493 RESARCH ARTICLES

KEYWORDS: ROBOTIC ARM, AGRICULTURE, COMPUTER VISION.

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"Control and Dynamic Simulation of Wire-Driven Precise Spray Robotic Arm"

Research topic: This article proposes a new type of robotic arm for precise pesticide spraying in citrus orchards.

- **Technology:** Wire-driven robotic arm
- **Method:**
  - Uses two segments and wires to achieve bending and movement in two directions.
  - PD control ensures precise movement.
  - Joint state observers predict joint positions and speeds for improved control.
  - Dynamic simulation helps optimize performance.

Benefits:

- Precise spraying reduces pesticide waste and environmental pollution.
- Bendy arm allows for maneuvering around leaves and branches for targeted spraying.

Significance:

- This design offers a potential solution for more efficient and environmentally friendly pesticide application in citrus farming.

"Recognition and Localization Methods for Vision-Based Fruit Picking Robots: A Review"

Research topic: This article reviews the application of machine vision for fruit picking robots.

- **Techniques and methods:**
  - Machine vision with algorithms for:
    - Localization (finding fruit position)
    - Target recognition (identifying fruit type)
    - 3D reconstruction (building a 3D model of the fruit)
  - Digital image processing techniques (traditional computer vision methods)
  - Deep learning-based algorithms (cutting-edge AI for image recognition)

Key findings:

- Machine vision improves efficiency and functionality of harvesting robots.
- Challenges exist for achieving high accuracy in real-world conditions, such as:
  - Varying lighting
  - Fruit obscured by leaves or branches
  - Robots operating in dynamic environments

Future directions:

- Research to improve:
  - Recognition and localization success rates under challenging conditions
  - 3D reconstruction accuracy
  - Fault tolerance of vision systems in complex environments

Significance:

- This review highlights the potential of machine vision for robotic fruit harvesting and identifies areas for future development.

"Adaptive Visual Servoing for Obstacle Avoidance of Micro Unmanned Aerial Vehicle with Optical Flow and Switched System Model"

Research topic: This article proposes a vision-based system for obstacle avoidance in micro unmanned aerial vehicles (MUAVs).

- **Techniques and methods:**
  - Visual servoing: Uses camera information to control flight path.
  - Optical flow: Analyzes motion in camera image to estimate distance to obstacles.
  - Multi-thread processing: Ensures reliable and continuous processing of camera data.
  - Switched system model: Accounts for different flight modes during obstacle avoidance.
  - Adaptive control scheme: Adjusts flight path based on real-time obstacle detection.

Evaluation:

- Simulations and experiments demonstrate the effectiveness of the system in avoiding obstacles.

Significance:

- This system offers a potential solution for safe and autonomous navigation of MUAVs in complex environments.

"Design and performance of a robotic arm for farm use"

Research topic: This article describes the development and evaluation of a 4-degree-of-freedom robotic arm for harvesting heavy-weight crops.

- **Technology:** Articulated robotic arm
- **Method:**
  - Design focuses on cost-effectiveness and functionality for agricultural environments.
  - 4-degrees-of-freedom allows for maneuverability.
  - Kinematic and dynamic aspects are considered for real-world performance.
  - PLC system is used for control.

Performance:

- Payload capacity: 0.21 times its own weight
- Average accuracy: 1.85 millimeters
- Repeatability: ±0.51 millimeters
- Offers a workspace volume of 8.27 cubic meters with a reach of 1.36 meters.

Benefits:

- Designed for efficient harvesting of heavy crops like pumpkins and watermelons.
- Offers potential for use in other industries with minimal modifications.

Significance:

- This robotic arm design contributes to automation in agriculture, addressing labor shortages and potentially improving efficiency.

"Kinematics Analysis and Simulation of A 5DOF Articulated Robotic Arm Applied to Heavy Products Harvesting"

Research topic: This article presents the design and simulation of a 5-degree-of-freedom robotic arm for harvesting heavy crops.

