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A Review On AI–Powered Pest Management System

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Abstract: This project develops an autonomous robotic system for efficient pest monitoring and control in agriculture. Traditional methods, like manual sticky traps, are labor-intensive and costly. Our robot uses high-resolution cameras and multispectral imaging to survey fields, capturing pest data that's analyzed with computer vision algorithms. Using the IP102 dataset and YOLOv8 model, the system identifies harmful insects and distinguishes between static and flying types. Targeted control measures are applied: static pests receive precise organic or chemical sprays based on crop damage, while flying insects are eliminated using lasers—multi-diode for groups and single diode for individuals. GPS ensures boundary adherence, and a GSM module alerts the farmer. This solution aims to reduce pesticide use, enhancing sustainability and efficiency.

Index Terms-: Pest Detection, Agriculture, Robot, YOLOv8, IP102, Static, Flying, Harmful Insect, Image Recognition, Laser, Pesticide

I. Introduction

Insects pose significant challenges to both agricultural productivity and human health, as many serve as disease vectors and can damage crops, impacting global food supplies. Traditional pest control methods, like sticky traps and manual inspections, are labor-intensive, costly, and often rely on broad-spectrum pesticides that can harm the environment. The need for a more precise, efficient, and sustainable solution is urgent, especially as farming operations expand and the agricultural sector strives to reduce chemical usage. This project aims to address these challenges by developing an autonomous robot capable of real-time pest identification and targeted control, enhancing both crop yield and environmental sustainability.

The motivation behind this project is to leverage advanced technologies—such as computer vision, machine learning, and robotics—to modernize pest control. By using high-resolution imaging and AI algorithms like YOLOv8 for pest identification, this system can distinguish between harmful and benign insects, as well as static and flying types, enabling specific and appropriate responses. The robot can deploy precise doses of organic or chemical sprays based on crop damage assessment and eliminate flying pests with lasers. Equipped with GPS and GSM, the robot ensures accurate field navigation and notifies the farmer of its activities, providing a cost-effective, environmentally friendly, and highly efficient alternative to traditional pest control methods.

II. PROBLEM STATEMENT

Identify the harmful insects in the field and eradicate them using laser beam technology or spraying precise pesticides.

III. OBJECTIVES

- To study different algorithms that can automatically detect insects.
- To design a moving robot by using GPS.
- To identify flying good and harmful insects.
- To identify swarm on the field and their flying patterns.
- To eradicate flying insects or swarm using laser beam technology.

IV. METHODOLOGY

This section outlines the approach taken to develop the robotic pest monitoring system.

Data Collection:

- Compile an extensive dataset of pest images, utilizing the IP102 dataset with labeled pest species examples.
- Capture real-time, high-resolution images using multispectral imaging systems mounted on the robotic platform to monitor crops effectively.

Image Preprocessing:

- Apply preprocessing techniques such as noise reduction, normalization, and resizing to enhance image consistency and quality before analysis.

Model Development:

- Implement the YOLOv8 algorithm, known for efficient object detection, to train on the pest image dataset.
- Fine-tune the model for improved accuracy in detecting and classifying pests based on unique characteristics.

Pest Detection:

- Deploy the trained model on the robot to process real-time images and classify pests.
- Categorize pests as static or flying based on their observed characteristics and behavior.

 Real-time Monitoring and Notification:

- Integrate a continuous monitoring system to analyze images in real-time and notify farmers about pest detections.
- Include notifications with pest types and associated threat levels to inform farmers promptly.

Evaluation and Optimization:

- Perform field tests to assess pest detection accuracy and efficiency in real conditions.
- Collect user feedback to refine the algorithm, improving system performance with each iteration.

Reporting:

- Develop a reporting feature that summarizes pest detection activities, providing insights and trends for farmers to aid decision-making over time.

