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Image Recognition based Smart Plant Care System

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***Abstract*: This paper introduces a novel automated plant care system designed to autonomously water plants by identifying them and assessing their individual watering needs. The system utilizes the YOLOv5 object detection model to accurately identify various plant species and integrates moisture sensors to monitor soil conditions, ensuring optimal hydration levels. The primary aim of this work is to streamline plant care processes, significantly reduce water wastage, and promote sustainable gardening practices. The integration of advanced object detection with real-time moisture assessment allows the system to deliver precise amounts of water to different plants, catering to their specific requirements. Simulation results validate the identification of plants and effectiveness of the system in optimizing water usage while maintaining plant health. This approach demonstrates the feasibility of using machine learning for environmental sustainability.**

***Keywords*: Image recognition, Machine learning, Object detection, Plant care, Smart system.**

1. Introduction

For making our ecosystem greener, more and more plantation of trees or plants can play a big role. However, other than just planting the seeds or plants, there are a number of external environmental factors that play an important role in keeping plants healthy. Adequate amount of watering is one of the included factors, playing a vital role. Manual judgement of water based on predictions of moisture level is not an optimal watering method. In this era of AI/ML, learning based on sensors input can help in designing a fully automatic watering system that can take care of watering the plants. However, this system is a combination of many engineering technologies like mechatronics and Machine Learning. In this context, we started our thought process with reference to general principles of an automatic plant care system. We performed some experiments to understand the needs of the plants, found in [1].

In [1], we presented a block-level description of a mechatronics-based plant care system involving features to automatically water plants. This mechatronics-based system was automated by the voltage input data recorded with the help of a multimeter, different voltages portraying the variation in moisture level of the plant soil. In further research, we strived to improve upon the automation system, adding image recognition technology to the equipment in order to detect the type of plant and its specific watering requirements. This image recognition system ensures a more accurate and artificially intelligent plant watering system, one that takes into account external factors such as plant type and soil type. Unlike the motive of [1], the work presented in this paper aims to design an automatic watering system that functions not only on a small scale, but also on a large scale. Further, we would like to spread its potential of use to rural areas, where plants and farms require excessive manual labor and efficiency.

2. Literature Review

A significant number of experiments and research have been conducted towards designing watering systems for plants, displayed in other journals. In [2], authors propose an AI-based water management system, which uses PHI sensors to assure quality and conductivity of water treatment. Another instance of an automatic plant watering system is displayed in [3], where authors use input data of the date and time, as well as of the water flow pulses to create an automated drip irrigation system. [4], on the other hand, involves a moisture sensor that detects the moisture in the soil around a plant and accordingly provides data regarding the plant's watering needs. However, this system lacks the variation in watering needs depending on the plant type and soil type by using an image recognition system. A similar limitation is seen in [5]. Still, [5] considers additional, useful inputs in the system proposed by its authors, consisting of sensors for humidity and temperature alongside soil moisture levels. [5] also uses the modern technology of regression analysis as well as the programming languages Python and Tableau to analyze how different environmental factors affect the plant's growth. [6] shows relevance to our research in the form of a sewage system that allows gray water to be reused. Inspiration can be taken from this system when formulating a watering system that takes water conservation into account. [2], [7] and [8] provide preliminary ideas regarding infrastructure properties of the watering system, which could be implemented in the future. These ideas are in the form of artificial intelligence-based and IoT-based systems of communication between the main machinery and the sensors. [9] portrays inputs in the form of images, but the data is used simply to monitor the plants' health and detect any plant diseases.

In general, our proposed system involves the recognition of plant type and mapping with its needs, further applying this learning through ML, to decide the optimal watering level for different types of plants. We present some simulation results as a proof-of-concept demonstration. This kind of work and

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demonstration is not available in prior research to the best of our knowledge.

3. AI/ML Based Smart Plant Care System

A plant watering system without manual labour requirements – that ensures plants are optimally watered without having a wastage of water – is shown in Figure 1. Here the watering system is a movable sprinkler directly connected to water pipes. Its water supply can be controlled based on the output of mapping algorithm. The mapping algorithm uses information gathered by sensors about moisture level and plant type, and then determines whether or not the plant is hydrated, based on its needs. Moisture level is measured through moisture sensors inserted in the soil around the plant. A camera is placed above the plants; this camera feeds images to the ML-based algorithm. The output from the ML-based reinforcement learning algorithm denotes the identified plant. The data of the specific plant type is given to the mapping algorithm to decide a watering level as per the specific requirements of that plant based on its type.

