www.editada.org

International Journal of Combinatorial Optimization Problems and Informatics, 16(1), Jan-April 2025, 202-207. ISSN: 2007-1558.
https://doi.org/10.61467/2007.1558.2025.v16i1.951

DOCTORAL THESIS SUMMARY
Design and Control of a Precision Farming Device

Student: *Rubén Oswaldo Hernández Terrazas*
Polytechnic University of Pachuca. Mexico
rterrazas@upp.edu.mx

Advisor: *Juan Xicoténcatl-Pérez*
Polytechnic University of Pachuca. Mexico
xico@upp.edu.mx

Advisor: *Jorge A. Ruiz-Vanoye*
Polytechnic University of Pachuca. Mexico
jorgeruiz@upp.edu.mx, jorge@ruizvanoye.com

Abstract: Precision agriculture has revolutionised the way farmers manage their crops, maximising efficiency and minimising environmental impact. This thesis addresses the design and implementation of a device that identifies the corn plant and with the help of artificial intelligence implement a robotic arm that delivers herbicides and in some cases precision lasers.

We will explore the design and control of a precision farming device, from basic principles to the most advanced technologies currently in use. We will analyse the sensorisation tools, control systems and optimisation techniques employed to ensure a more sustainable and profitable agriculture through: precision identification of maize plants and the use of a robotic mechanical arm equipped with two nozzles, one to deliver herbicide and the other to deliver lasers to the weeds surrounding the maize plants. The proposal aims for the expected results to reduce herbicide consumption by 30-50%, validating the feasibility of this scalable and sustainable solution to improve efficiency in agricultural infrastructures.

Keywords: Precision farming, Laser, robotic arm, computer vision.

Article Info
Received March 4, 2025
Accepted March 14, 2025

1 Introduction

Precision farming emerges as an innovative and sustainable solution. This practice uses technology to monitor crops more efficiently and accurately, and by applying agricultural inputs for weed and pest control such as pesticides, electromechanical systems (laser beam), only in the areas and quantities needed, environmental impact is significantly reduced. Precision farming not only optimizes the use of resources, but also improves productivity and long-term sustainability. Indiscriminate use of pesticides can lead to resistance in pests and weeds, making these chemicals less effective over time. Precision agriculture is emerging as an innovative and sustainable solution. This practice uses technology to monitor crops more efficiently and accurately, and by applying agricultural inputs for weed and pest suppression such as pesticides, electromechanical systems (laser beam), only in the areas and quantities needed, environmental impact is significantly reduced. Precision farming not only optimises the use of resources but also improves productivity and long-term sustainability.

1.1 Motivations

Indiscriminate use of pesticides can lead to resistance in pests and weeds, making these chemicals less effective over time. Precision farming is emerging as an innovative and sustainable solution. This practice uses technology to monitor crops more efficiently and accurately, and by applying agricultural inputs for weed and pest suppression such as pesticides, electromechanical systems (laser beam), only in the areas and quantities needed, the environmental impact is significantly reduced.

1.2 Description of the research problem

Agriculture is very important in the development of mankind by providing essential food and resources. However, the extensive use of pesticides in traditional agriculture has led to serious environmental and health problems. These chemicals not only kill pests or weeds, but also contaminate soil, water and affect biodiversity, putting the health of humans and ecosystems at risk. Indiscriminate use of pesticides can lead to resistance in pests and weeds, making these chemicals less effective over time.

1.3 Objectives of the thesis

Main Objective:

Design and develop a device through precision agriculture that provides the identification of weeds and pests for eradication using automatic, mechanical or optical devices.

Specific Objectives:

1. Develop an image identification algorithm to identify and eradicate weeds
2. develop a precision hybrid mechanism to reduce the amount of herbicide/and Laser in the affected areas
3. develop a precision algorithm to adjust the use of Laser and herbicide
4. perform performance and comparative tests of the developed algorithms
5. perform device performance data collection to adjust the algorithms, improve the precision of the Laser and refine the application of herbicides.

