PhoenixBot: Towards an ecological weed management robotic system

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A. Introduction

Background & Motivation:

- Global food systems must significantly increase global food production to keep pace with a growing population [1].
- Agriculture must also adapt to mitigate the harmful environmental effects caused by mainstream unsustainable farming practices [1].
- Increased yield and sustainable farming practices are often considered mutually-exclusive [3].
- Robotic agricultural systems could play a vital role in improving both yield and sustainability [3].
- Current robotic systems use either precise herbicide spraying, which uses harmful chemicals, or require heavy tillage, negatively affecting soil health [1, 5].

Objectives:

- Develop a robotic system framework to enable sustainable ecological weed management practices on small-scale farms

B. Ecological Weed Management (EWM)

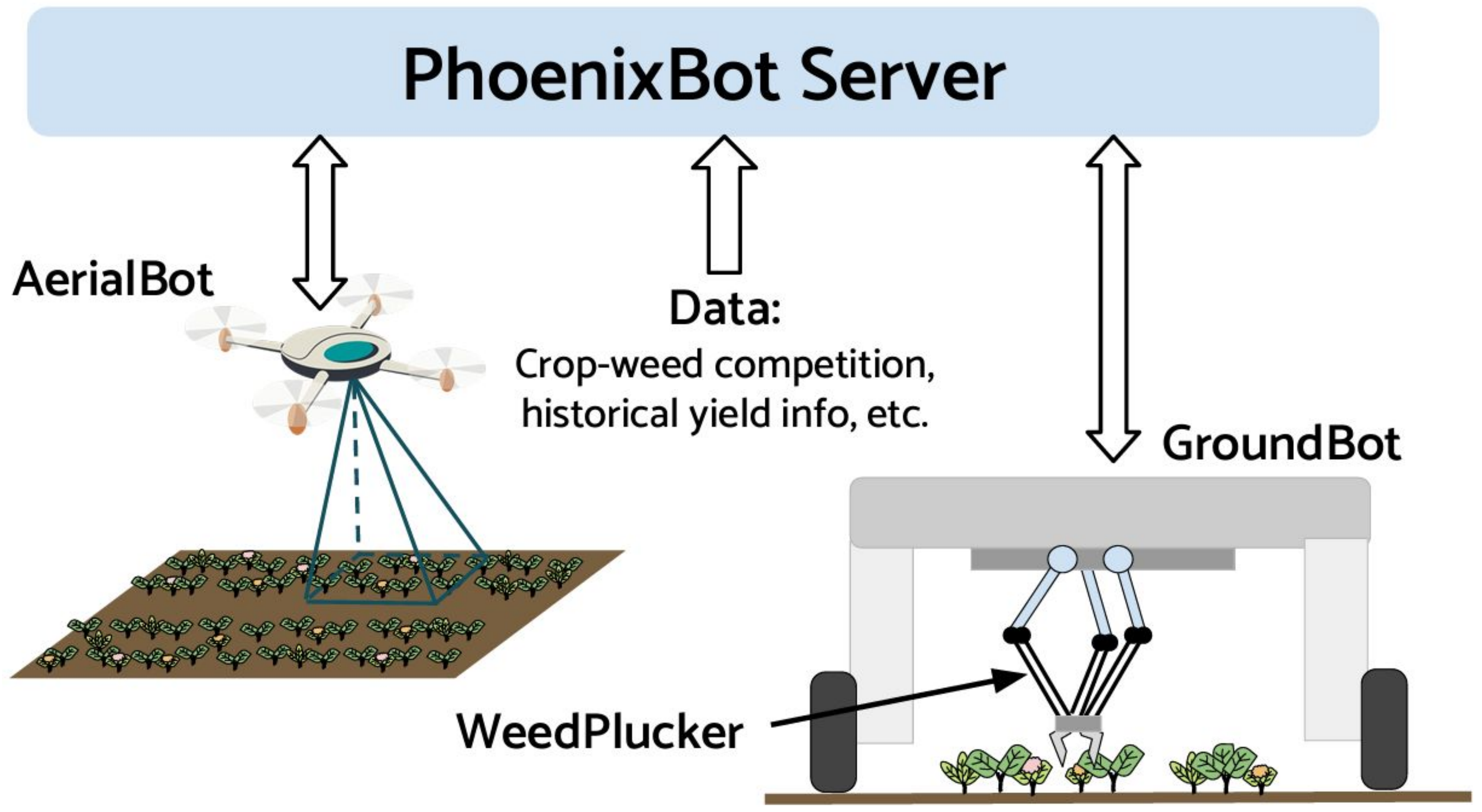
EWM Basics

- Challenges the notion that all non-crop plants are harmful, emphasizing an agroecological viewpoint that some non-crop plants are beneficial [3, 6].
- With EWM, only plants causing 'significant harm' are defined as weeds and should be controlled, retaining non-harmful 'aliae plantae' [1].

EWM vs. Non-EWM Approaches

- Studies suggest that well-managed weed biodiversity (such as through EWM) can increase crop yields [2].
- Any tool for weed management can become obsolete through weed adaptation if applied broadly, but can be beneficial if used judiciously in an EWM style [1].
- Current research is much more focused on "weed control" as opposed to "weed management" [1].

C. The PhoenixBot Framework



AerialBot - Unmanned aerial vehicle (UAV)

- Captures high-resolution aerial images of farmland routinely
- Images used for plant species identification and generating weed and yield maps

GroundBot - *farm-ng* Amiga (autonomous micro-tractor)

- Navigates crop rows using GPS and visual navigation
- Mechanically removes weeds with minimal soil inversion using **WeedPlucker** delta configuration arm with end-effector gripper

PhoenixBot Server

- Processes aerial images to generate map of crop and non-crop
- Determines which plants to target based on historic information

D. Implementation and Challenges

- **WeedPlucker:**
  - Composed of linkages in delta configuration that enable movement within a work envelope. Potential challenges: workspace size & speed/force capability.
  - Worm gear-powered gripper that pinches weeds for removal; more iteration of gripper design necessary.
- **Plant Detection & Classification:**
  - Uses OpenCV HSV filtering and Pl@ntNet model to identify and classify plants.
  - More research necessary to gather reliable crop-weed competition data for classification and targeting.
- **Other Potential Challenges**
  - ROS integration and on-site internet connectivity could present challenges for both vehicles.
  - Navigation using crop-row tracking on GroundBot

E. Discussion

- We hypothesize that our proposed system, which enables ecologically-sensitive plant species-specific weed management, holds the potential to unlock the next paradigm of robotics-driven environmentally sustainable weed management practices.
- Our current work is focused on GroundBot vehicle, with AerialBot work to begin in Fall 2024.
- Our ongoing work is to continue fabrication and begin field testing to validate the potential of our proposed system.

References

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