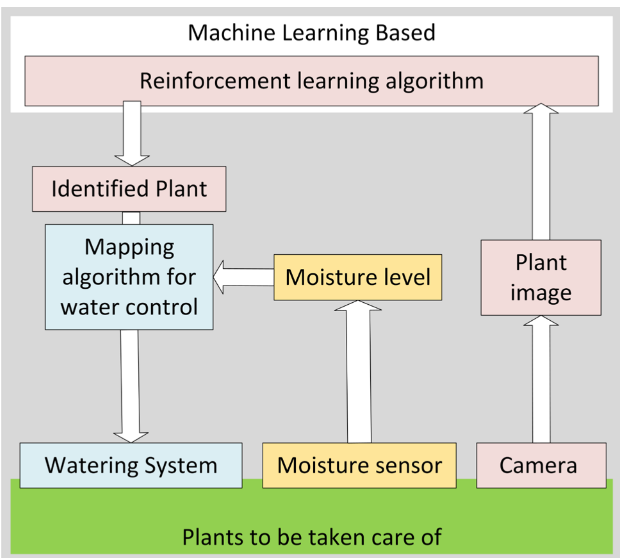

Fig. 1. Block diagram of AI/ML based smart plant care system

Reinforcement learning (RL) is a subset of machine learning used to leverage algorithms to train machines in recognizing patterns. These patterns are then used to make decisions on newly fed inputs in real time. We take advantage of this feedback mechanism to identify plants and accordingly map them to their optimal moisture levels.

A. Identification of Plants

The AI/ML machine is trained with an image set of sample plants. Camera images can be fed to the algorithm to then identify the plant. An example of training for rose plants is shown in Fig.2. We have trained our prototype for three types of plants: roses, daisies and sunflowers. Image sets were collected for these plants and the ML machine was trained. Further, on the basis of plant type, needs are mapped and can be communicated to the water level control system. In this work, we only mapped the values of moisture level for plants to demonstrate the idea. Our idea can be extended with data sets of other parameters (inputs for multiple types of sensors) to quantify the various environmental and soil nutrient needs of different types of plants.

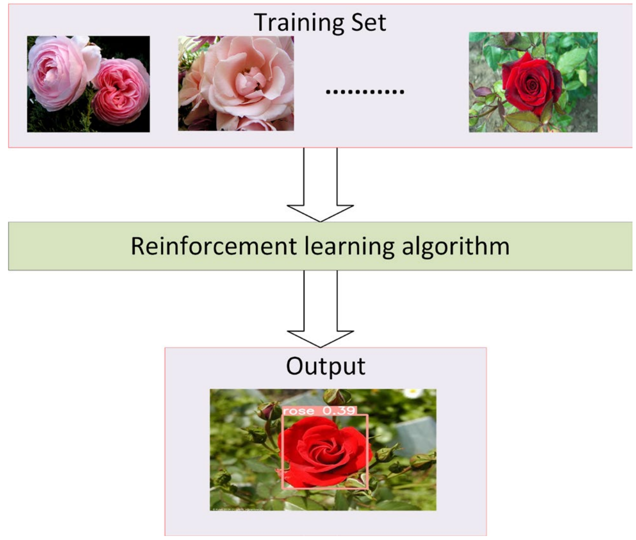

Fig. 2. Block diagram of AI/ML based Smart plant care system

B. Mapping Algorithm for Water Control

Algorithm 1 (in Figure 2) demonstrates how the watering system is activated. It uses images from the camera, I, and moisture levels from the sensors, V, as inputs for the algorithm. First, the sensors are initialized and calibrated to needs. The images are extracted and processed through the detection model to identify the plant, D. The detections are then used to map the plants to their corresponding required moisture levels, R. Required moisture levels are compared with current moisture levels retrieved from the sensors, V, to determine if the moisture level is above the required amount for the plant. If R, required moisture, is less than the detected moisture, V, then the signal to turn on the water system is not sent. The difference between the moisture level (present and required) can be used to adjust the water level to sprinkle on plants. Currently it is shown just for turning on and off the watering for the plants. This algorithm can be extended to precisely and accurately control the exact amount of the water given to plants in order to reduce water useage and maximize plant health.