Brief description of the contribution of the thesis:

The investigation of a hybrid system that uses lasers and herbicides to eliminate weeds and pests represents a significant advance. This approach allows for precise and accurate application, reducing the amount of herbicides needed and therefore decreasing soil and water contamination.

2 Background

Highly accurate identification of Corn plants that allow implementing weed elimination methods. The objective of this project is to develop a computer vision model based on Machine Learning (ML) algorithms for the identification of Corn and weeds. using Python.

Agriculture is very important in the development of humanity by providing essential food and resources. However, the extensive use of pesticides in traditional agriculture has generated serious environmental and health problems. These chemicals not only eliminate pests or weeds, but also contaminate the soil, water and affect biodiversity, putting the health of humans and ecosystems at risk.

This practice uses technology to monitor crops more efficiently and accurately, and by applying agricultural inputs for the elimination of weeds and pests such as pesticides, electromechanical systems (laser beam), only in the necessary areas and quantities, the environmental impact is significantly reduced.

Robotics, as a multidisciplinary field, has experienced exponential evolution in recent decades, transcending the limits of industrial automation to enter areas as diverse as medicine, space exploration and agriculture. This document delves into three fundamental areas of robotics: the modeling and control of robotic arms, the teleoperation of manipulators, and the development of robotic implements for precision agriculture.

Robot weeders can employ various techniques to remove weeds, such as mechanical cutting, selective application of herbicides, and laser removal. Laser weed removal is an innovative technique that has several advantages over other methods. This approach is precise, selective and does not generate chemical waste.

Robotic weeders are designed to perform tasks that traditionally required human labor, significantly enhancing efficiency. For instance, systems utilizing convolutional neural networks (CNNs) enable real-time weed detection with high accuracy, identifying and classifying weeds through image analysis (Olsen et al., 2019; Patel et al., 2022; , Wang, 2023; , Liu & Bruch, 2020). The automated detection capabilities allow for selective application of herbicides or mechanical removal, greatly reducing the overall quantity of chemicals used in agriculture and mitigating negative environmental impacts associated with herbicide overuse (Zhang et al., 2022). Furthermore, autonomous systems can operate within the crop rows, employing techniques such as in-row hoeing or spot spraying, resulting in substantial herbicide savings (Gerhards et al., 2022).

In addition to precise weed control, robotic weeders advance the concept of precision agriculture, which emphasizes site-specific weed management strategies. This approach leverages technologies such as GPS and drones to assess weed infestation levels across various spatial and temporal dimensions (Kaushal et al., 2023; Roslim et al., 2021). By combining aerial insights with ground-based robotic systems, farmers can implement targeted interventions that optimize resource use, enhancing crop yields while reducing operational costs (Debbarma et al., 2023).

Further, the growing reliance on autonomy in agricultural practices is fueled by the increasing demand for food alongside a shrinking agricultural workforce. Robotic weed control technologies not only alleviate labor shortages but also enhance efficiency in agricultural operations, ensuring that food production adapts to contemporary challenges (Esposito et al., 2021; Bajwa et al., 2015). Additionally, innovations in drone technology and unmanned aerial vehicles (UAVs) have provided farmers with new tools to monitor and manage weed presence in real-time, facilitating a rapid response to weed outbreaks and lessening competition with crops for essential resources like water and nutrients (Roslim et al., 2021).

Despite these advancements, challenges remain. Effective integration across various robotic systems is crucial for optimizing their functionalities while ensuring operability with existing agricultural practices (Gerhards et al., 2022). Additionally, ongoing research is necessary to address the interoperability of sensing technologies and robotic controllers to achieve seamless operation across different agricultural contexts (Westwood et al., 2018).

This paper has looked at three key areas of robotics: the modeling and control of robotic arms, the teleoperation of manipulators, and the development of robotic implements for precision agriculture.

