PROJECT NAME

Date: 2. December 2024

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DTU

27020 Interdisciplinary bioengineering

SIM track

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1. Introduction

Pesticides, particularly herbicides, play a crucial role in modern agriculture by protecting crops from weeds and increasing productivity [9]. However, their widespread use has raised significant environmental concerns, especially regarding water pollution [8]. As such, the question arises if there is a way to solve the problem of weeds in agriculture, in a way that, the environmental consequences are limited as much as possible.

1.1 Weed Impact

Weeds pose a significant threat to agricultural productivity by competing with crops for essential resources like water, nutrients, and sunlight. They can reduce crop yields, diminish product quality, and increase production costs [9]. This represents the main problem of weeds, because if they did not compete with the crops, they would not be an issue. However, if left uncontrolled, weeds can lead to an 100% loss of yield. As a final remark, the weeds are the main cause of the proliferation of pests [12].

1.2 Cost of Weeds

It is difficult to make an accurate analysis of the losses that appeared as a result of weed competition. Howerver, several attemps were made in the recent history. In 1967, weeds caused 8% loss of potential of the agricultural production of the US. Another estimate was, that 9.7% of the possible crop yield was lost in that year. In 1975, according to 1967's calculations, an estimate was made that weeds eliminated 14.6% of the total potential crop yield in the world [12]. Although, there are many more estimates, their enumeration does not fit in the scope of this paper. These examples, should be sufficient in providing the reader an overview of the trouble of weeds in agriculture.

1.3 Pesticide Impact

While pesticides are an efficient counter-measure to weeds, they pose high problems for the environment. First of all, they affect non-target organisms such as humans, birds and fishes and cause adverse effects to their health as the pesticides collect in their cells. This is due to their formation as bio-active molecules to eliminate fungal, vegetal and animal species [8]. Equally important are the indirect effects of pesticides in accelerating soil erosion, while the movement of pesticides into surface and groundwater affects wildlife and contaminates drinking water beyond safe levels [2].

1.4 Fate of Pesticides

Furthermore, the widespread issue of surface and groundwater pollution, is the main result of the extensive use of herbicides and pesticides [9]. Pesticides meet a variety of fates after being applied to Earth, and Figure 1.1 shows the general picture of their path in the environment. It is seen, that soil and water deposition represent the main end point of a pesticide's "life".

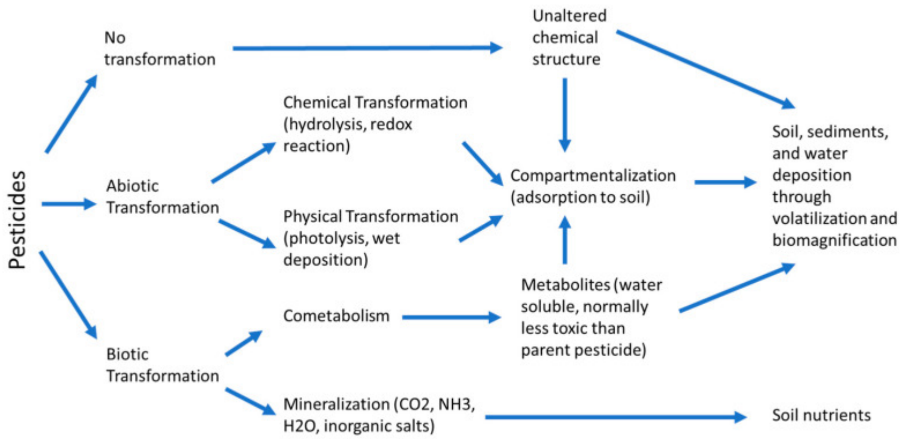

Figure 1.1: Fate of Pesticide [9]

1.5 Water Pollution Impact

The exceedence of pesticides in surface water and ground water in Europe is still detected at the reporting sites [4]. Therefore, the probability that a higher number of people will feel the consequences of contamination are raised. The consequences can include endocrine dysfunction, oxidative stress, immune and neurological system problems, and chromosomal changes. Moreover, pesticides usually occur in mixtures that are difficult to evaluate, therefore they may include additive effects [1]. As such, there is a real motivation to limit the contamination of water with pesticides, by finding an innovative way to treat crops of weeds, limiting the use of the above mentioned substances.

2. Proposed solution

In the below sections, a description on how the data needed to analyze the issue of weeds, and the usage of indiscriminate pesticide was gathered. The proposed solution is an efficient system that reduces pesticide usage by accurately identifying weed species and targeting them specifically, rather than applying chemicals indiscriminately across the field. The proposed solution integrates robotics, machine learning and cloud services. At last, a quantitative analysis will be done to show how this solution actually benefits society.

