

IMPROVEMENT OF THE SORTING PROCESS USING A COMPUTER VISION SYSTEM AND A LIGHT SENSOR IN SORTING AGRICULTURAL PRODUCTS

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Abstract. This article considers the issue of improving the sorting process of agricultural products, in particular fruits and vegetables. Due to the low accuracy and subjectivity of traditional sorting methods, the need to use modern technologies is justified. The study proposes an integrated approach to determine the external characteristics of products (color, shape, size) using a computer vision system and to evaluate internal quality indicators (ripeness, chemical composition) using near-infrared (NIR) spectroscopy.

Also, a statistical selection method and a prediction model based on PLS and SVM algorithms were developed for evaluating product groups. The proposed system allows to improve the quality of export-oriented products, automate the sorting process and reduce the human factor. As a result, the sorting accuracy increases, the export of low-quality products decreases, and the overall production efficiency increases.

Keywords: Computer Vision, Near-Infrared Spectroscopy, Fruit Sorting, Ripeness Detection, Machine Learning, Agricultural Product Quality, Automated Sorting System, Non-Contact Inspection.

Introduction. Today, as the volume of agricultural production increases, there is an increasing need for advanced technologies that meet the requirements of their storage, processing and delivery to consumers in good quality. In particular, non-contact, automated approaches are becoming increasingly important instead of traditional methods for sorting and delivering fruits and vegetables for export. The share of CIS countries in the total volume of exports of fresh fruit and vegetables from Uzbekistan was 69.4 percent in 2019 and 57.7 percent in 2024. At the same time, the share of fresh fruit and vegetables exports to the European Union countries, on the contrary, was 2.1 percent in 2019, but this figure increased to 2.4 percent in 2024.[1]

January-October 2025 in the months 1.8 million tons from the country fruits and vegetables export made (fruit) and berries – 523.2 thousand tons), which is worth 1.7 billion US dollars ripe.[2] Fruits in export main products: grapes, dried grapes (raisins), peaches, cherries, apricots and other fruits. Dried fruits, especially raisins and dried apricot, for export separately place occupies.[3] This sector Uzbekistan in export important place holds, village farm export about 5–6% of the organization will. [4] Main export Markets: Russia, Kazakhstan, Pakistan, China and other CIS countries and Near East and Europe countries to the markets delivered (directly) statistic indicators every year changes).

But the fruit and of vegetables external appearance, interior quality and new status in determining traditional, human to the factor dependent methods enough accuracy and efficiency does not give. Human by executable visual assessment subjective be, mistake probability top, sort process speed and will be low.





Figure 1. Such an approach following problems brought issues:

1. Subjectivity – Each to a person typical view, fatigue, attention weakening or experience shortage the product wrong to evaluate take.
2. Low accuracy – Human eye only external to look approximately I will evaluate. takes, internal quality indicators .
3. Low efficiency –Large volume products short time inside in the selection this problem serious color.
- 4.Product violation – Some in cases quality inspection for to the product damage delivered.

Above problems are being exported also affects products does that is to export sent Any products inside defect to be if it is being exported product completely back will be returned.

President Mirziyoyev's "Fruits, Vegetables" dated 30.07.2025 and food products export " to increase " dedicated video conference in their statements It is said that sometimes abroad buyers Uzbekistan's fruit is called " raw " " in the case " he refuses or quality enough at the level Realizing that it won't be possible, the burdens being stopped or back This export is being returned. to the process negative impact shows. [5] So man hand with sorting also with computer see through sorting is also an issue enough solution do Computerized see through fruit and vegetables sorting according to one how many scientists' scientific affairs taken away. Jyoti A. Kodagali and S. Balaji scientists entitled "Computer Vision and Image Analysis based Techniques for Automatic Characterization of Fruits – A Review ". in the article computer see and image analysis methods of fruits appearance, color, structure and other visual attributes according to classification and to sort application and various research and algorithms. As a result, computer vision technologies fruit classification and in the selection fast, objective and consistent results give to take showed. From this outside they orange, pomegranate, pear, banana such as fruits research on [6]