V. WORKFLOW

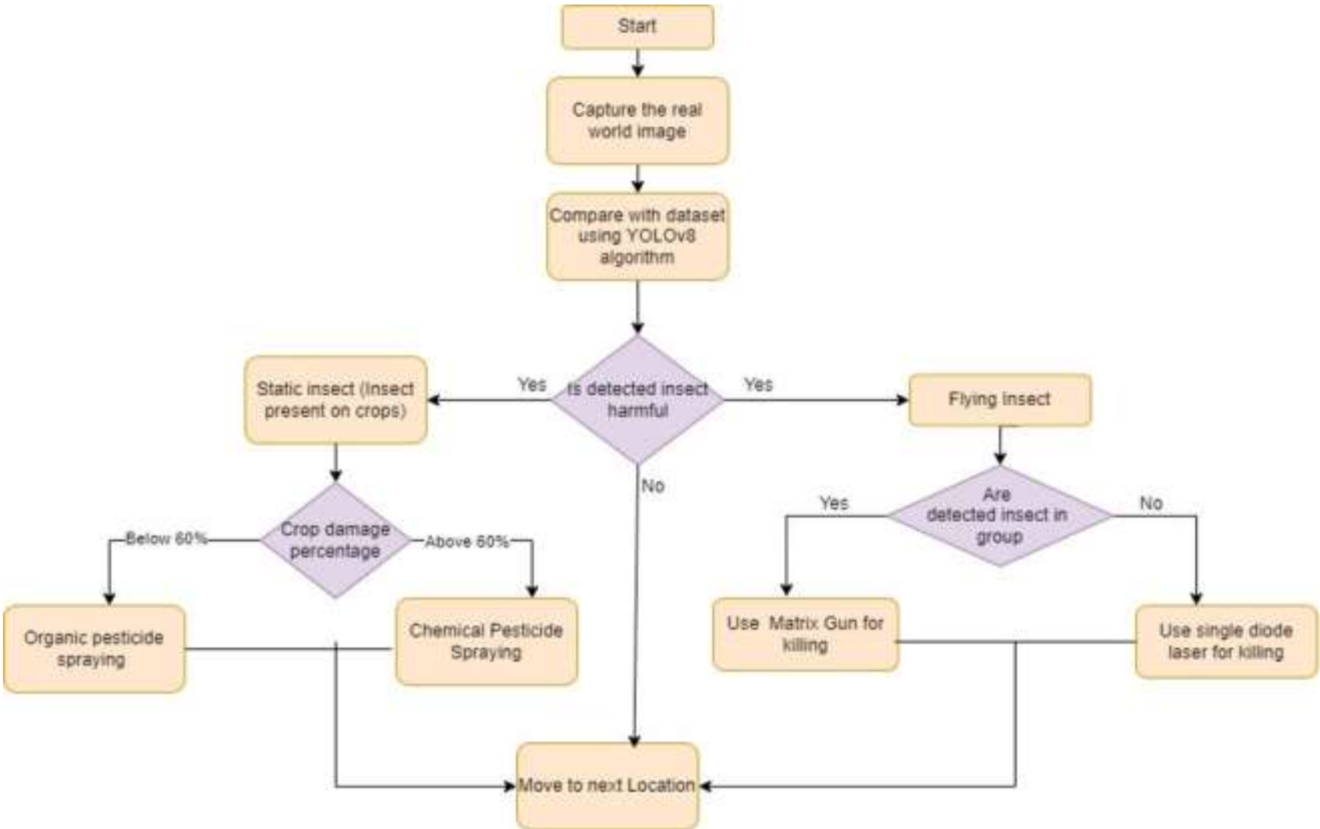

Figure 1: Workflow for System

- Start: The process begins.
- Capture the real-world image: A real-time image of the crop field is captured, presumably using a camera or sensor.
- Compare with dataset using YOLOv8 algorithm: The captured image is analyzed by the YOLOv8 algorithm, a real-time object detection model, which compares the image against a dataset to identify insects.

Is detected insect harmful?:

- If No, move to the next location (no action is needed for non-harmful insects).
- If Yes, proceed to determine the type of insect and appropriate response.

Insect Type (Static or Flying):

- Static insect (insect present on crops): If the insect is on the crop, evaluate the Crop damage percentage.
  - If below 60%, use Organic pesticide spraying.
  - If above 60%, use Chemical Pesticide Spraying.
- Flying insect: If the insect is flying, assess whether it is in a group.
  - If Yes, use a Matrix Gun to target multiple insects.
  - If No, use a single diode laser to target the individual insect.
- Move to next location: After addressing the insect threat based on the detection and decision tree, the system proceeds to the next location to continue monitoring.

