

Design and Development of Machine Vision Based Smart Harvester

Jegadeeswaran N¹, Shashikumar M², Spandana PS³, Tanya Sharma⁴, Evelyn John⁵, Gorantla. Rohitha Reddy⁶, Pradeep R L⁷, Shreyas Patil⁸

¹Professor, Department of Mechatronics Engineering, REVA University, Bengaluru, Karnataka, India

²Head of the Department, Department of Agriculture Engineering, REVA University, Bengaluru, Karnataka, India

³⁻⁸Students, Department of Mechatronics Engineering, REVA University, Bengaluru, Karnataka, India

DOI: <https://doi.org/10.51244/IJRSI.2026.1309000186>

Received: 23 September 2026; Accepted: 28 September 2026; Published: 17 October 2026

ABSTRACT

Leafy vegetables such as spinach, coriander, amaranthus, fenugreek, lettuce, and parsley are essential crops grown worldwide. However, their harvesting remains largely manual, resulting in challenges such as labor shortages, inconsistent quality, physical strain, crop damage, and high operational costs. Existing mechanized harvesters suffer from limitations like bulky designs, high power requirements, crop damage, and lack of integration with modern sensing technologies. This paper presents a comprehensive review and analysis leading to the development of a Smart Harvester for Leafy Vegetables with Integrated Collection Mechanism, combining automated cutting, machine-vision-based plant identification, and gentle conveying into a single system. The proposed design aims to enhance harvesting efficiency, reduce root damage, ensure hygienic handling, and minimize human effort.

INTRODUCTION

Leafy vegetables constitute a vital part of global food systems, especially in Asian and African countries where varieties like spinach, fenugreek, amaranthus, coriander, and lettuce are consumed daily [1]. Despite advancements in agricultural mechanization, the harvesting of leafy crops remains predominantly manual. Traditional harvesting methods require farmers to bend, squat, and work for long hours, leading to fatigue, musculoskeletal disorders, and accidental plant damage [2,3].

Manual harvesting also suffers from inconsistencies in cutting height, handling hygiene, and productivity [3]. As labor availability continues to decline and wages increase, farmers face mounting difficulty in completing harvesting operations on time. This not only reduces yield quality but also affects marketability, especially for leafy vegetables that are highly perishable [4,5,6].

Recent developments in agricultural IoT, machine vision, robotics, and compact mechanical designs present opportunities to automate leafy vegetable harvesting [7,8]. However, many existing mechanized harvesters are either too large, too expensive, unsuitable for small farms, or lack integrated collection mechanisms that prevent leaf contamination and damage [9,10,11].

To address these challenges, this study aims to conceptualize and justify a Smart Harvester that:

- Performs root-safe cutting of leafy crops,
- Integrates a vision-based or height-based detection system,
- Automatically collects the harvested yield in a tray or container,
- Offers portability suitable for small and medium-scale farms.

Experimental Setup

In the research work used Autodesk Fusion software tool for developing the model.