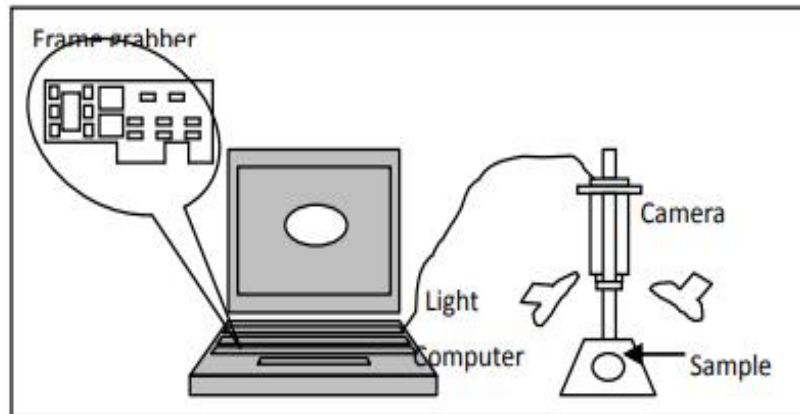


Figure 2.

Abdullah Al Masum et al., in their article titled “ Development of automated real-time mango grader using machine vision technique,” reported on the real -time mango fruit grading classification for automated conveyor + computer vision system and from the camera taken mango from images area property using sorting done They created The system produces mango fruit in real time. at the time theirs size determined and large, medium and small such as to categories 79.7–85.5% accuracy in separation achieved, general sorting The accuracy was ~89.1%. [9]

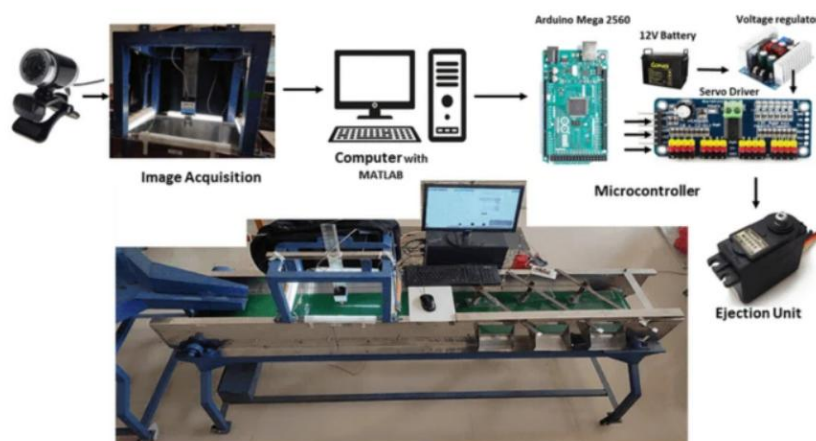


Figure 3.

In addition, Russian scientists such as Dmitry O. Khort, Alexey Kutyrev, Igor Smirnov have conducted scientific work on the use of hyperspectral analysis and machine learning algorithms for automated fruit sorting. Their research is aimed at identifying the quality and defects of fruits. Iranian scientists such as Abdollah Zakeri, Ruhollah Hedayati, Mohammad Khedmati, Mehran Taghipour-Gorjikotaie have used machine learning methods in jujube fruit sorting. They have developed a classification system based on the color, shape, size and surface defects of the fruits.