Algorithm 1: Feedback Algorithm

Input: *I (Images from sensor), V (moisture levels from sensors)*
Output: *W (Watering signal)*
Initialisation :
1: Initialize system and sensors
2: D ← detection model(I)
3: R ← map image to moisture(D)
4: ***if*** *R < V* ***then***
5: W ← False
6: ***else***
7: W ← True

*8: **w** is proportional to **R-V***
*8: **end if***
*9: **return** W*

4. Prototype Simulation and Result

To develop a prototype for this automated plant care system, we decided to proceed with the YOLOv5 detection system. This model is a real-time object detection model that can be trained on a custom dataset to fit the use case. This works perfectly for an automated plant care system. The model is used to initially identify the plant image that is captured. We then identified a small group of different plants that we wanted to test the system on. We decided to proceed and test using images of roses, daisies, and sunflowers. We started off by collecting images of the plants to build our dataset. This consisted of collecting and labeling around 120 total images while keeping the distribution of the images evenly spread. The images were labeled using a software called Roboflow. This software then split the labeled images into testing, training, and validation sets and created labels for each image. Using this labeled dataset, we trained our custom YOLOv5 model to detect the mentioned categories. Figure 3 displays the training box loss of our object detection model over 100 iterations, or epochs. Initially, there is a sharp decline in the graph, indicating the improvement of the model's learning.

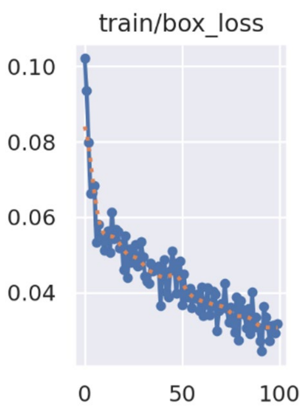

Fig. 3. Train box loss

To extract our results and use the outcomes, we modified the *detect.py* program within the model to output the detections made into a separate text file. Using this data, we created a simulation where we predefined moisture threshold for each plant. To simulate soil moisture levels, we generated random numbers from 0 to 100 representing the percentage of moisture in the soil. This number is then used to determine if the plant needs to be watered or not based on the level of moisture currently present in the soil.

As seen by (Figure 4), the trigger turns red or green based on the moisture conditions detected; red indicates that the moisture in the soil is low and needs water, while green indicates that the soil is adequately moist. When connected to watering systems such as sprinklers, this mechanism would trigger the activation of the sprinkler responsible for soil in moisture-lacking areas.

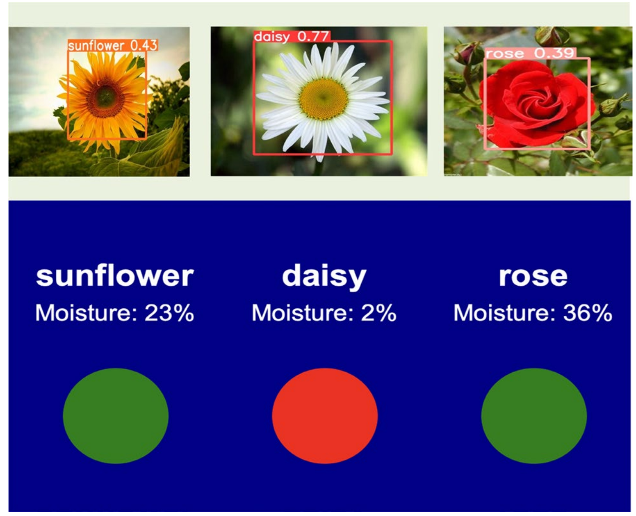

Fig. 4. Simulation output

5. Conclusion and Future work

The proposed smart plant care system is a solution for making earth greener with the help of emerging AI/ML methods. We have presented a prototype for a system with some results by taking a few test cases of plants. Such test cases can further be improved with adequate research on the variability of their specific parameter values (like a mean value of the moisture level in a specific plant). This system can be customized for a set of plants based on user needs. Applicability and implementation in real-life scenarios can only be pursued by increasing the number of parameters affecting and varying in plants. Thus, since the total number of potential factors is a large number, our idea can be extended with multiple different conditions, such as humidity, temperature, weather, and surrounding ecosystem environment. Despite these challenges, our proposed system can be enhanced to support large scale implementation, especially for farming purposes. Such implementation can further be optimized by increasing the number of datasets to be trained and by setting customized parameters based on specific requirements. Furthermore, we can make use of water conservation strategies to advance our system. Also, the aspect of using renewable energy sources to run this system is a prospective topic that can be explored. Such additional factors will make this system not only fully sustainable, but also optimally efficient and convenient to use.

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