Chassis/Frame

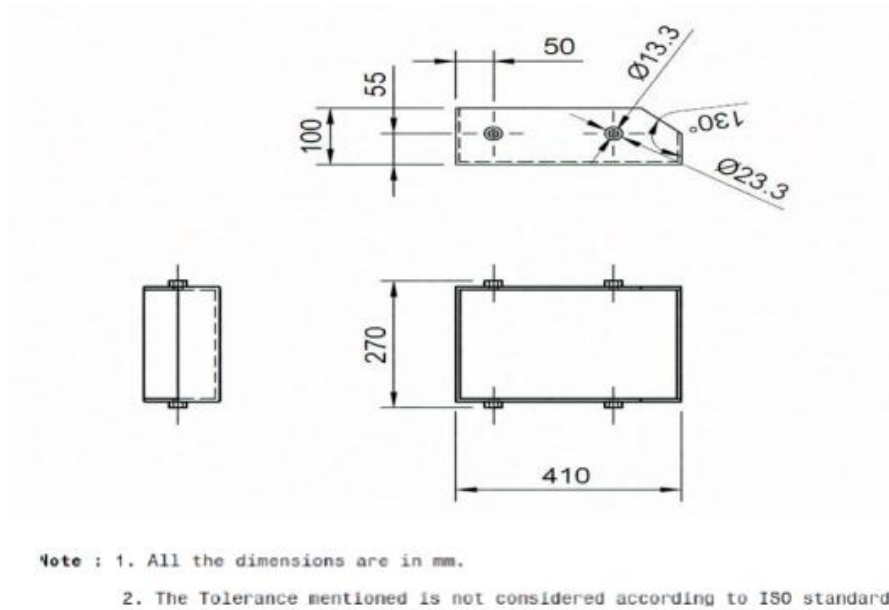


Fig.2.1. Chassis

Gripper Arm 01

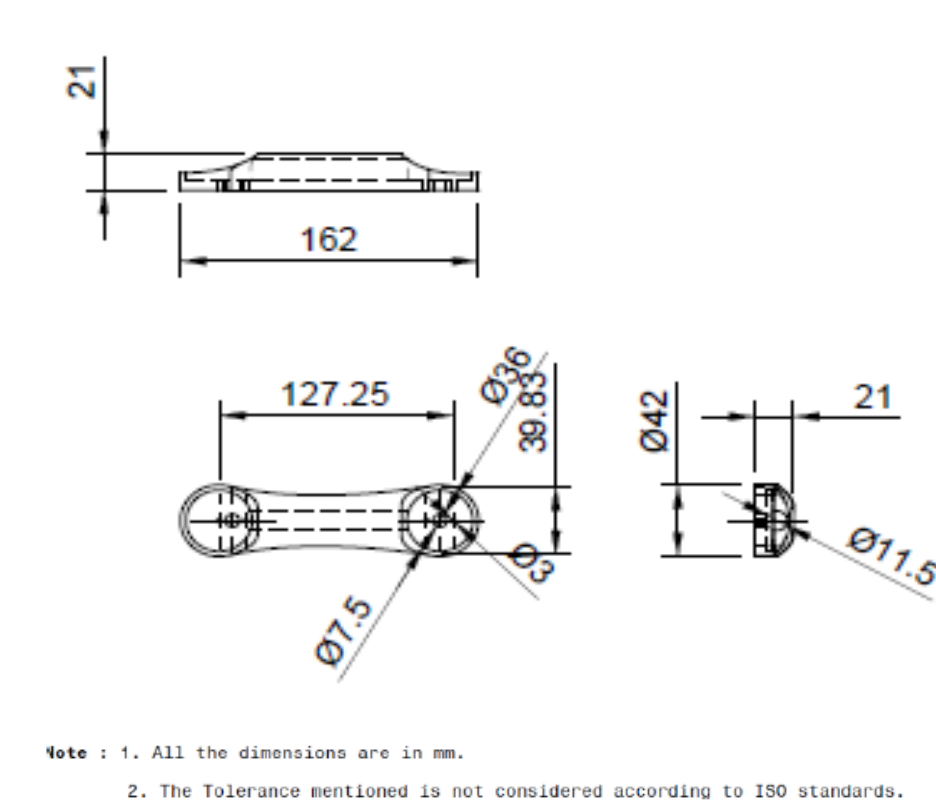
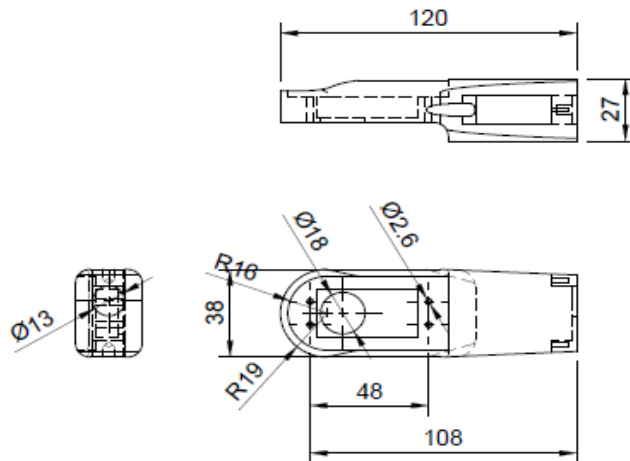


Fig.2.2. Dimensions of Gripper Arm 01

The gripper arm is designed using PLA pro material. The FT7125M servo motor is connected to it to give motion.

