All Sciences Proceedings

1st International Conference on Recent and Innovative Results in Engineering and Technology

August 16-18, 2023 : Konya, Turkey

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Intra-Row Weeder Design and Application By Using Image Processing and Artificial Intelligence Techniques

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Abstract **–** Agriculture plays an important role in the face of growing population and food demand worldwide. However, traditional farming methods provide limited productivity and use resources inefficiently. In this context, the integration of modern technologies into agriculture has great potential to increase productivity and promote sustainable agricultural practices. With world population growth, agriculture is a critical sector that needs to become more efficient. While traditional farming methods provide limited productivity, integrating modern technologies into agriculture can result in higher crop yields and lower costs with reduced labor. One of the most important applications used to increase productivity in agriculture is hoeing. In this paper, automatic hoeing machine design using image processing and artificial intelligence will be discussed.

Keywords –Artificial İntelligence, Computer Vision, Hoeing Machine, İmage Processing, İntra-Row Weeding

I. INTRODUCTION

Agriculture is not only an important activity to meet the most basic human need for food, but also an important source of economic income for many countries. For this reason, productivity is one of the most important issues in agriculture as in many sectors. In order to obtain more and better quality products, efforts to increase productivity in agriculture continue unabated. One of these efforts is to increase product efficiency by cleaning the weeds around the main plant with the 'hoeing' method in herbal agriculture. In the traditional methods of weed control, weeds are separated from the soil by means of hoeing tools that are still used today. The hoeing machines used today are generally designed to hoe the gaps between two rows of the main cultivated crop and the desired yield cannot be fully achieved because they cannot hoe the gaps around the plant and between two plants in the same row, which is the main problem. In this study, a new hoeing machine will be designed using image processing and artificial intelligence techniques to hoe between and around the crops in the same row.

II. MATERIALS AND METHOD

The system to be designed is envisaged to be integrated into the tractor. The system will consist of two main parts; the image acquisition-processing unit containing the camera or cameras and the actuator unit containing the actuators that will perform the hoeing process. Using image processing and artificial intelligence techniques, the camera system will be used to recognize the crops to be hoed and distinguish them from weeds, as well as to determine the local positions of the crops. In the study, it is aimed to use machine learning and deep learning algorithms with higher accuracy and speed in addition to classical classification algorithms while detecting crops and weeds. With the "V" shaped hoeing system, it is planned to design an electro-mechanical, hydraulic or pneumatic system that can be opened and closed

according to the size of the crop and to hoe around the crop with optimum opening without damaging the crop. In the object recognition algorithm, it is aimed to detect the crop instead of detecting weeds, which have many species and vary according to the region, making the system more effective and simpler and is expected to provide an effective solution to the problem as it hoes everything except the crop.

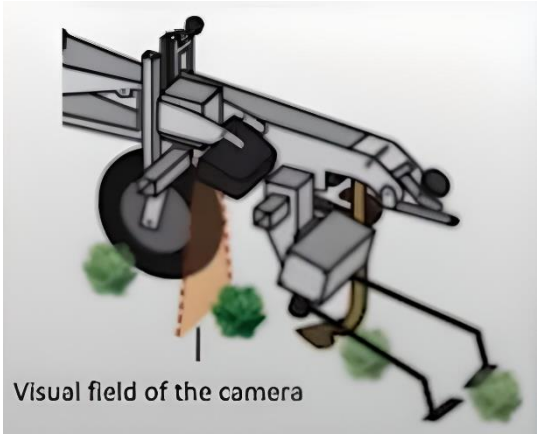

Fig. 1 General Design of System

A. *Image Processing and Plant Recognition*

Using image processing techniques, the types and sizes of plants can be determined from the collected field images. Image Processing and Deep learning algorithms create plant recognition models, allowing the machine to accurately classify plant species. In large leafy crops and in advanced stages of growth, even without machine learning applications, it is predicted that large green clumps can be detected as crops by using image thresholding, edge detection and clustering techniques from basic image processing techniques and partially successful hoeing can be done, although not as efficient as artificial intelligence supported systems.

By analysing field images, the machine can identify and distinguish between crops and weeds. This allows precise targeting of the hoeing operation, effectively removing weeds while minimizing damage to crops. The following image processing techniques can be used in this context:

- *Image Segmentation:* This technique separates crops from weeds by segmenting the image into meaningful regions. Various algorithms such as thresholding, edge detection and clustering can be used for accurate segmentation.

- *Feature Extraction:* Once the crops and weeds are segmented, relevant features can be extracted from the images. These features can include color, texture, shape and size, which can be used to classify and distinguish between crops and weeds.

- *Object Detection:* Object detection algorithms such as convolutional neural networks (CNNs) can be used to identify and locate weeds in the field. This allows the hoeing machine to precisely target the weeds for removal.

