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Smart Autonomous Gardening Rover with Plant Recognition using Neural Networks

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Abstract

Modernization of our environment (pruning trees for constructing tall buildings) results in climatic changes and ecological imbalance. To mitigate the effect, gardening (to plant trees and shrubs) becomes more and more important than just a hobby. Besides, maintenance of a garden is a tedious process and also time-consuming. Often the gardener lacks in knowledge about the requirements of plant (nutrient and the amount of water to be sprayed) to enhance its growth. In this regard, it is necessary to build an autonomous gardening robotic vehicle which automatically identifies and classifies the plant species using feature extraction algorithms (Scale Invariant Feature Transform (SIFT), Speeded-Up Robust Features (SURF), Oriented FAST and Rotated BRIEF (ORB)) and neural networks, respectively. It also measures the key parameters for gardening such as temperature, humidity, heat level, wind speed, wind direction and soil moisture. The data acquired from the on-board sensors of the gardening rover are sent to the cloud storage platform on a regular basis. Based on the acquired data and history, future predictions are made to maintain the garden more effectively and efficiently. A website and an android application are developed for monitoring and controlling the rover from a remote area. This system is a combination of new technologies involving an interdisciplinary approach to carry out precision gardening using Internet of Things (IoT).
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Keywords: Intelligent agriculture robotics, floriculture, horticulture, arboriculture, plant recognition methods, neural networks, Internet of things.

1. Introduction

Numerous autonomous robotic systems have marked its identity in the field of precision agriculture[1, 2] and few have been used in data collection alone[3]. But not many have tented their work in integrating agricultural robotic

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system with plant recognition system and Internet of Things (IoT). Adnan Shaout et al. demonstrated the use of preinstalled wireless sensor network in the farm field[4] but it requires more investment, installation and maintenance cost as the size of the field increases. Cheick Tidjane Kone et al. showed the increase in sampling frequency of sensor nodes during monitoring and controlling of crops in precision agriculture[5]. John D. Bolten et.al used soil moisture as a fundamental data source to monitor crop growth rate and thereby estimate the yield[6]. Askraba et al. designed an optoelectronics based real-time plant discrimination sensor based on thin film coatings combined with wavelength selective filters. Plant discrimination is carried out by measuring the slope of the spectral response and the normalized difference vegetation index[7] (NVDI). Fernando Vicente-Guijalba et.al proposed to utilize a multi-temporal remote sensing data by state-space analysis to monitor the agricultural crops[8]. Image processing algorithms to detect the plant location and disease identification are available in the extensive. Some of them are stated here, curve saliency[9] and least mean square method[10] for detection and location of plants.

Based on the detailed literature survey, it has been identified that there is no unique methodology or system to identify plants, provide the appropriate nutrients and water for enhancing the plant's growth. In this regard, this research work, a smart autonomous gardening rover (also named ALIVE – Autonomous Laboursaving Internet of Things Veteran Energizer) with plant recognition system (Scale Invariant Feature Transform (SIFT), Speeded-Up Robust Features (SURF), Oriented FAST and Rotated BRIEF (ORB) and Brute Force Matcher (BFM) algorithms combined with Machine Learning techniques) is designed, developed and demonstrated. The smart rover will perform in-situ analysis of the soil and environment. It has all the necessary sensors embedded into it. The acquired on-board sensor data gets uploaded to the cloud storage platform, thereby increasing the accuracy of decision making process. Based on the acquired and the history of data, it makes the decision on the amount of water and fertilizer to be delivered to the plant. In that sense, the proposed system will act as an assistant to the gardener by doing almost all the work which a gardener does in his day to day activities, right from monitoring of weather, plant growth and watering to plants.