Scientists such as Syed Sohaib Ali Shah, Ayesha Zeb, Waqar S. Qureshi, Muhammad Arslan, Aman Ullah Malik, Waleed Alasmary, Eisa Alanazi in their article “Towards fruit maturity estimation using NIR spectroscopy” analyzed the use of NIR spectroscopy and chemometric algorithms (PLS, LSSVM) to determine fruit ripeness. A model was developed to predict ripeness indicators based on NIR spectra on various fruits (apple, mango, grape, apricot). PLS and other regression models showed good accuracy in predicting ripeness for various fruits, but it was emphasized that a separate model is needed for each variety.[7]

Research methodology. The combined use of modern measurement and control tools, in particular computer vision and near-infrared (NIR) technologies, allows for automatic, non-



contact, high-precision product evaluation. Computer vision allows for rapid and accurate analysis of external characteristics of fruits and vegetables, such as color, shape, and size, while NIR technology allows for evaluation and prediction of product quality based on their water and sugar content. [8]

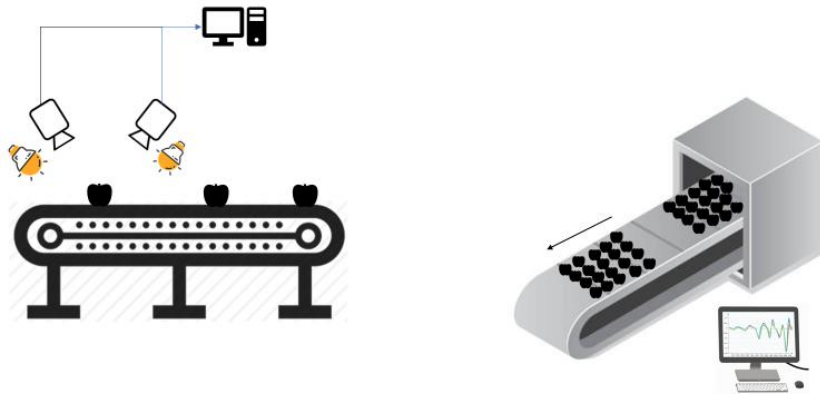


Figure 4.

Cartesian robot (Cartesian robot), as well as also called *gantry robot*, three son to move has There are many robots. industry in applications wide Its X, Y and Z axes are to a rigid structure has to be, to be right corner under Robot arm to the end installed with working organ (end-effector) 3 freedoms together degree (DOF — Degrees of Freedom).

Robot's every one read linear the movement done increases and this action is mainly linear drive mechanism through provided [5]. Linear of proceedings types of the following consists of :

- belt -driven,
- gear rail and rack -and-pinion-driven,
- spherical ball -screw-driven,
- linear linear motor-driven.

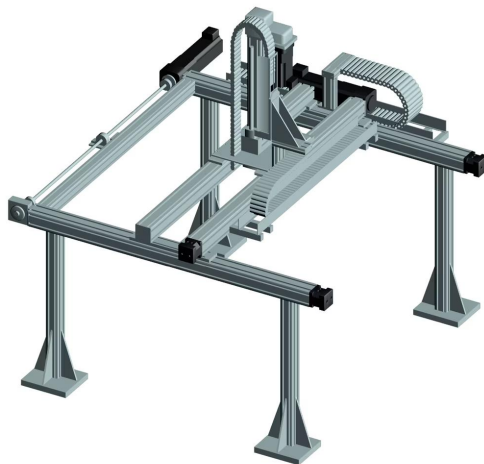


Figure 5.

In practice the most many used — belted extension mechanism. Linear walk type robot constructive solution and technician requirements looking at is selected.

Belted striped don't walk main components :

- electricity engine,
- reducer (gearbox),
- linear guides,
- belt pulley system (belt–pulley system),
- industry management controller.



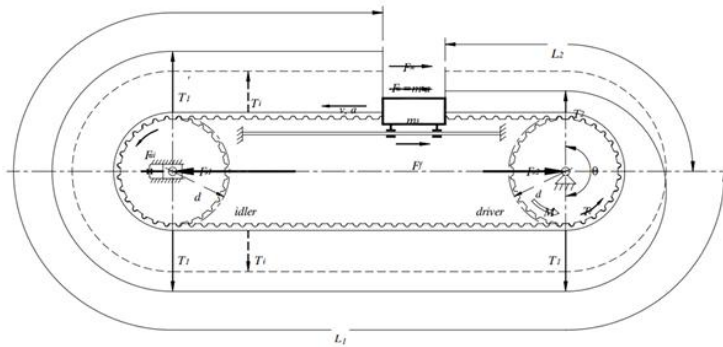


Figure 6.

