International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 10 Issue: 10 | Oct - 2026 SJIF Rating: 8.659 ISSN: 2582-3930

Design and Fabrication of an Automated Fruit Sorting Conveyor System

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Abstract— Manual fruit grading is repetitive and may pro- duce inconsistent results, while industrial sorting lines can be impractical for small producers and educational laboratories. This paper presents a fabrication-oriented design for a com- pact automated fruit-sorting conveyor. The proposed prototype combines a singulating feed, a low-speed belt, an inspection station, a controller, and a servo-operated diverter. A camera under controlled illumination is proposed for visible surface and color features, while a load cell measures fruit mass. The controller assigns each item to configurable grade bands and routes it to a corresponding collection bin. Preliminary sizing calculations use stated design assumptions: a 0.10 m/s belt speed, 0.30 m fruit spacing, and a 25 mm drive-roller radius. These assumptions give a spacing-limited theoretical rate of 20 fruits per minute and a roller speed of approximately 38 r/min; these are design estimates, not measured prototype performance. The paper also defines a fabrication and validation approach, including accuracy, throughput, fruit-damage, and reliability measurements. No experimental results are claimed because a completed prototype and test data were not supplied.

Index Terms—Fruit sorting, conveyor system, machine vision mass grading, automation, post-harvest handling.,

I. INTRODUCTION

Sorting and grading are important post-harvest operations because fruit lots are separated using properties such as size, color, mass, and visible defects. Manual inspection can be labor-intensive, and its consistency depends on the inspection process. Research prototypes have combined conveyors with machine vision and automated separation,

demonstrating ways to integrate sensing with fruit handling [1], [2]. Other work has used image features such as color and fruit diameter to define grades [3]. This paper proposes a compact, low-speed conveyor in- tended as a fabricationready educational or small-scale de- sign. The system uses controlled image capture and mass measurement and does not claim to assess internal quality. Its contributions are a modular mechanical and control architecture, preliminary drive and throughput sizing from stated assumptions, and a validation plan that separates design estimates from measured results. Fruit-specific thresholds must be established through calibration before production use.

II. PROBLEM IDENTIFICATION

A small-scale sorter should move fruit through an inspection point and direct each item to a selected bin with limited manual intervention. The proposed prototype is designed around the following requirements:

Feedfruitindividuallytoreduceoverlapandpreservethe association between an inspected item and its selected bin.
Provide repeatable sensing conditions, particularly stable illumination for image-based color assessment. Handle fruit gently and avoid sharp edges or excessive Coordinate sensing, classification, belt motion, and diimpact at feed and discharge points. verter position without losing track of an item.
Allow thresholds to be calibrated for the selected fruit and market specification.

The design is limited to external visual features and mass. It does not determine internal defects, sweetness, firmness, or food safety. Since fruit varieties have different size, color, and mass distributions, the operator must establish and document grade bands for the crop being sorted.

III. LITERATURE REVIEW

Chen et al. developed an online citrus-sorting vision system that combined defect detection with tracking of fruits moving on a conveyor. Their system reported 93.6% detection pre- cision for its

citrus test set, illustrating the role of tracking between inspection and sorting [1].

Chakraborty et al. presented an integrated citrus machine combining washing, image-based sorting, and weight grading. The embedded vision model reported 97.6% classification accuracy for its defined accept/reject task [2]. This result belongs to that machine and dataset and is not assumed performance for the present design.

Xu, Hui, and Wan described an apple-sorting approach using RGB images, HSV color features, contour extraction, and diameter estimation. They reported a maximum diameter deviation of 1.35 mm relative to manual measurement in their tests [3]. This work supports the use of image features for size- related grading, while emphasizing that accuracy depends on the imaging setup and measurement method. Prior systems differ in crop, hardware, dataset, and grading objective. The proposed prototype therefore adopts a narrower scope—external appearance and mass with a single diverter— and treats throughput and accuracy as quantities to be mea- sured rather than borrowed from other systems.

IV. RESEARCH METHODOLOGY

A. System Architecture

The process consists of singulation, conveying, inspec- tion, decision, and discharge. An adjustable hopper or guide presents fruit individually onto the belt. An entry sensor detects fruit arrival. At the inspection station, the belt pauses briefly while a camera captures an image under fixed LED il- lumination and a load-cell platform records mass. A controller

compares the extracted features with calibrated grade limits. The belt then carries the fruit to a servo-operated diverter that directs it to one of three bins: Grade A, Grade B, or reject/other. Grade definitions are set for the selected fruit and are not prescribed here. The functional sequence is shown in Fig. 1.

