Using Multi-Spectral Imaging for Real-Time Weed Control in Fallow Fields

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Executive Summary:

One of the major challenges in agriculture is keeping fallow fields and the understory of perennial crops clear of weeds. Weeds in fallow fields can cause unnecessary resource uptake (leading to reduced yield in the following crop) and increase the seed bank for the following crop (leading to increased yield and/or increased weed control costs for the following crop). Weeds in the understory of perennial crops directly compete with the crop, leading to reduced yield. Three general groups of methods for controlling weeds on bare ground include herbicides (including glyphosate and 2,4-D), mechanical removal (tillage), and steam saturation. Spot-spraying is commonly used in multiple perennial crops like orchards and nurseries, but that practice is labor intensive as one person covers 4 to 5 acres a day. The amount of herbicide applied is highly variable as well. In contrast, spraying a field with herbicides uniformly leads to wasteful herbicide use as the weeds themselves do not cover the field uniformly, resulting in significantly increased cost and adverse environmental impact. Unfortunately, many herbicides are being overcome by herbicide resistance in weeds, and are ineffective in certain situations (Burke et al. 2009; Bartroso et al. 2018). While not prone to herbicide resistance, tillage is energetically intensive, and can degrade soil structure. Similarly, steam saturation of weeds is an environmentally
attractive method to kill weeds, but requires a considerable amount of energy, and supplying the equipment with water can be logistically challenging.

Traditionally, weed control measures would be applied to an entire field, regardless of the actual density of the weeds. However, for precision weed control (the application of control measures only where weeds are present), interventions only need to be applied where weeds are growing. In fields that are relatively free of weeds, this could make the direct cost of control negligible (although fuel would still be needed to drive over the field). Oregon growers need a low-cost optical weed detection sensor that can control a variety of precision weed control measures. Two devices are currently used for precision weed control in Eastern Oregon: the WEED-IT and the WeedSeeker. However, these devices are expensive (approximately $1,000 per sensor for the WeedSeeker and $8,000 per sensor for the Weed-It), and they have a reputation for being unreliable in some situations (especially when weeds are small, or the field is dusty; Oregon wheat growers, personal communication).

We requested $15,000 to develop a significantly lower cost and open source sensor as an alternative to these commercial products. We evaluated a relatively new sensor that at the time had never been applied to this end use before. We discovered this sensor can be used to calculate the normalized difference vegetation index (NDVI) and act as a chlorophyll detector. When evidence of chlorophyll is detected, the WeedWarden sends a signal that can be used to control a spray valve or activate some other weed intervention device such as steam or tillage attachments.

To date, we have collected data that validates our approach. We are near the end of our funding, so further funding will need to be secured to enable us to deploy this system on an autonomous rover that will host the WeedWarden sensor and various weed intervention systems to determine the most effective application of our discoveries.

Objectives:
The objective of the Weed Warden is to provide an open source, low cost (<$500) weed detection sensor that will ultimately reduce the use of herbicides and cut costs for farmers. In the end we would like to see Weed Warden controlling an array of sensors and sprayers mounted on a tractor boom or rover.

Procedures:
To detect plants, the Weed Warden uses the Sparkfun Spectral Triad sensor, the Adafruit Feather M0, and the OPENs Lab Hypnos Board. See URLs to these links below. The Feather M0 serves as the controller for the system. The Hypnos is datalogger and power management device. The Spectral Triad is a $65 sensor that can detect the light from 410nm (UV) to 940nm (IR). In addition, 18 individual light frequencies can be measured with precision down to 28.6 nW/cm² and accuracy of +/-12%. We use these data to calculate NDVI and this indicate when it detects chlorophyll, a tale-tale sign there is a plant in the viewing range.

The method for determining the presence of grass is to use the normalized difference vegetation index (NDVI). NDVI works by measuring the difference between near-infrared (which vegetation strongly
reflects) and red light (which vegetation absorbs). After calibrating the sensor on a dirt surface, the Weed Warden can detect vegetation when it is placed under the sensor by using a threshold that is set by the calibration sequence. Periodic calibration periods are advised so the sensor can adapt dynamically to gradual changes in light conditions throughout the day. This could potentially make the system more robust than commercially available options, but more testing is needed.

Figure 1 shows a graph of the NDVI index (grey) movement based on whether there is vegetation underneath the sensor or not. The green lines represent the presence of vegetation underneath the sensor and the orange line is the threshold which the NDVI index must cross for the system to recognize that there is vegetation underneath the sensor. If the NDVI index crosses the threshold line, then the Weed Warden will classify the sample as vegetation.

*Figure 1: Shows the graph of the NDVI index for a 5 inch bundle of grass at 1 foot off the ground*
The testing setup for the Weed Warden has been to use a bundle of grass similar to the one in figure 2 and a cart with the Weed Warden mounted on it such as the figure at the top of this report. The Weed Warden has been tested at heights of 3 feet, 2 feet, and 1 foot. Optimal heights between 1 and 2 feet.

The Weed Warden has an onboard 12V relay via the Hypnos board, which can be used to trigger a sprayer or other weed removal device when vegetation is detected. The Hypnos Board also has micro-SD card logging capabilities that are being used to log data from the triad sensor to further improve the detection algorithm.

**Significant accomplishments to date:**
Significant accomplishments include the following:

- Consistent detection of large vegetation samples at 3-foot height.
- Consistent detection of small vegetation samples at 1-foot height.
• Successful development of calibration code to allow the Weed Warden to perform in various environments.
• Eliminated the need for a shade cover or external light by using calibration code.
• Eliminated EVI and PSND indices as candidates for vegetation detection on the Weed Warden.
• Integration of Hypnos Board to include datalogging and 12V control.

Future advancements if more funding can be procured will be:

• Deployment at 1ft height on an autonomous rover.
• Experimentation with different weed interventions.
• Exploration of embedded machine intelligence (neural net) detection instead of our currently basic threshold detection algorithm.

Additional Funding Received:
We received no additional funding so far for this project, but plan to seek more soon.

Future Funding Possibilities:
Agricultural Research Foundation
USDA
NSF

Sparkfun Spectral Triad Sensor:
https://www.sparkfun.com/products/15050

Adafruit Feather M0:
https://learn.adafruit.com/adafruit-feather-m0-basic proto/pinouts?view=all

OPEnS Lab Hypnos Board:
https://github.com/OPEnSLab-OSU/OPEnS-Lab-Home/wiki/Hypnos