Gripper Arm 02



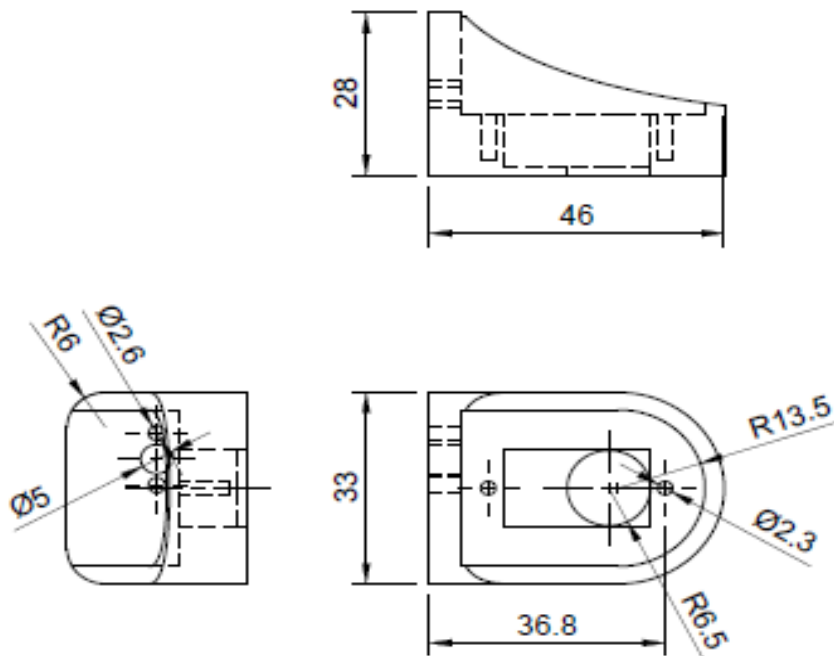
Note : 1. All the dimensions are in mm.

2. The Tolerance mentioned is not considered according to ISO standards.

Fig.2.3. Dimensions of Gripper Arm 02

The gripper arm is designed using PLA pro material. The FT7125M servo motor is connected to it to give motion.

Gripper Arm 03



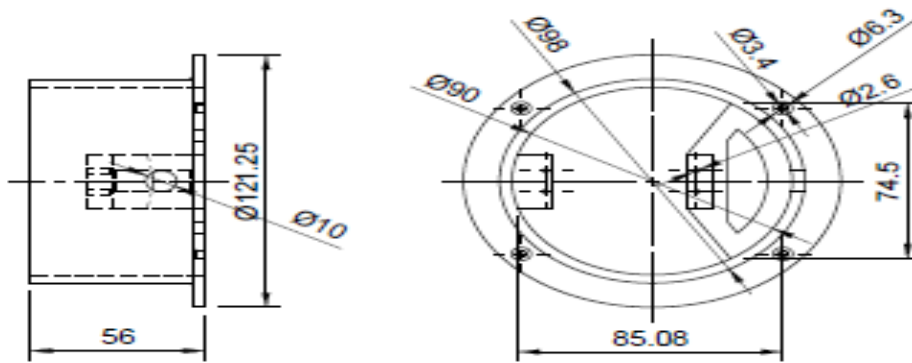
Note : 1. All the dimensions are in mm.

2. The Tolerance mentioned is not considered according to ISO standards.

Fig.2.4. Dimensions of Gripper Arm 03

The gripper arm is designed using PLA pro material. The FT7125M servo motor is connected to it to give motion.

