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MyGreen: An IoT-Enabled Smart Greenhouse for Sustainable Agriculture

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Abstract—**The Internet-of-Things (IoT) has reshaped the smart agriculture by not only given a boost to the productivity and optimized the resources, but it has also increased the efficiency and has minimized the cost of production. This article highlights the potential of sensors and IoT in the field of greenhouse farming and presents the future of automation. The different parameters such as humidity, water nutrients solution level, pH and EC value, temperature, UV light intensity, CO_2 level, mist, and amount of insecticides or pesticides are monitored through various sensors so that significant knowledge about the early fault detection and diagnosis can be done. A Decision Support System (DSS) presented in this article acts as the central operating system which governs and coordinates all the activities. Furthermore, the article also accounts for the different challenges of greenhouse Rose farming and highlights a new IoT based solution which is smart and sustainable. The model presented in this article is well adapted to the changing environment, thereby redefining the terms of sustainability.**

I. INTRODUCTION

Over the years, Agriculture has seen many revolutions, be it the improvement in farming practices or an extension in the field of modern agriculture. The technical improvements in agriculture have driven the wave of green revolution. Green Revolution has created opportunities for the farmers to learn and adopt the scientific way of operating the farms thereby decreasing the manual form of labour and embracing automation. Greenhouse farming has become the key to smart and sustainable agriculture as it relies on data. Data-centric agriculture has transformed agriculture by making it more precise and accurate thereby consolidating the overall farming process.
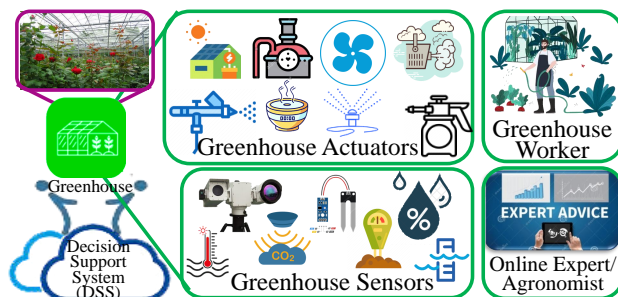

Fig. 1: IoT-Enabled Greenhouse.

Trivial methods of agriculture pose a variety of threats to the growth and nourishment of the plants. Availability of manpower, precision in the percentage of disease detection accuracy, the decision regarding the time interval of irrigation, feeding the plants with the correct proportion of fertilizers, and pesticides are some of the challenges which the farmers go through during the production. The growth of plants mainly depends on environmental parameters like humidity, soil moisture, CO_2 level, etc. It is impossible to monitor and control all the parameters together in an open environment. However, greenhouse farming is a good alternative technique that helps in a higher yield of crops and balances the parameters (Refer Fig. 1). It is

a protected cultivation and the process starts from seedlings, saplings, plantations, etc. It is seen that the growth rate of plants in a greenhouse cultivation is almost twice as faster as an open-field cultivation.

The cultivation of roses inside greenhouse faces several challenges which include: the correct proportion of nutrients available to the plant, variability in temperature and humidity, accurate monitoring of the soil and its moisture, detection, and prevention from diseases, and information collection periodically. Although these problems are addressed in the literature [1], [2], however, it includes manpower involvement and does not have a precise rate of accuracy. This article proposes an IoT based infrastructure as a solution to encounter the various problems mentioned. The solution aims at decreasing the involvement of manpower and making the cultivation more automated.

Rose farming for commercial use is usually done in open-field cultivation and greenhouse cultivation (protected cultivation). In recent years, rose farming has gained an immense amount of attention both in the national and international markets and many people have come forward to adapt rose farming commercially. However, rose plants need to be taken proper care of to make it commercially acceptable in the market.