VI. SYSTEM ARCHITECTURE

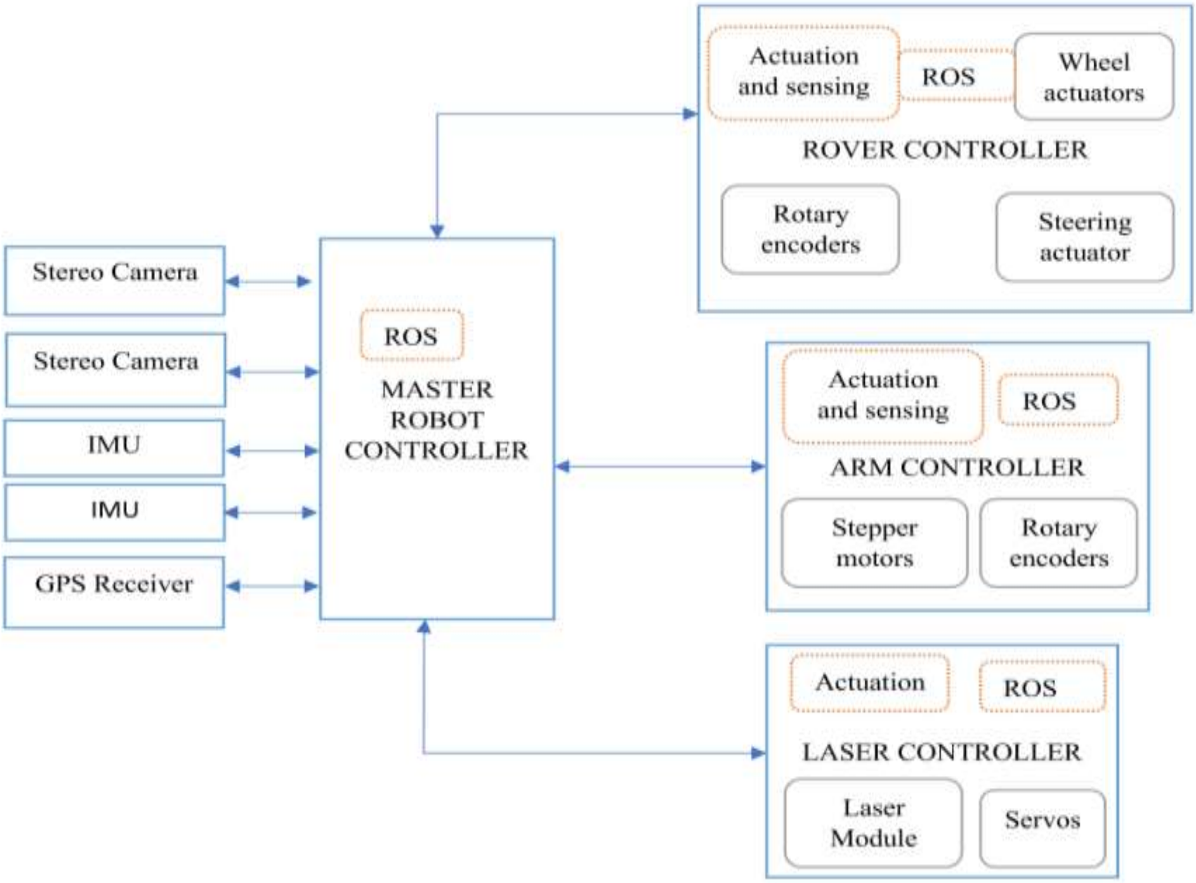

Figure 2: System Architecture

This diagram represents a high-level system architecture for a robot with multiple controllers. It outlines the various components and how they interact through the main **Master Robot Controller** using the **Robot Operating System (ROS)** framework. Here's a description of each component:

1) Master Robot Controller

- **ROS (Robot Operating System)**: Acts as the central framework enabling communication, data processing, and coordination between components.
- Interfaces with several external sensors:
    - **Stereo Cameras**: Two stereo cameras for visual perception, providing depth information and 3D mapping capabilities.
    - **IMUs (Inertial Measurement Units)**: Two IMUs for measuring orientation, velocity, and acceleration, aiding in the robot's navigation and stability.
    - **GPS Receiver**: Provides geolocation data, enabling outdoor navigation.

2) Rover Controller

- Responsible for controlling the rover's movement and mobility.
- **Actuation and Sensing**: Manages actuation of wheels and other motion-related sensors.
- **Wheel Actuators**: Control the rotation and movement of the rover's wheels.
- **Rotary Encoders**: Provide feedback on wheel rotation, helping to measure distance travelled.
- **Steering Actuator**: Controls the direction in which the rover moves, enabling steering adjustments.

3) Arm Controller

- Manages the robotic arm's motion and positioning.
- **Actuation and Sensing**: Controls the arm's movements and sensors for feedback.
- **Stepper Motors**: Drive the arm's movements with precision, allowing it to perform tasks like picking up objects.
- **Rotary Encoders**: Monitor the arm's movement, providing accurate position feedback for control.

4) Laser Controller

- Controls the robot's laser module, likely used for object detection, measurement, or scanning.
- **Actuation**: Drives the movement of the laser and servo mechanisms.
- **Laser Module**: Emits laser beams for sensing or scanning purposes.
- **Servos**: Adjust the position of the laser module, providing precise control over its direction.

Each controller communicates with the **Master Robot Controller** via ROS, enabling synchronized operations and data sharing across the robot's subsystems.

VII. CONCLUSION

Automatic harmful insect detecting and management robots have the potential to revolutionize the agriculture industry. These robots offer a number of benefits, including increased efficiency and reduced labor costs. They can operate 24/ 7 and can cover large areas quickly and efficiently. Additionally, they can reduce the use of harmful herbicides and pesticides, leading to a more sustainable and environmentally friendly approach to agriculture.

VIII. FUTURE SCOPE

The future scope of this robotic pest detection and control system is extensive. Integrating advanced sensors like LiDAR and hyperspectral imaging could improve accuracy in diverse environments. Enhanced AI models may further refine pest identification, even for new species. By incorporating real-time weather data, the system could adjust strategies dynamically, optimizing pesticide usage based on conditions.

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