of more than 3 tons/hour and can be adjusted to increase the

speed by 20% more, the productivity will increase by 20% (increase by 600kg/hour). After enhancing and refining the machine, it has achieved high accuracy in handling defects, classifying sizes and weights (up to 3.6 tons/hour), resolving problems in terms of labor and productivity compared to the previous manual method, saving a great deal of manpower, and achieving classification accuracy that meets the standard. The mango sorter can work continuously for 18 hours per day and has a capacity of 3 tons of mangoes per hour, which means 54 tons of mangoes can be sorted per day, which is significantly higher productivity than the manual method. This significantly reduces labor costs for businesses, as one mango sorter can replace more than 20 skilled workers. In Fig. 5, the use of a mango sorter increases the accuracy of the classification, with a rate of over 97% for the size of the mango. This assists in reducing grading errors and ensuring product quality. When using the manual classification method, the enterprise will need to hire more than 20 workers at a salary of around 50,000VND per hour of work, bringing the total cost of wages for 20 workers to up to 8,000,000VND per day, but the accuracy of the sorting process cannot be guaranteed, and high productivity can not be achieved. The use of mango sorters allows the business to produce a greater quantity of mangoes, reaching approximately 1620 tons of mangoes per month, while also increasing production speed by 20%. This helps businesses save over 240,000,000VND per month and requires only a small quantity for machine maintenance. Note that these figures are only calculated on 8 hours per day, however, the system can be operated continuously for 24 hours. Using an automatic mango sorting machine reduces labor costs, boosts productivity, and improves the accuracy of the sorting process.

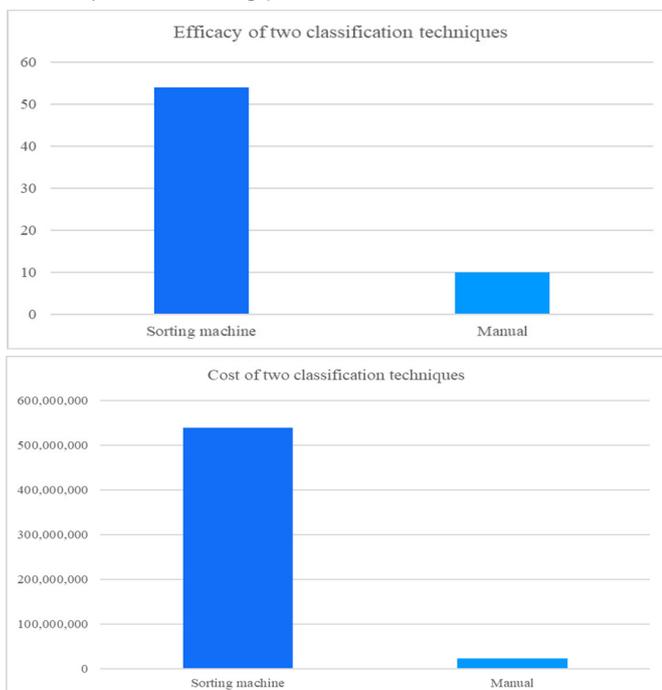


Fig. 5. Productivity and cost comparison of machine and manual sorting

5. CONCLUSIONS

This study has designed and developed a high-accuracy and high-productivity system for the automatic classification of mangoes using computer vision and artificial intelligence. This method can classify up to three tons of mangoes per hour based on their color, size, and weight. By utilizing image processing and machine vision technology, the study has analyzed various factors affecting the accuracy of image data collection and the capabilities and efficacy of artificial intelligence in mango classification. The study has also proposed an information retrieval method that aims to improve the transparency and authenticity of Vietnamese mangoes. This method utilizes blockchain technology, which is a decentralized and secure way of storing and sharing data, by using blockchain, the method can ensure the immutability and traceability of information related to Vietnamese mangoes.

ACKNOWLEDGEMENT

This research is funded by the University of Economics Ho Chi Minh City, Vietnam.

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