B. Mechanical Design and Fabrication

The frame may be fabricated from aluminum profile or mildsteel angle, with a food-contact-compatible belt and smooth rollers. Preliminary belt dimensions are 600 mm long and 150 mm wide. Adjustable side guides reduce lateral movement, while a compliant feed ramp and padded bin liners are intended to limit impact. The drive roller has a 25 mm radius for the calculations in Section V. A guarded low-voltage geared motor drives the roller, and slotted idler mounts allow belt-tension adjustment.

The inspection station is mounted on a rigid section of the frame. For mass measurement, the load cell supports a short weigh platform isolated from the conveyor frame as far as practical. A camera is mounted above the belt inside a light enclosure to reduce variation from ambient illumination. The diverter is positioned downstream with a clear path to each bin. Dimensions are preliminary and should be adjusted after the fruit variety, motor, belt, and fabrication materials are selected. Figure 2 illustrates the proposed arrangement.

C. Sensing and Control

An optical or infrared sensor detects fruit presence. A camera and fixed LED source provide images for color, approximate size, and visible surface-feature assessment. A load cell with a suitable signal-conditioning module measures mass at the paused inspection station. A microcontroller coordinates sensor inputs, belt motion, and servo actuation; a single- board computer may be added if image processing exceeds the microcontroller's capability.

For each fruit, the controller records an item sequence number, mass, extracted image features, assigned grade, and diverter command. The belt remains stopped during
measure- ment to reduce motion blur and load-cell disturbance. After classification, the controller restarts the belt and schedules the diverter for the item's arrival. In a fabricated system, timing should use an encoder or calibrated travel-time measurement, with an entry sensor to detect missed or unexpected items. If sensing or communication fails, the machine should stop and signal a fault rather than route an unclassified fruit.

D. Classification Logic and Item Tracking

The controller can be implemented as a finite-state sequence: ready, detect, inspect, classify, transport, discharge, and fault. In the detect state, the entry sensor confirms a single fruit and assigns it an identifier. The conveyor pauses at the inspection station; the camera acquires an image and the load cell records a stable mass reading. The classification routine extracts visible color statistics and, if camera calibration permits, an approximate projected diameter. A rule table then maps the measured features to the operator-defined grade limits. The controller stores the grade with the fruit identifier before restarting the belt.

The distance between the inspection point and diverter determines when the gate must move. For a single-item proto- type, belt travel can be tracked with an encoder or a calibrated time delay, with the entry sensor used to detect a missed or additional fruit. The selected grade commands the servo to one of the collection positions. The gate returns to a neutral position after discharge. If the sensor sequence, mass reading, or image is invalid, the controller stops the belt and indicates a fault instead of making an unsupported classification. This sequence prioritizes traceable item handling over maximum speed.

E. Sensor Calibration and Grade Thresholds

Before each test session, the empty weighing platform should be tared and checked with reference masses covering the intended operating range. A linear calibration can be represented as $m = aV + b$, where V is the conditioned loadcell output, m is estimated mass, and a and b are fitted using reference measurements. Repeated readings at each reference point reveal drift and short-term variation. The camera should be fixed in position and focus, with exposure and white balance held constant. A reference scale placed at the fruit plane can convert image dimensions to physical units; a neutral color target can help check lighting consistency.

Grade limits should be developed from representative fruit of the intended variety. Each calibration fruit should receive a reference grade using a written manual protocol, and threshold selection should use only the calibration subset. A separate validation subset should be held back until the thresholds and software are fixed. This prevents the reported test accuracy from simply reflecting repeated adjustment

to the same sam- ples. The decision table may combine mass bands with color or visible-defect rules, but any thresholds must be reported with the crop, sample range, lighting, and camera conditions. Image appearance and mass alone do not establish internal quality.

F. Fabrication and Evaluation Procedure

Fabrication proceeds by assembling and aligning the frame, rollers, belt, inspection platform, camera enclosure, and bins; wiring the motor driver, sensors, controller, and power supply; and checking actuators and sensors independently. The empty belt is then run to verify tracking, speed, stopping, and emergency-stop behavior. The weighing station is calibrated with reference masses and fruit samples, and imagethresholds are established under the final lighting arrangement.