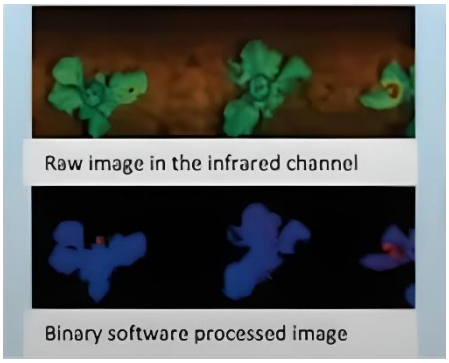

Fig. 2 Crop Detection with Basic Image Processing Techniques

In their 1998 study, Kollenburg-Crisan, L.M. et al. aimed to design an inter-row hoeing system by trying to detect the crop with optical methods without image processing in a cucumber cultivated area. However, it was not technically efficient to distinguish between weeds and crops with the optical system, and since the hoeing system they designed consisted of inclined and fast rotating parts, it was not successful in crop detection and could not produce an efficient result by scattering too much soil[1].

In their 2006 study, Griepentrog, H. et al. designed rigid steel combs connected to a continuously rotating ring and developed a system that hoes independently of each other by avoiding the crop. With their system, they aimed to hoe between crops by using RTK (Real-Time Kinematics) method with pre-recorded crop positions via GPS. However, the RTK system they used could not provide sufficient accuracy for the crop location required for this study[2].

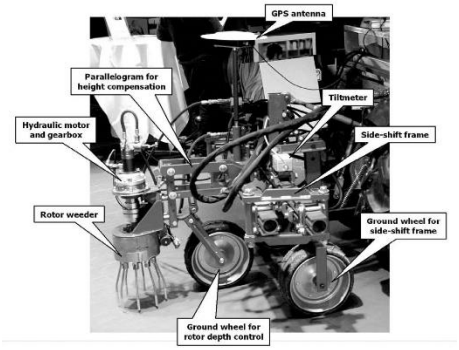

Fig. 3 The system designed by Griepentrog, H. et al.

In their 2002 study, Baerveldt and Astrand designed an autonomous system as opposed to tractor-mounted systems. They used a total of two cameras in the system, one for the robot to move along the row and one to detect the products by looking at their color and shape. For the hoeing process, they used a rotary system and lifted the hoe when it reached the crop by means of a pneumatic cylinder and lowered it again after passing the crop. Although the anchoring process achieved its goal, the autonomous approach they applied reduced the speed and increased accuracy, reliability and safety problems[3].

Fig. 4 The autonomous system designed by Baerveldt and Astrand

In their 2018 study, Vedula R. et al. designed a servo-controlled rotary brush hoeing unit and an image processing supported system. The hoeing unit performs the hoeing function by rotating and changing the angle according to the detected crop, and the crop recognition process is performed using the Haar Cascade Classification algorithm after filtering the images taken through the camera in the system with simple techniques using OpenCV libraries. They demonstrated their work on a prototype model [4].

In their 2008 study, Tillett et al. used open source image processing software for crop recognition. They used a semicircular disk as a hoeing tool and performed the hoeing process by adjusting its angle according to the crop position detected through image processing. They performed this process while the tractor was traveling at a speed of 1.8 km/h and stated that the accuracy decreased as the tractor speed and weed density increased[5].

B. Artificial Intelligence Supported Plant Recognition Strategies

Artificial intelligence algorithms integrated into the machine determine the most appropriate hoeing strategies after identifying the plants. Predefined hoeing parameters and methods, specific to each plant type, enable the machine to hoe with minimal damage to the plant. These strategies optimize water and chemical use while maintaining plant health and increasing agricultural yields.

Artificial intelligence techniques can enhance the hoeing machine's capabilities, enabling it to make intelligent decisions and adapt to changing field conditions. The following AI techniques can be used:

- *Machine Learning:* By training machine learning models on labelled images of crops and weeds, the hoeing machine can learn to accurately classify and distinguish between them. This enables real-time decision making and precise weeding.

- *Reinforcement Learning:* Reinforcement learning algorithms can be used to train the hoeing machine to optimize its actions based on feedback from the environment. The machine can learn to adapt its hoeing strategy according to the growth patterns of crops and the presence of weeds.

- *Deep Learning:* Deep learning models such as CNNs can be used for image classification and object detection tasks. These models can provide accurate weed identification and localization by learning complex patterns and features from images.

C. Automated Weeding Process

The machine moves across the field according to defined hoeing strategies. It continuously monitors and evaluates the plants in the field with image processing cameras and sensors. Based on instantaneous data, artificial intelligence algorithms determine the main crop locations for

hoeing. The machine implements these strategies thanks to combined mechanical and automation systems. If the tractor deviates from the line during operation, actuators on the horizontal axis both warn the operator and correct the hoe actuators to align them with the row.

Fig. 4 Row Weeding Machine Example

III. RESULTS

An automated hoeing machine powered by image processing and artificial intelligence offers the potential to increase productivity in the agricultural sector. Plant recognition and customized hoeing strategies provide better results than traditional methods. In addition to hoeing weeds with software revisions to be made with the same technical infrastructure, thinning can also be done simultaneously with hoeing for healthier plant growth in crops whose frequency cannot be adjusted during planting. The integration of image processing and artificial intelligence techniques in hoeing machine design offers a promising solution for efficient and automated weeding in agriculture. Further research and development in this area could lead to advances in agricultural applications, increasing productivity and sustainability.

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