2. Smart Autonomous Gardening Rover (ALIVE)

Rover named ALIVE is designed to monitor and maintain the garden. In a multispecies garden, attention to individual plant species is necessary to enhance the plant growth. Most of the reported research work or industrial products deals with the increase in productivity of a single plant species by incorporating the wireless sensor networks (for monitoring the health condition) in the farm field. In the proposed research activity, attention to individual plant species is carried out based on the in-situ analysis of soil nutrients, moisture condition, environmental parameters and weather prediction. Plant species identification is carried out using image acquisition and feature extraction techniques. Based on the prediction, the smart rover delivers the required quantity of nutrients and water to the plant. Thus, the proposed system stands tall and unique among other products and ideas available in the market. Machine learning and IoT are the pillars which root the project so deep and unique. In addition, it is the first of its kind in the field of autonomous gardening.

2.1. Mechanical Structure, Hardware and Software Specifications

Mild steel is used to build the rover base with the appropriate dimensions as shown in Fig.1. Rover's base can withstand an overall weight up to 30 kg and it encloses the electronic components, storage tanks for water and fertilizer. Rocker-Bogie suspension system is integrated in the rover design thereby increasing its manoeuvrability. It also decreases the maintenance related expenses involved for a suspension system. A slight modification to the original rocker-bogie suspension system is introduced for extensive vehicle stability. The "rocker" part of the suspension system is fixed to a central frame which connects it with the "bogie". During navigation of the rover in an uneven environment, when one bogie moves upward, the other goes down thereby maintaining its balance.

The rover has three arms (camera holding arm, water/fertilizer spraying arm, soil moisture measurement arm) designed for dedicated purposes. The camera holding arm is made of PVC tube to hold the Pi camera and Raspberry Pi module. Two Futaba servo motors provide 2 degrees of freedom (DOF) for the head movement. This head movement is required for detecting and identifying the plant species during the navigation of rover. The head continuously looks around for a predefined pattern and stops immediately when it senses a plant. Furthermore, the camera holding arm also encloses sensors for measuring temperature and humidity. The distance to the plant is calculated with the help of ultrasonic sensors attached to this arm. The water/fertilizer spraying arm of the rover has sprayer connected to the water and fertilizer storage tanks. 2 degree of freedom (DOF) arm movement is achieved by Futaba servo motors. The soil moisture measurement arm of the rover holds the soil moisture sensor's probe. The probe is inserted into the soil using a rack and pinion system that effectively handles this operation. The probe gets inserted into the soil, reads the moisture content and sends it to the on-board controller.

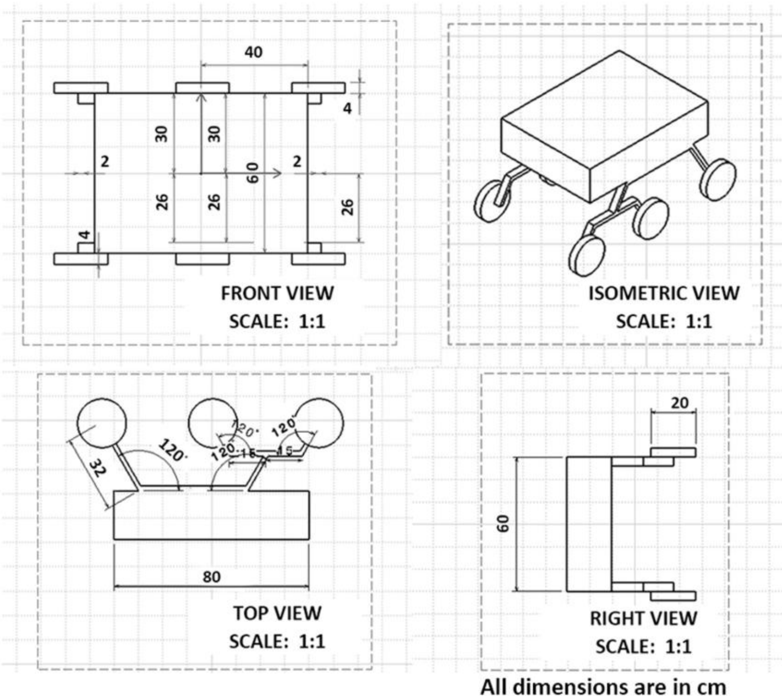

Fig.1. Mechanical design of the rover

Table 1. M265 Temperature and Relative Humidity Sensor Module DHT11 specifications