Validation should use a labeled sample set of the intended fruit variety. Each sample is independently graded by a defined reference procedure and then processed by the machine. Rec- ommended measurements include the confusion matrix and per-grade precision and recall, total sorting accuracy, mass- measurement error, diameter error if size is estimated, through- put, misrouting rate, visible bruising or damage, and jam

V. DESIGN CALCULATIONS

The following calculations provide preliminary motor and spacing estimates. The values are design assumptions, not readings from a fabricated machine.

A. Spacing-Limited Throughput

Let belt speed be v = 0.10m/s and center-to-center fruit spacing be s = 0.30m. The ideal spacing-limited rate is

$$Q = \frac{60\,v}{s} = \frac{60(0.10)}{0.30} = 20 \text{ fruits/min.}$$

This is an upper bound based only on spacing. A provisional 75% utilization allowance gives 15 fruits/min for layout planning, but actual throughput will be lower if inspection dwell time, diverter motion, or manual loading dominates. Throughput must be measured after fabrication.

B. Drive-Roller Speed

For roller radius r = 0.025m, the required roller speed is

$$n = \frac{60v}{2\pi r} = \frac{60(0.10)}{2\pi(0.025)} \approx 38.2 \text{ r/min.} \quad (2)$$

A geared motor with an output speed near 38 r/min is a reasonable starting selection; its speed should be adjustable for calibration and gentle handling.

C. Preliminary Drive Torque

Assume an equivalent moving loadofm=3kgand an effective resistance coefficientμresistanceis=005

. Estimated belt

$$F_r = \mu mg = 0.05(3)(9.81) \approx 1.47 \text{N.} \quad (3)$$

Applying a service factor of 2 gives a design tangential force of approximately 2.94 N. The corresponding roller torque and mechanical power are

$$T = F_r = 2.94(0.025) \approx 0.074 \text{Nm,} \quad (4)$$

$$P = Fv = 2.94(0.10) \approx 0.29 \text{W.} \quad (5)$$

These simplified estimates omit belt pretension, startup friction, misalignment, and gearbox losses. The selected motor must provide rated output torque above the calculated value at operating speed, with additional margin for those effects. Actual requirements should be checked on the assembled conveyor.

D. Inspection-to-Diverter Timing

If the distance from the inspection point to the diverter is ,nominaltraveltimeattheassumedbeltspeedis

td= dv= 0.20 0.10 = 2 0 s (6)

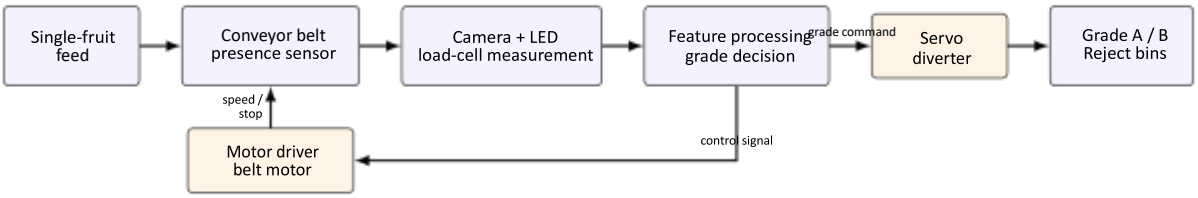


Fig. 1.Functional block diagram of the proposed fruit-sorting conveyor.

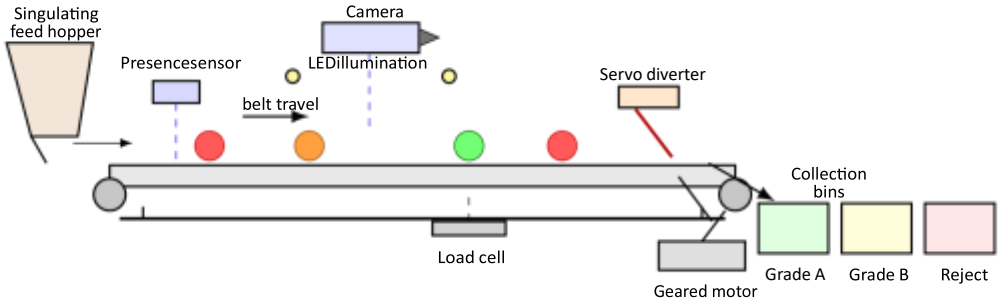


Fig. 2. Conceptual side-view illustration of the proposed conveyor, sensing station, drive, and sorting bins. This is a design schematic, not a photograph of a completed prototype.