Base of the gripper



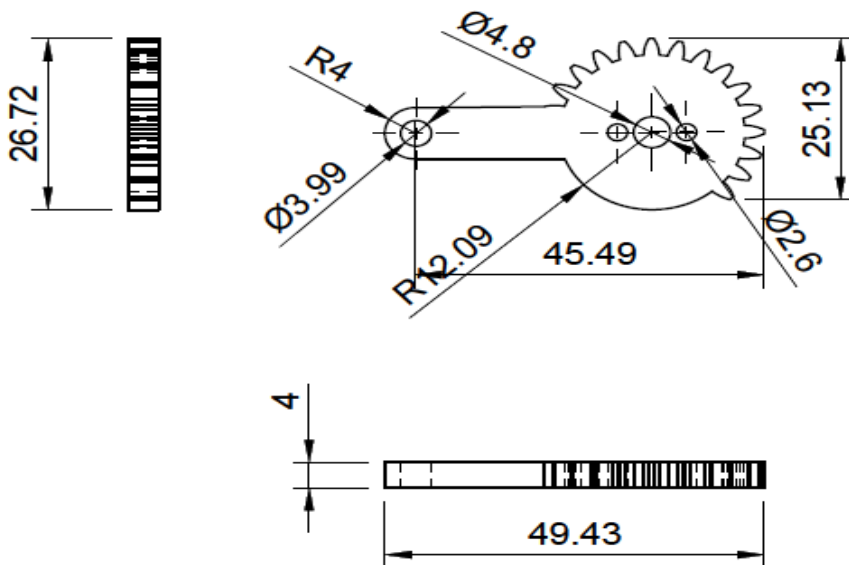
Note : 1. All the dimensions are in mm.

2. The Tolerance mentioned is not considered according to ISO standards.

Fig.2.5. Dimensions of base of the gripper

The gripper arm is designed using PLA pro material. Designed to hold the arm.

Gear 1 and 2



Note : 1. All the dimensions are in mm.

2. The Tolerance mentioned is not considered according to ISO standards.

Fig.2.6. Dimensions of gear 1 & 2

The gear is designed using PLA pro material. The gear is attached to the arm and the gripper

Analysis

The total deformation obtained from the ANSYS simulation was found to be approximately 0.000386 mm, which is extremely small. The maximum deformation occurs at the top surface of the chassis. This indicates that the structure exhibits high stiffness and is capable of resisting deformation under the applied loads. The negligible deformation confirms that the design is mechanically stable.

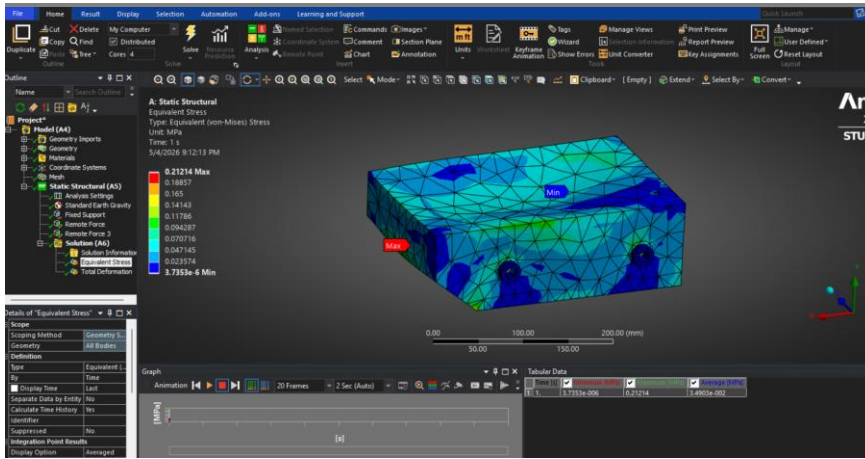


Fig.2.7. Equivalent Stress Analysis using Ansys

The maximum equivalent (Von-Mises) stress developed in the structure was found to be approximately 0.212 MPa. This stress is significantly lower than the yield strength of PLA Pro material (approximately 50 MPa). The stress concentration is observed near edges and mounting regions due to geometric discontinuities.