PCB size	3.1 cm x 1.4 cm
Humidity measurement range	20% - 95%
Temperature measurement range	0 – 50 degree Celsius
Operating voltage	3.3 – 5 volts

Table 2.Soil moisture sensor HL69 specifications

Panel PCB size	3 cm x 1.5 cm
Soil probe dimension	6cm x 3cm
Cable length	21 cm
Operating voltage	3.3 – 5 volts

Lithium Ion rechargeable battery with a rating of 12V/7.5A is used as the power source for the rover. High torque 200RPM/12V DC motors with metal gearbox of torque 32 kg-cm are used for the movement of the rover towards a desired position with minimal effort. In addition, a 5V submersible DC pump is used for spraying water and fertilizer to the plants. The rover has a powerful Raspberry Pi-2 mini-computer for operation control and an ATmega2560 microcontroller for rapid prototyping as shown in Fig. 2. Raspberry Pi acts as a master, commands its slave ATmega2560 microcontroller to perform the operations required for each plant. Pi-camera acts as the embedded vision system for the rover and it acquires the images or videos for detecting and identifying plant species with the predefined patterns stored in the database. Detecting and identifying plant species, connecting to the internet and the overall decisive operations are performed by Raspberry Pi-2. The operations like manoeuvrability, water spraying, fertilizer spraying and insertion of sensor for acquiring environmental values are performed by ATmega2560 microcontroller. The robot uses M265 temperature, soil moisture probe and relative humidity sensor module DHT11 for measuring the garden's humidity, heat level and moisture content. The data acquired from the on-board sensors of the gardening rover are sent to the cloud storage platform (Firebase) to enable prediction in the near future. Results of the prediction and the current health status of each plant in the garden can be viewed from the website or an android application. Specifications about the sensors are provided in Table 1 and Table 2.