This is a starting calibration estimate only. Belt slip, acceleration, and servo response can change arrival time; an encoder or repeated timing tests should synchronize item tracking and gate actuation.

VI. ADVANTAGES AND APPLICATIONS

A. Advantages

The modular design separates conveyance, inspection, control, and discharge so individual modules can be replaced or upgraded. Controlled lighting and a stationary inspection interval are intended to support repeatable sensing, while configurable thresholds allow adaptation to different fruit lots. Low belt speed and padded contact surfaces are design mea- sures intended to reduce handling impact; testing is required to confirm these benefits.

B. Applications

The proposed system can serve as a teaching and research platform for conveyor control, machine vision, sensor integra- tion, and post-harvest grading. With crop-specific calibration and suitable cleaning and guarding provisions, it may also be evaluated for small-scale packing operations, farm coopera- tives, and laboratory studies. It is not presented as a certified commercial food-processing machine.

VII. CONCLUSION

This paper presents a fabrication-oriented design for an automated fruit-sorting conveyor using single-item feeding, controlled image capture, mass measurement, and servobased discharge. Preliminary calculations indicate a roller speed near 38 r/min for a 0.10 m/s belt and a spacing-limited upper rate of 20 fruits/min under the stated geometry. These are design estimates, not experimental performance results. The design provides a basis for prototype construction, but grading accuracy, achievable throughput, fruit-handling quality, and reliability remain to be measured using a defined fruit variety and reference procedure.

The calculations give a spacing-limited theoretical rate of 20 fruits/min and a roller speed of approximately 38 r/min at the stated belt speed and roller radius. The torque estimate is also conditional on the assumed equivalent load and resistance co efficient. These values are for initial component selection only: they do not account fully for belt pretension, startup .loads, imageprocessing delay, fruit variability, or actuator settling time. No constructed machine or experimental measurements are claimed in this paper. Accordingly, no accuracy, damage, or operating-rate benefit can yet be attributed to the proposed design. The principal outcome is a testable prototype specifica tion and evaluation procedure. A completed build should be assessed using fruit samples graded independently under a written reference protocol. The resulting evidence can estab lish whether the selected mechanism and sensing arrangement meet the intended small-scale

use case, and can guide redesign before any operational or economic claims are made.

VIII. FUTURE SCOPE

A. Prototype Construction and Mechanical Testing

The first stage is to fabricate the frame, belt, inspection plat form, guarding, and diverter, then measure belt speed, tracking, stopping distance, motor current, and gate repeatability under empty and loaded conditions. The weighing platform should be checked across its operating range before fruit trials. Handling tests should record drops, jams, bruising, and fruit orientation so that guides, belt material, and bin padding can be adjusted based on observations rather than assumptions. A documented bill of materials and dimensioned drawings would also make the prototype easier to reproduce. .

B. Vision, Calibration, and Control Improvements

Further work can create a crop-specific image dataset con taining representative varieties, grades, surface defects, and lighting conditions. Training, threshold selection, and final evaluation should use separate data partitions, and perfor mance should be reported by grade as well as overall. Multi view imaging or a fruit-rotation mechanism could reduce hidden surface areas; an encoder and item-tracking logic could improve synchronization between inspection and the diverter. Future comparisons should test whether mass and image features together improve grade decisions over either sensor alone, while retaining a safe stop-and-alert response for uncertain classifications.

C. Scale-Up and Deployment

A larger system would need tests under sustained opera tion, varying fruit sizes, and realistic feed rates. Foodcontact materials, cleanability, dust and moisture protection, electrical guarding, emergency stops, and operator access should be evaluated before field trials. Energy use, maintenance require ments, labor saved, sorting consistency, and fruit damage should be compared with the existing manual process using the same fruit lots. Finally, the prototype should be checked on more than one crop only after separate calibration and validation for each crop; thresholds and classification models should not be assumed to transfer between species or varieties

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