- **Method:**
    - Kinematic analysis using Denavit-Hartenberg method for movement and positioning.
    - Solidworks 2014 software for design and component analysis.
    - Standard mechanical formulas for dynamic analysis.

Design:

- 5DOF articulated robotic arm for mounting on a robot tractor.
- Focuses on reducing torque requirements for efficient operation.
- Materials and motor placement are optimized to minimize torque.

Performance (simulation results):

- Achieved significant torque reduction (29.7% to 68.9%) through design optimization.
- Maximum reach: 1421 mm from base, 2026 mm from attachment point.
- Inverse kinematic analysis confirms good operational performance.

Significance:

- This design offers a potential solution for automated harvesting of heavy crops, reducing strain on farmers and potentially improving efficiency.

"A Novel Machine Learning based Autonomous Farming Robot for Small-Scale Chili Plantations"

Research topic: This article proposes a machine learning-based autonomous robot for use in small-scale chili plantations.

- **Technology:**
  - Machine learning for pest and disease detection
  - Image processing for nutrient deficiency identification
  - Robotics for autonomous navigation
  - Sensors for data collection

Method:

- The robot uses a camera to capture images of chili plants.
- Machine learning algorithms analyze the images to identify pests, diseases, and nutrient deficiencies.
- The robot can autonomously navigate through the plantation using robotics techniques.
- A mobile application provides a user interface for controlling and monitoring the robot.

Benefits:

- Early detection of pests and diseases can help prevent crop losses.
- Identifying nutrient deficiencies allows for targeted fertilization.
- Automation can reduce labor costs and improve efficiency.

Significance:

- This system offers a potential solution for improving crop health and yield in small-scale chili farming.
- The approach could potentially be adapted for use with other crops as well.

* 3D -> 2D

"Co-robotic harvest-aid platforms: Real-time control of picker lift heights to maximize harvesting efficiency"

Research topic: This article proposes a co-robotic system to improve efficiency in fruit harvesting using orchard platforms.

- **Technology:** Co-robotic harvester with adjustable platforms
- **Method:**
    - Uses a vision system to estimate fruit distribution ahead of the harvester.
    - Sensors in picking bags measure each worker's picking speed.
    - A model-based control algorithm adjusts the platform heights based on:
        - Incoming fruit load (abundance of fruit to be picked)
        - Worker picking speed
    - This adjusts fruit picking supply (worker availability) to match fruit picking demand (amount of fruit to be picked).

Benefits:

- Improves efficiency by matching worker effort to fruit availability.
- Achieved a 9.5% improvement in harvesting throughput in apple orchard trials.

Significance:

- This co-robotic system offers a potential solution for increasing productivity in fruit harvesting while reducing manual strain on workers.

* Prototype

"Tomato Harvesting Arm Robot Manipulator; a Pilot Project"
Research topic: This article describes a pilot project for a robotic tomato harvester.

- **Technology**: Robotic arm manipulator with image processing
- **Method**:
  - Uses a simple image processing algorithm to detect red and green tomatoes.
  - The location of the tomato determines the movement of three servo motors controlling the arm.
  - The arm extends towards the detected tomato and harvests it.

Performance:

- Achieved successful harvesting of tomatoes in a controlled setting.
- Average harvesting time:
  - Red tomato: 4.932 seconds
  - Green tomato: 5.276 seconds
- Total cycle time (including return to standby position):
  - Red tomato: 9.676 seconds
  - Green tomato: 10.586 seconds (slower due to robot positioning, not color)

Significance:

- This pilot project demonstrates the feasibility of using a simple robotic arm with image processing for tomato harvesting.
- This approach has potential for further development and implementation in digital farming solutions.