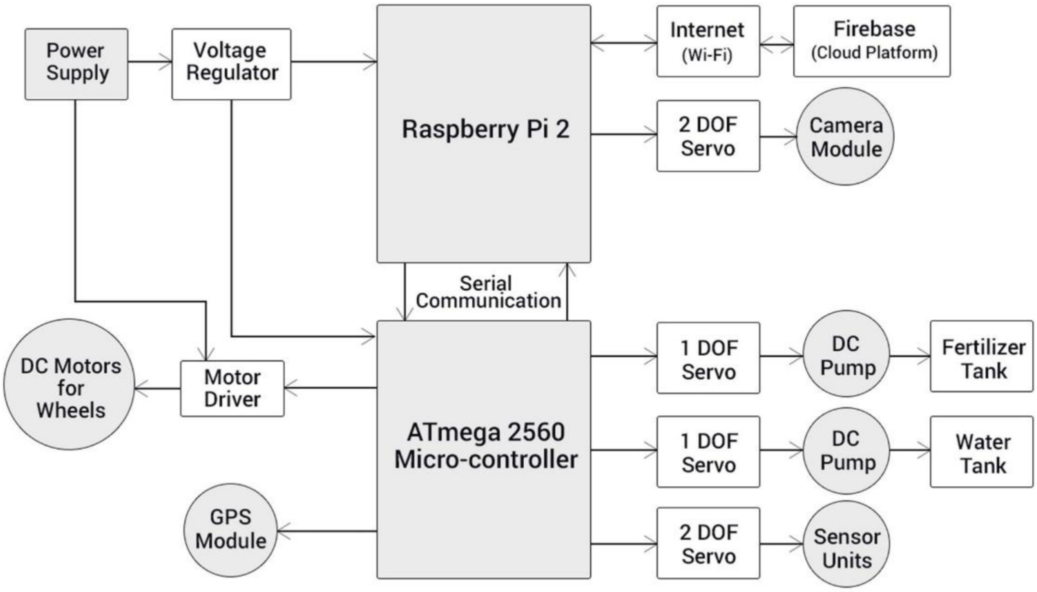

Fig. 2. Block diagram representing the smart autonomous gardening rover

Privacy preservation and security is ensured by creating a unique rover ID using a dedicated website or an android application. After successful registration, the user's data will be stored in an online cloud storage platform named "Firebase". As shown in Fig.3, Firebase provides real-time cloud storage enabling the rover as well as applications such as android app and website to communicate with the database using JavaScript Object Notation (JSON). The JSON object will hold key-value pairs such as user_name, user_password, user_email, user_robot_id and user_alive_data. Furthermore, the JSON object "user_alive_data" will have the rover's sensor data as well as other data such as battery_level, water_level, wind_flow_direction, wind_flow_speed, time and date.

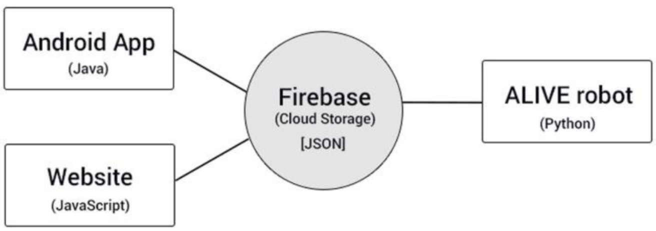

Fig.3. Cloud Storage

3. Methodology

Detection and identification of plant, navigation of rover in the garden, and agricultural assistance to the gardener are the key functions to be addressed for a precision gardening. Figure 4 represent the operation methodology for the smart autonomous gardening rover using a fish-bone diagram.

