Mechanical Precision Weeding with a Robot Dog

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1 Introduction

Herbicide-based weed control has a negative environmental impact and is becoming even more unsustainable as weeds increase their resistance to herbicides. We propose a novel solution, utilizing small mobile robots for mechanical weeding, eliminating the need for herbicides. This method offers advantages over other automated mechanical weeding approaches, including reduced soil compaction and easier scalability. Our solution involves a Boston Dynamics SPOT quadruped robot equipped with a custom weed removal tool featuring a milling bit at its end. The tool is positioned using only the degrees of freedom of the robot base using its legs while its feet stay at the same position, as shown in Figure 1. Legged locomotion instead of conventional wheeled locomotion also enables more flexibility to remove weeds in different types of fields such as strip, row, or fully mixed intercropping. We integrate this system and develop a software architecture that enables autonomous weed removal. We experimentally tested the current proof of concept both in an indoor and outdoor environment. [1]



Figure 1: Robot dog with a custom-made weeding tool

2 Proposed Approach

The simplified process diagram is shown in Figure 2. It alters between locomotion and static-feet weed removal phases. During the static feet removal phase, the system first receives the weed locations from the camera and determines the order to remove the weeds that lie within the workspace. These weeds are removed one by one while the feet remain static, after which the robot walks to the next position.

Weed detection: The weed plants are detected by a trained YOLOv8 neural network, applied to 2D images from a RealSense L515 RGB-D camera, which are combined with the depth data to retrieve the 3D position of the weed plants.

Weed selection: For every detected weed we check if it lies within the workspace, which is an experimentally validated subset of all theoretically kinematically reachable positions to remove weeds.

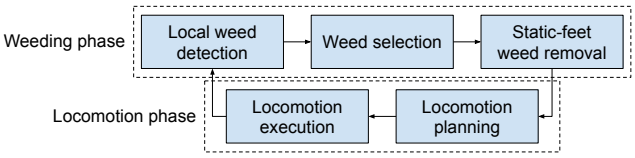


Figure 2: Simplified Process Diagram

Static-feet weed removal: The body pose of SPOT is determined using inverse kinematics, maintaining fixed foot positions, to position the end effector for weed removal per plant. This process is executed in two steps to enhance accuracy and robustness. Initially, the end effector is positioned slightly above and in front of the weed, enabling a new image to refine its exact location. Subsequently, the end effector is adjusted to the target position and the milling bit is turned on for weed removal.

Locomotion planning and execution: Once all reachable weeds have been removed, the robot determines the next position to remove weeds and walk there using SPOT's locomotion interface.

3 Results

The system was tested indoors with artificial plants and in a maize field with real weed plants. During the indoor tests, 82 out of 100 plants were successfully touched at the desired location (the milling bit was turned off). Tests in the real field to actually physically remove the weeds have been started and show promising results.

References

[1] T. M. E. Janssen, "Mechanichal precision weeding with a robot dog," Master's thesis, Eindhoven University of Technology, 2024.

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