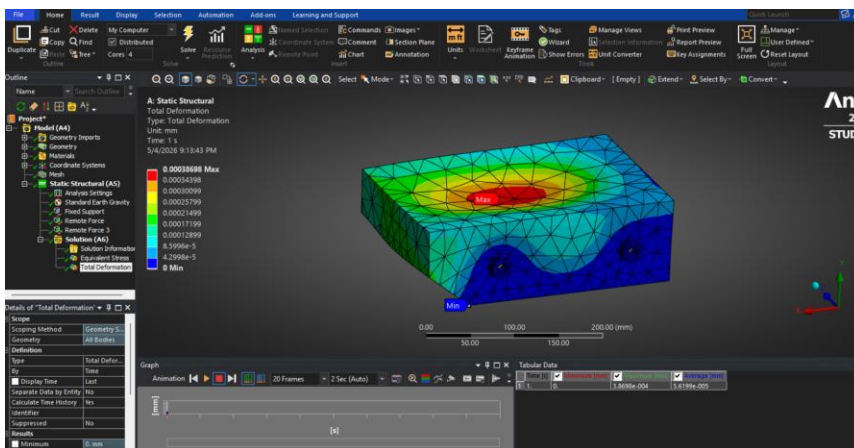


Fig.2.8. Total Deformation Analysis using Ansys

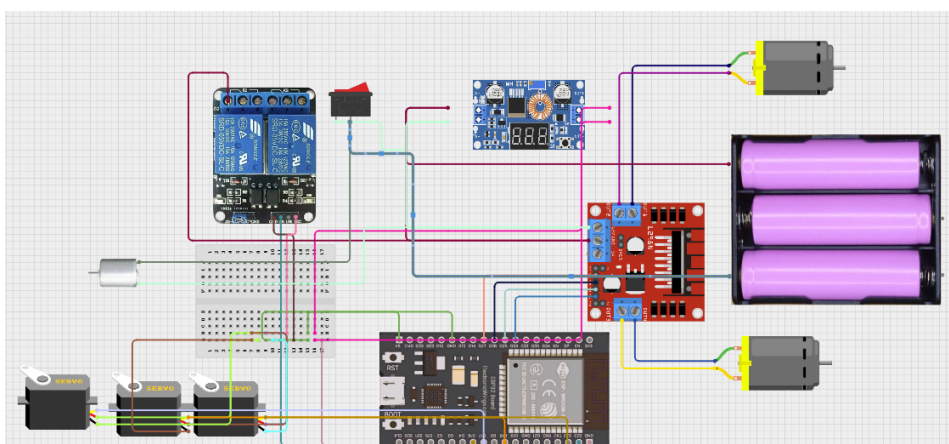


Fig.2.9 Electrical circuit diagram

RESULTS AND DISCUSSION

The experimental setup was developed to evaluate the performance of the Autonomous Leafy Crop Harvesting Robot under controlled conditions. The robot was assembled with all mechanical, electrical, and control components integrated, including the chassis, robotic arm, gripper mechanism, cutting motor, and control

system.

Initial testing was carried out using coriander leaves as the sample crop. The robot was programmed to detect, approach, grip, cut, and place the harvested leaves into the collection box.

During the initial trials, the system did not perform as expected due to limitations in the cutting mechanism and motor capacity. The blade initially used was too small, resulting in ineffective cutting of the plant stems. This issue was resolved by replacing it with a larger and more suitable blade capable of providing sufficient cutting area and efficiency.

Additionally, the DC motor used for the cutting mechanism was initially underpowered, which led to insufficient cutting force. The motor was later upgraded to a higher power rating to ensure effective and clean cutting of the stems. After these modifications, the robot successfully performed the harvesting operation by cutting the coriander leaves and placing them into the collection box.

Further improvements were made to enhance overall system performance. The weight distribution of the robot was adjusted to improve stability during operation. The gripper mechanism was also modified by incorporating a softer material to ensure gentle handling of the leaves, preventing damage during gripping and placement.

Additional testing is currently being conducted using different types of plants to evaluate the system's adaptability and its ability to identify and harvest crops other than coriander. These tests aim to validate the robustness and versatility of the robot in real-world agricultural scenarios.

CONCLUSION

The development of a Smart Harvester for Leafy Vegetables with an Integrated Collection Mechanism addresses the need for modernized, efficient, and precise harvesting solutions, especially for small and marginal farmers. The system integrates automated cutting, smart sensing, and hygienic collection to improve productivity while minimizing manual labor and root damage. Through literature review and methodological analysis, it is clear that most existing harvesting technologies are either expensive, bulky, or not tailored to Indian agricultural conditions. The proposed harvester concept bridges these gaps by offering a compact, energy-efficient, and cost-effective alternative. Its design supports sustainability, enhances farmer efficiency, reduces physical strain, and delivers consistent cutting quality. This innovation has the potential to significantly uplift the leafy vegetable sector by reducing post-harvest losses and ensuring cleaner, safer produce handling.

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