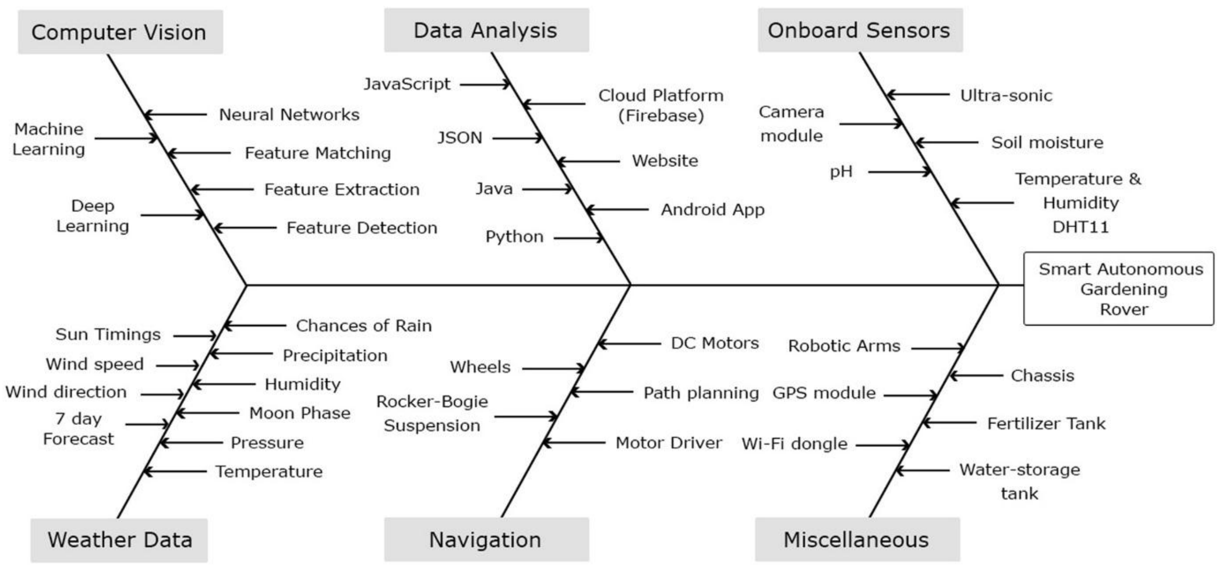

Fig.4. Operation Methodology

3.1 Plant Recognition:

Data acquired from the camera module and ultrasonic sensors are used to detect the plant in the garden. Using feature extraction techniques like SIFT (Scale Invariant Feature Transform), SURF (Speeded-Up Robust Features) and ORB (Oriented Fast and Rotated Brief), the features of a particular plant are extracted and stored in the database. Using feature matching techniques such as Brute-Force matcher and FLANN (Fast Library for Approximate Nearest Neighbours) matcher, the real-time continuous image sequence obtained via the camera module will be matched with the stored feature extracted image in the database. Neural networks is used to perform one-to-many matching and generates a threshold value. Large threshold value indicates the identification of a particular plant species. In addition, an algorithm estimates the rover's distance from the plant using triangle similarity technique. The distance is then fed as the error to a PID controller which acts as a closed-loop navigation control for the high torque DC motors. Rover automatically moves to the next plant on the completion of its recognition process.

3.2 Path Planning Algorithm:

For navigating inside the garden, the rover uses a path planning algorithm which is a combination of DFS (Depth First Search) and shortest path algorithms. Each plant in the garden will act as a node. On successful detection of plant, measurement of environmental parameters and after providing its attention, the rover moves to the nearest neighbouring plant based on the path planning algorithm. Once the rover reaches the final plant in the garden, it then comes back to the initial position to start the loop once again.

3.3 Agricultural Operations:

The M265 temperature sensor, DHT11 relative humidity sensor module and the HL69 soil moisture sensor are fixed in the sensor arm of the rover and interfaced with the ATmega2560 microcontroller. The microcontroller controls the operation of robotic arm to insert (rack and pinion design) the soil moisture sensor into the soil. A submersible water pump is fixed inside the water tank and fertilizer tank. Based on the collected sensor readings, the spraying arm controlled by the ATmega2560 microcontroller gets aligned to spray water/fertilizer, according to the plant’s need.

4. Results, Discussion and Conclusion

Design of smart autonomous gardening rover with rocker-bogie suspension system is shown in Fig. 5. The rover recognizes a plant, measures the environmental parameters (moisture, temperature, humidity, etc.) and delivers the appropriate amount of water, fertilizer to enhance the growth of plant. Data analysis is performed using the data collected by the rover and the result gets populated in the website and Android app to provide a detailed statistics about the garden.

Fig.5. (a) Smart autonomous gardening rover (ALIVE); (b) Feature extracted plant image; (c) Real-time plant image matched using FLANN matcher

4.1 Plant Recognition System:

Plant recognition is carried out using ORB, FLANN matcher combined with neural networks. As shown in the Fig.5. (b) and Fig.5. (c), the feature extracted dataset image is matched with the real-time image sequence obtained via the camera module.