This to the picture according to, if the moving mass leading from the pulley moving away if so, belt tension leading pulley and moving mass between decreases, belt system remaining in part and increases and on the contrary. Moving mass linear routers along slips and this movement is friction because of to resistance occurs.

To the picture based on see maybe a belt tension moving of the mass to the position related in the process of becoming changed stands.

Massani linear routers along to move for necessary was general longitudinal The force F of the following to the assembly equal to :

- acceleration force F_a ,
- friction force F_f ,
- weight of strength structural part (vertical in the procedures) F_g ,
- assistant pulley converts power F_{ab} ,
- belt inertia forces F_{ai} .

$$F_t = F_a + F_f + F_g + F_{ab} + F_{ai}$$

Extended in appearance:

$$F_t = m_s a + \mu_r m_s g \cos \beta + m_s g \sin \beta + \frac{\omega_b L b}{g} a + \frac{2 J_i \alpha}{d}$$

this on the ground :

- m_s — moving mass,
- a — acceleration,
- μ_r — friction coefficient,
- β — angle of deviation (slope),
- L — belt length,
- b — belt width,
- w_b — belt comparison weight,
- J_i — auxiliary (idler) pulley inertia moment,
- α — its corner acceleration,
- d — pulley diameter,
- g — free fall acceleration.

Cartesian of robots linear belted proceedings high accurate positioning in their duties Therefore, their dynamic model harvest to do and system behavior simulation to do important importance has.

Zero is zero. friction forces and of the belt elasticity clear positioning complicates. Therefore for linear proceedings for clear dynamic models and stable management regulators working exit necessary is considered.

Linear don't walk mathematician model harvest to do for spring – mass system acceptance will be done



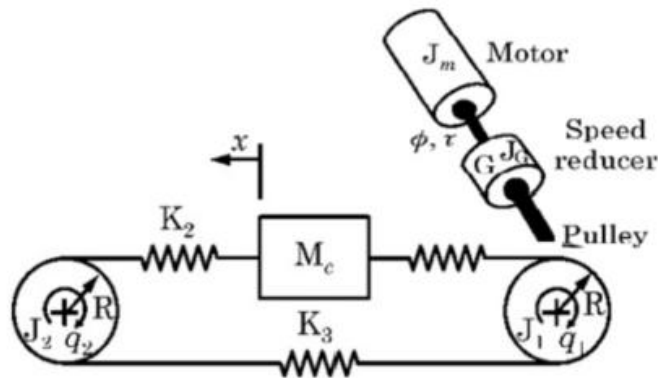


Figure 7.

This in the scheme:

- J_m — engine inertia moment,
- G — reducer transmission ratio,
- R — pulley radius,
- J_i — pulley inertia moment,
- M_c — moving load mass,
- K_2, K_3 — belt elasticity coefficients,
- x — linear shift,
- φ — angle shift,
- τ — engine moment.

Based on this model linear belted don't walk differential equations will be issued and of the system dynamic behavior analysis will be done.

Initially fruits computerized in the selection in pieces if sorted then the NIR sensor in the next step with and from the control of the sensor Here the NIR sensor is one group from fruit optional 5 or 6 (per box) wearable fruits to the number related) fruit using a sensor scanner does and PLS (Partial Least Squares) and SVM (Support Vector Machine) algorithms based on to us general box for prediction through him/her evaluating gives.

Conclusion. This in research village farm products, in particular fruit and vegetables sorting process improvement issue complex approach based on seeing Traditional sorting methods subjectivity, low accuracy and efficiency level enough not being analysis modern automated technologies application necessity based on was given. Research as a result computerized see system and close infrared (NIR) spectroscopy technologies integration through products contact not, fast and high in accuracy assessment opportunity created. Computerized see using of fruits external signs determination with together, NIR technology through their internal quality indicators, in particular ripeness level was evaluated.

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