2.1 Analyzed

The research began with a review of existing agricultural solutions that are primarily used across farms today. This involved looking at the usage of autonomous robots in fields, existing machine learning models for identifying crops and their accuracy. Existing autonomous robots are all quite large and heavy which can possibly play a role in soil erosion. For the autonomous robot to navigate the field and complete its job accordingly, it has to have 3 key concepts [7]:

1. A sensing system for navigation purposes and measuring important physical and biological properties of the agricultural system.
2. The capability of decision making for processing information from the sensor system to determine its next step.
3. Actuators to manipulate the agricultural system accordingly.

Existing autonomous robots in agricultural fields often use the Hough transform for identifying crop rows. This method is effective for navigation in fields where gaps between crops occur due to factors such as poor germination or insect damage. Using the Hough transform, the outliers detected in the pattern can be indicative of weeds.

Two different weed control robots have been developed with distinct vision methods and operating speeds. The fast robot which is capable of speeds up to 16 km/h, utilized real time color segmentation to identify crop rows, making it highly effective in dynamic field conditions. The slower robot at speeds up to 6 km/h, relied on extracting row midpoints for guidance, offering good accuracy under controlled conditions with lighter weed pressure [7].

2.2 Methods and technologies

As stated in the proposed solution to the problem formulation of the excessive use to pesticide in weed control, several existing technologies are to be applied. Technologies such as, methods from deep learning and machine learning, computer vision, cloud computing, and sensor technologies. these are integrated and some adapted to solve the problems of weeds in agriculture.

2.2.1 Machine Learning Models for Weed Detection

Convolutional Neural Networks (CNNs), are to be used for image classification from the hyper spectral cameras the autonomous robot is equipped with. Resnet is a CNN that allows for retraining on all data, this technology makes it possible for each robot to be trained on specific data from each respective farm, making the system highly adaptable. The ResNet152V2 model yields an accuracy between 78.0% and 94.2% [10].

2.3 Lacking technologies

2.4 Quantitative analysis

3. Impact / relevance

The proposed solution offers an opportunity to reduce the environmental footprint of agriculture by optimizing the application of already-in-use chemical herbicides and pesticides. Traditional spraying methods often result in overuse, which pollutes water sources and harms non-damaging species [3]. However, while the targeted spraying system reduces chemical usage, it does not eliminate reliance on these substances.

3.1 Environmental impact

Reducing chemical use benefits small animals and organisms that contribute to biodiversity and are crucial to ecosystem balance. These species, often unintentionally affected by blanket pesticide applications, play essential roles in pest control, soil health, and pollination [3]. Despite the benefits, it is important to acknowledge that the solution does not eliminate the risk of ecological harm. The continued use of chemicals, even in reduced quantities, may still affect sensitive environments [6].

3.2 Societal impact

From a societal perspective, this technology represents a step toward addressing public concerns about chemical residues on food. The reduction in chemical spraying can alleviate some health and environmental anxieties [3], supporting sustainable farming practices. However, it is crucial to emphasize that this solution does not eradicate the use of chemicals, which may limit its appeal to advocates of completely organic or chemical-free agriculture [6].

3.3 Farmers

Farmers represent a critical stakeholder group. The proposed robot offers clear advantages, such as improving crop yields through targeted spraying and minimizing human exposure to chemicals, thereby reducing health risks [5]. Furthermore, it supports compliance with increasingly stringent environmental regulations [3], helping farmers align with sustainable practices.
Nevertheless, this technology presents challenges, particularly for small-scale or resource-constrained farmers. The high initial cost and continues payments for the machine learning model may make adoption impossible for some.

3.4 Regulators and environmental advocates

The technology aligns with the efforts to reduce the environmental impact of the current farming practices. It can serve as a practical example of sustainable innovation and it can promote compliance with environmental polices. Although many are working on completely removing such chemicals from agriculture practices [3].

3.5 Consumers

Consumers, who are increasingly conscious of the environmental and health implications of their food [3], may prioritize food produced with minimized chemicals. This perception can translate to market advantages for farmers using the robot. This perception can translate to market advantages for farmers adopting the robot.

3.6 UN Sustainable Development Goals

The weed-detection robot directly contributes to several UN SDGs:

- **Goal 2:** Zero Hunger [11] - By improving crop yields and ensuring more sustainable farming practices, the solution supports food security.
- **Goal 12:** Responsible Consumption and Production [11]- The robot optimizes chemical usage, ensuring efficient resource consumption and reducing waste.
- **Goal 15:** Life on Land [11] - By preserving biodiversity and minimizing chemical impact on non-target species, the technology promotes sustainable ecosystems.
- **Goal 6:** Clean Water and Sanitation [11]- The reduction in chemical runoff directly protects water quality, contributing to clean water sources for communities.

While the robot makes meaningful contributions to these goals, its reliance on chemicals and accessibility barriers for smaller farmers highlight areas requiring further innovation and policy support.

4. Future perspectives / discussion

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5. Conclusion

The weed-detection robot reduces agriculture's environmental footprint and aligns with global sustainability goals. However, reliance on chemicals and high costs highlight the need for further innovation and support.

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Appendix