4.2 ALIVE User Interface:

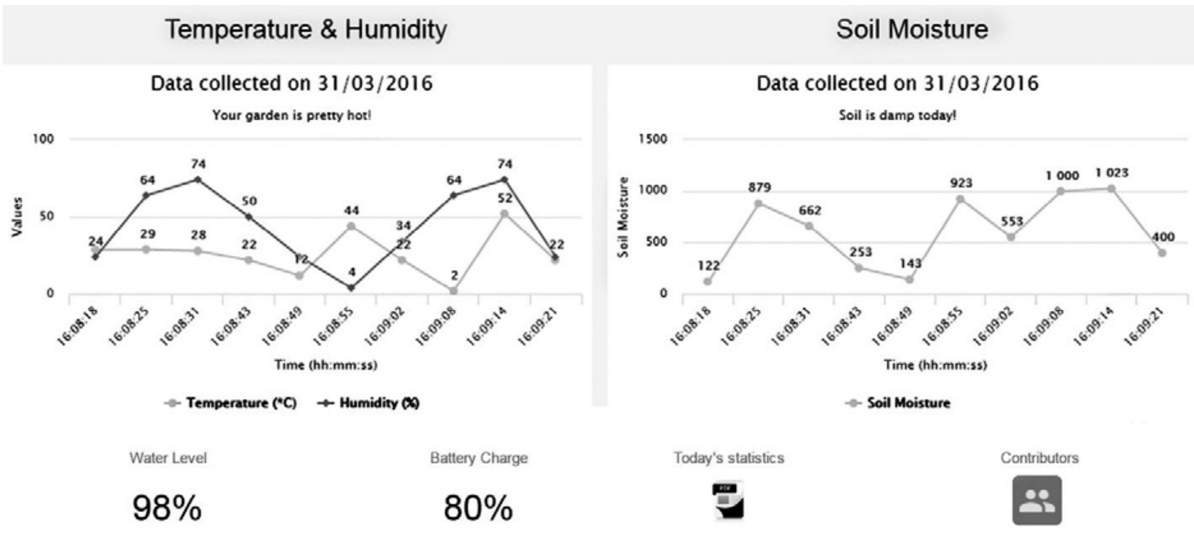

Fig. 6. ALIVE website (Dashboard)

Dashboards are created in website as well as Android application to inform the user about the current weather status (chances of rain, sunrise and sunset time, actual temperature, direction of wind, phase of moon, pressure, humidity), rover sensor data (Temperature, Humidity and Soil Moisture), live status of rover (GPS location and current activity) and controls as shown in the Fig.6 and Fig.7, respectively. The user can also download the entire statistics for the current day’s data from the cloud. Android app also supports in obtaining the picture of the plant just by a click of a button. The statistics menu will act like a “future predictor” by informing the user about the weather predictions for the next 16 days, hourly weather forecast, daily weather forecast as well as the amount of water needed for a plant for the upcoming day. For example, it informs user that “Your tomato plant needs water in next 4 hours for its well growth”. In the near future, the rover's ability can be extended to large farm field by appropriate manoeuvring and maintenance. In addition, agricultural assistance such as picking fruits, identifying disease at the premature stage, sowing, ploughing and much more could be performed.

