Developing a Laser-Based Robotic Weed Management System For Agricultural Crops

Introduction

Weed management is a major challenge in crop production and weed control expenses rank among the top of any agricultural input. Industrial agriculture heavily relies upon herbicides, which contribute 68% to the total pesticide usage in the US (NASS 2010). Heavy and injudicious use of herbicides has led to herbicide-resistant weeds and environmental health concerns. Mechanical tools have limitations under wet soil conditions and accessing near- or intra-row weeds, in addition to their negative impact on soil health. Therefore, there is an urgent need to develop new and more precise tools to control weeds, especially to address problematic weeds that plague crop production.

Our team aimed at developing a robotic platform that supports precision weed management by integrating a high-power laser and a computer-vison-based weed detection system. While towing the system on the back of a tractor, a stereo camera along with onboard image processing algorithm identifies and localizes the weeds, signaling the high-power laser to take action. This project went through multiple iterations and its feasibility and effectiveness have been thoroughly tested in this research.

Methods and Results

An important focus of our project has been making a stationary prototype to illustrate the functionality and test the capabilities of the system:

- The basic framework of the system is a laser mounted on a motorized gimbal system attached to a microcontroller which interfaces with the stereo camera (Figure 1a).
- Laser power supply, gimbal, Nvidia Jetson microcontroller and Intel RealSense stereo camera were intergraded onto the frame.
- The system aims weeds radially based on their locations calculated from the depth data generated by the stereo camera (Figures 1b).

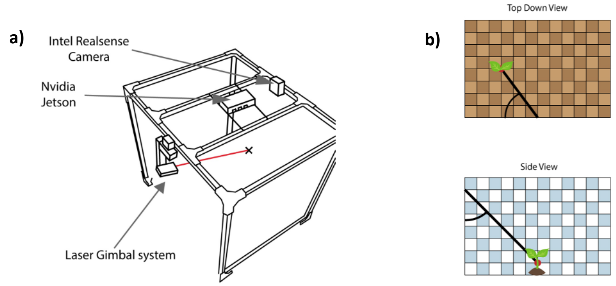

Figure 1: **a)** Sketch of the framework used to prototyping the laser-based robotic weed control system. The frame consists of a gimbal system that controls laser rotation, a Nvidia Jetson microcontroller, a Intel RealSense stereo camera and a power supply system (not shown in the sketch); **b)** Top and side view of the laser and plants showing laser targeting mechanism.

Another focus has been developing a machine-learning-based weed detection algorithm:

- An algorithm called FasterRCNN (Ren et al. 2015) implemented in Tensorflow is used.
- The algorithm uses the stereo camera to capture an image of weeds beneath the frame. Using the trained machine learning algorithm, weeds in the captured image are detected and bounding boxes are drawn around each weed (Figure 2).
- Using the LiDAR in the stereo camera, the distance of a weed from the camera is determined. Each weed is given a specific coordinate which is sent to the motor to control laser movement.

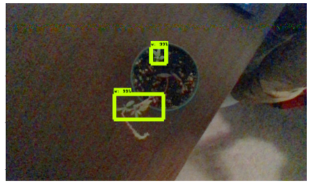

Figure 2: An example of weed detection result using the trained FasterRCNN algorithm. Weeds in the image are outlined by a bounding box with prediction confidence annotated at the top left corner of each box.

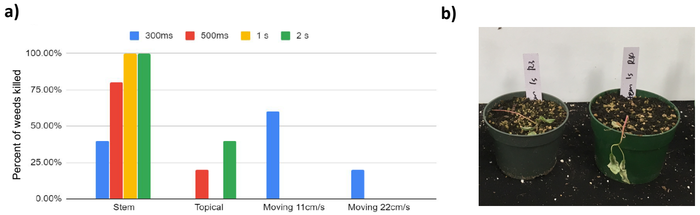

Figure 3: **a)** Average percentage of Palmer amaranth plants killed by laser with stationary laser radiation at stem, stationary radiation at topical meristem, moving radiation at 11cm/s and moving radiation at 22cm/s; **b)** Image showing Palmer amaranth plants killed by 7-watt laser with laser radiation focused on stem for one second.

The last focus is determining the most efficient method of killing weeds using high-power laser.

- A 7-watts laser was mounted on a tripod. Palmer amaranth, one of the most problematic weeds in Texas was used as a test species.
- Multiple experiments and scenarios were established. The scenarios included moving laser radiation, static radiation, different radiation positions, and different time durations (**Figure 3**).

Conclusion

The results showed that laser is a powerful tool for weed management, especially for controlling weed seedlings when laser is focused on the stems. This result provides valuable information in determining the best design solution of our robotics platform. With current progress that has been made in image processing algorithm and laser control mechanism, a fully functional prototype that can be tested in field will be soon developed.

References

Ren, Shaoqing, et al. "Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks." *Advances in Neural Information Processing Systems (NIPS)*, 2015.

USDA National Agricultural Statistics Service. "Agricultural Statistics 2010". Accessed April 2020. https://www.nass.usda.gov/Publications/Ag_Statistics/2010/2010.pdf

innovation X — Powered by: Texas A&M School of Innovation

Texas A&M University College of Agriculture & Life Sciences

Texas A&M University School of Innovation

Texas A&M University Engineering