3 Proposed Solution Approach

Robotics, as a multidisciplinary field, has experienced exponential evolution in recent decades, transcending the limits of industrial automation to enter areas as diverse as medicine, space exploration and agriculture. This document delves into three fundamental areas of robotics: the modeling and control of robotic arms, the teleoperation of manipulators, and the development of robotic implements for precision agriculture.

First, we examine the design, modeling, and control of a four-degree-of-freedom robotic arm (ArmX), a system that serves as a platform for exploring advanced kinematics, dynamics, and control concepts. The implementation of a graphical interface in LabWindows/CVI facilitates the interaction between the user and the robot, allowing the planning and execution of complex trajectories. Significant improvements are proposed, such as the incorporation of external sensors and artificial vision systems, in order to provide the ArmX with perceptive and adaptive capabilities that expand its range of applications.

Second, the teleoperation of five-axis robotic arms is addressed, a technique that allows remote manipulation of objects in dangerous or inaccessible environments. Instrumentation of the human arm using motion and force sensors enables the intuitive replication of movements in the slave robot. The benefits and challenges of teleoperation are analyzed, such as the extension of human capabilities and communication delays, respectively.

Finally, the development of a robotic implement for laser weed control is presented, an innovative system that unites robotics with precision agriculture. The integration of computer vision and advanced control systems allows for the selective detection and removal of weeds, reducing dependence on herbicides and promoting more sustainable agricultural practices. Modeling and Control of Robotic Arms Modeling and control of robotic arms is a key research field in robotics. These arms are complex mechanical systems that feature multiple degrees of freedom, allowing them to perform a variety of manipulation tasks. Understanding the kinematic and dynamic modeling of these systems is crucial to designing effective control strategies. The kinematics of a robotic arm refers to the relationship between the positions and orientations of its joints and the position and orientation of its end effector.

4 Experimental results

Using neural networks, an algorithm was designed capable of identifying images of weeds and those that are not weeds. Image processing in Python is capable of building neural networks for image classification. On the other hand, we are participating in an article with the title of "Predictive algorithms for the detection of weeds in hyperspectral images" and finally, the mathematical model of the mechanical arm of the Precision Agriculture device is being transferred to the control laws.

Real-Time Detection of Weeds through Artificial Vision Techniques
research and development focused on real-time detection of weeds using artificial vision techniques. Its objective is to reduce the use of herbicides in precision agriculture.

Different types of sensors for weed detection:

- Sensors that analyze the spectrum of reflected light
- Sensors that use image taking (detection through color, shape and texture analysis).
- Use video cameras for color detection in uncontrolled lighting conditions
- Texture analysis to identify the presence of weeds.
- Determine the most suitable artificial vision method (processing strategy) for local species.
- Develop a control system for spraying herbicides on fallow weeds.
- The social impact of the project focuses on reducing the use of herbicides and contributing to more sustainable agriculture.

This means that the benefit for the environment will be a way to mitigate the problems of large-scale agriculture and make this economic activity more sustainable.

5 Conclusions

This research project proposes the design and implementation of a hybrid precision Agriculture Device, to reduce weeds, the use of herbicides and improve product quality in addition to reducing costs and reducing the risk of diseases in humans. An algorithm was designed in Python to identify weeds, and work is also being done with Matlab to train the movements of the mechanical arm that will carry the AP device. Therefore, it seeks to contribute significantly to an improvement in the field of engineering and agriculture.

The robotics research areas that have been analyzed present great potential to improve efficiency, safety and sustainability in various applications, especially precision agriculture. The combination of robotics, artificial vision and laser technologies offers innovative solutions for weed control and reducing environmental impact.

6 References

Bajwa, A., Mahajan, G., & Chauhan, B. (2015). Nonconventional weed management strategies for modern agriculture. Weed Science, 63(4), 723-747. https://doi.org/10.1614/ws-d-15-00064.1

Bolton, W. Mecatrónica. Sistemas de control electrónico en ingeniería mecánica y eléctrica. 2da Edición. Alfaomega; 2011.Disponible en: www.teczazamora.blogspot.com

Castillo, V. S. (2023). Analysis of the scientific production on the implementation of artificial intelligence in precision agriculture. LatIA, 1, 1-1.