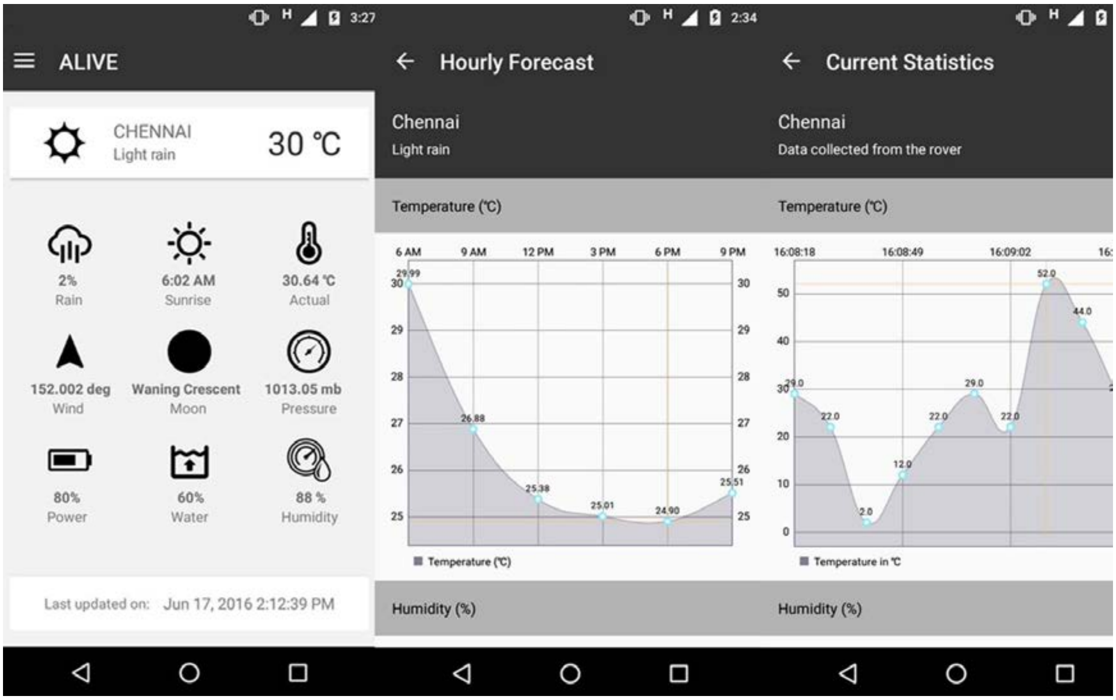

Fig. 7. ALIVE android app (Dashboard)

References

1. Jnaneshwar Das, Gareth Cross, Chao Qu, Anurag Makineni, Pratap Tokekar, Yash Mulgaonkar, Vijay Kumar. “Devices, systems, and methods for automated monitoring enabling precision agriculture”. *IEEE International Conference on Automation Science and Engineering (CASE)*, 2015, p. 462 - 469.
2. Fernando Alfredo Auat Cheein, Ricardo Carelli. “Agricultural Robotics: Unmanned Robotic Service Units in Agricultural Tasks”. *IEEE Industrial Electronics Magazine*, 2013, 7:3, p. 48 - 58.
3. Halil Durmuş, Ece Olcay Güneş, Mürvet Kırcı, Burak Berk Üstündağ. “The design of general purpose autonomous agricultural mobile-robot: 'AGROBOT'”. *Fourth International Conference on Agro-Geoinformatics*, 2015, p. 49 - 53.
4. Adnan Shaout, Karen Juzswik, Kiet Nguyen, Heather Peurasaari, S. Awad. “An embedded system for agricultural monitoring of remote areas”. *11th International Computer Engineering Conference (ICENCO)*, 2015, p. 58 - 67.
5. Cheick Tidjane Kone, Abdelhakim Hafid and Mustapha Boushaba, "Performance management of IEEE 802.15.4 wireless sensor network for precision agriculture".*IEEE Sensors Journal*, 2015, 15:10, p. 5734-5748.
6. John D. Bolten, Wade T. Crow, Xiwu Zhan, Thomas J. Jackson, Curt A. Reynolds. "Evaluating the utility of remotely sensed soil moisture retrievals for operational agricultural drought monitoring".*IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 2010, 3:1, p. 57-67.
7. S. Askraba, A. Paap, K. Alameh, J. Rowe, Craig Miller. "Optimization of an optoelectronics based plant real-time discrimination sensor for precision agriculture". *Journal of Lightwave technology*, 2013, 31: 5, p. 822-830.
8. Fernando Vicente-Guijalba, Tomas Martinez-Marin, Juan M. Lopez-Sanchez. "Dynamical approach for real-time monitoring of agricultural crops". *IEEE Transactions on Geoscience and Remote Sensing*, 2015, 52:6, p. 3278-3294.
9. Jingting Lu, Xiaoping Liu. “Foot plant detection for motion capture data by curve saliency”. *International Conference on Computing, Communication and Networking Technologies (ICCCNT)*, 2014, p.1 - 6.
10. Baojie Fan, Yingkui Du. “Novel Dominant Plant Detection Algorithm for Image Sequence”. *Seventh International Conference on Image and Graphics (ICIG)*, 2013, p.313 - 317.