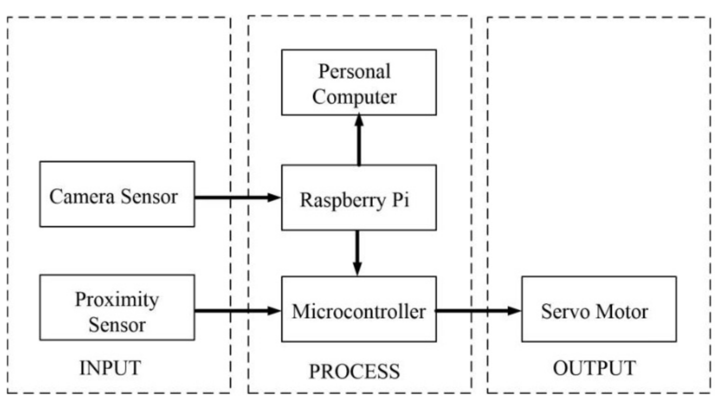


Figure 1. Diagram block of the proposed method

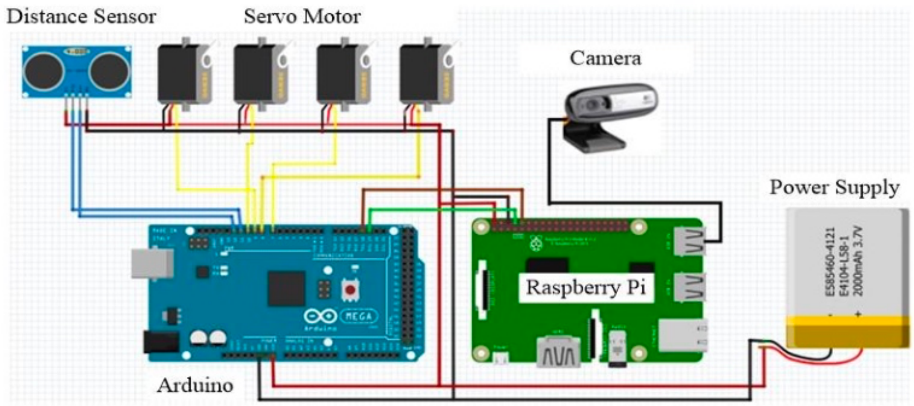
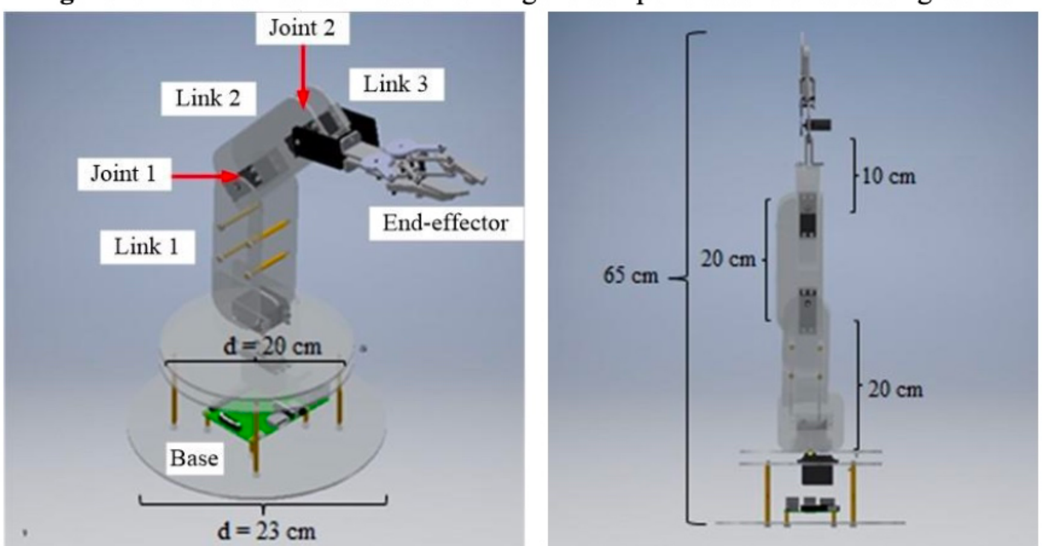


Figure 2. The electrical connection among the components of the harvesting robot.



(a) Robot specification (b) Robot links specification