Debbarma, B., Saha, A., & Teli, S. (2023). Uav technology for precision weed detection and management. planthealth, 1(1), 08-10. https://doi.org/10.54083/pha/1.1.2023/08-10

Esposito, M., Crimaldi, M., Cirillo, V., Sarghini, F., & Maggio, A. (2021). Drone and sensor technology for sustainable weed management: a review. Chemical and Biological Technologies in Agriculture, 8(1). https://doi.org/10.1186/s40538-021-00217-8

Gerhards, R., Sanchez, D., Hamouz, P., Peteinatos, G., Christensen, S., & Fernández-Quintanilla, C. (2022). Advances in site-specific weed management in agriculture—a review. Weed Research, 62(2), 123-133. https://doi.org/10.1111/wre.12526

Kaushal, A., Almurshed, O., Alabbas, A., Auluck, N., & Rana, O. (2023). An edge-cloud infrastructure for weed detection in precision agriculture., 0269-0276. https://doi.org/10.1109/dasc/picom/cbdcom/cy59711.2023.10361387

Liu, B. and Bruch, R. (2020). Weed detection for selective spraying: a review. Current Robotics Reports, 1(1), 19-26. https://doi.org/10.1007/s43154-020-00001-w

Olsen, A., Konovalov, D., Philippa, B., Ridd, P., Wood, J., Johns, J., … & White, R. (2019). Deepweeds: a multiclass weed species image dataset for deep learning. Scientific Reports, 9(1). https://doi.org/10.1038/s41598-018-38343-3

Patel, D., Gandhi, M., Shankaranarayanan, H., & Darji, A. (2022). Design of an autonomous agriculture robot for real-time weed detection using cnn., 141-161. https://doi.org/10.1007/978-981-19-6780-1_13

Restrepo-Arias, J. (2023). Método de clasificación de imágenes, empleando técnicas de inteligencia artificial, integrado a una plataforma IoT de agricultura inteligente.

Rojas, A. R., Velastegui, A. H., Solórzano, F. C., Fiallos, F. M., Medina, D. M., & Paredes-Beltran, B. (2024). Aplicación de Redes Neuronales Artificiales para la Estimación de Precipitaciones: Caso de Estudio de la Cuenca del Río Pastaza, Ecuador: Application of Artificial Neural Networks for Rainfall Estimation: Case Study in the Pastaza River Basin, Ecuador. Revista Científica FINIBUS-Ingeniería, Industria y Arquitectura ISSN: 2737-6451, 7(14), 131-146.

Roslim, M., Juraimi, A., Che'Ya, N., Sulaiman, N., Manaf, M., Ramli, Z., … & Motmainna, M. (2021). Using remote sensing and an unmanned aerial system for weed management in agricultural crops: a review. Agronomy, 11(9), 1809. https://doi.org/10.3390/agronomy11091809

Saleiro M, Carmo B, Rodrigues JM, du Buf JH. A low-cost classroom-oriented educational robotics system.Social Robotics. 2013; pp. 74–83.

Wang, Y. (2023). A deep learning-based approach for vision-based weeds detection. International Journal of Advanced Computer Science and Applications, 14(12). https://doi.org/10.14569/ijacsa.2023.0141207

Westwood, J., Charudattan, R., Duke, S., Fennimore, S., Marrone, P., Slaughter, D., … & Zollinger, R. (2018). Weed management in 2050: perspectives on the future of weed science. Weed Science, 66(3), 275-285. https://doi.org/10.1017/wsc.2017.78

Zhang, W., Miao, Z., Li, N., He, C., & Sun, T. (2022). Review of current robotic approaches for precision weed management. Current Robotics Reports, 3(3), 139-151. https://doi.org/10.1007/s43154-022-00086-5