II. OUR VISION OF IoT-ENABLED GREENHOUSE

Our vision of greenhouse farming aims at developing an extensively automated system of smart agriculture wherein the involvement of manual labour is minimal and productivity is maximum (Refer Fig. 1). Our model is framed in such a fashion that it involves less cost, has an effective risk management plan, and is focused upon better precision in decision-making. Our model is smart, sustainable, and is data-centric, meaning that is relies on the data and constantly learns from it, hence giving a better user experience. In short, our model will definitely aid to the existing methods of farming and will help in better growth and development. The proposed IoT-based solution is responsible for allocating resources, optimization of resources, coordinating the activities, time management, human effort management, gathering information, and taking decisions by using the data analytics.

III. SMART AND SUSTAINABLE AGRICULTURE-RELATED WORKS

The IoT is making the fabric of the world around us smarter and more responsive, merging the digital and physical universes [3]–[6]. Several studies and extensive research have been conducted in the area of smart farming. IoT forms the backbone of automated smart farming. It is oriented towards analytics and sensors [1]. The approach presented in [3] uses IoT in agriculture through sensors , optimization of the use of water, energy, and fertilizers through automated smart irrigation [2], monitoring environmental factors using different sensors to improve the yield and control the environmental parameters [4], proposing a smart farming system for a closed area such as greenhouse and enhance the productivity using different kinds of sensors, and monitoring plant growth and development using the leaf as an indicator called the Internet of Leaf Things (IoLT) in [5]. An automated system of plant disease detection is proposed in [7]. Similar work is carried by [8] which proposes Farm as a Service (FaaS) integrated system and analyses environmental and growth information of strawberry plants using IoT.

Modern agriculture deals with yet another advanced form of farming, precision agriculture. It uses IoT, cloud computing, and edge computing to enhance the production of crops and interact and monitor with the plants in real-time using Cyber-Physical System (CPS) [4]. Data-driven agriculture is yet another advancement in the field of agriculture as it helps in avoiding the misuse of resources and environmental pollution on a significant level. In [9], the status of the advanced farm management systems is reviewed and gives an insight into the crucial steps needed for sustainable agriculture.

The following article emphasizes the IoT-enabled automation of rose farming inside a greenhouse.

IV. CHALLENGES OF TRADITIONAL GREENHOUSE OR GREENHOUSE FARMING

This Section presents a selected challenges of traditional greenhouse farming which intend to solve through our proposed MyGreen.

a) The proportion of nutrients made available: Since, most of the work in the trivial farming incurs manual labour and consumes a great amount

of time, hence at times, it is not possible to feed the plant with the desired amount of nutrients (NPK) which slows down the growth of the rose plants and does not give proper yield.

b) Temperature and Humidity: Excess high temperature and humidity affect the development of leaves and shoots adversely. It also results in discoloration of the petals and the blackening of the leaves. Higher temperature also affects the size of the flower and fewer and smaller petals. Therefore, a system of automation is required which would keep track of these factors accurately and efficiently.

c) Accurate monitoring of the soil and its moisture: Soil monitoring at regular time intervals is quite necessary as it may lead to several problems in plant growth. Too little moisture can result in yield loss and plant death and too much of it causes root diseases and wasted water. It is seen that the bare-dry or over-wet soils may damage the roots of the rose plants, hence rich and well-draining soil is required for better and quality produce. An efficient system of control and monitoring is required which would ease the process of manual labour and result in better output.

d) Detection and prevention from diseases: Rose plants may suffer from diseases because of low temperature, insufficient light, chemical residues and insects, pets, or bacterial diseases. Almost 90% of the plant's diseases can be identified through the nature of the leaves like color fading, Bullheads, limp neck, blackening of rose petals, pale foliage, blackspot, powdery mildew, downey mildew, etc. however, manual monitoring of these diseases is a cumbersome task and hence it requires automation.

e) Information collection at regular time intervals: Trivial methods of rose farming requires manual investigation and collection of data related to the growth and development of the plant. Collection of data such as soil moisture, need for fertilizers, pesticides or insecticides, humidity, and temperature manually affect the accuracy and precision and also increases the load on the farmers. Hence, an automated system of data acquisition and monitoring is needed which would help in making the farming independent of manual labour.
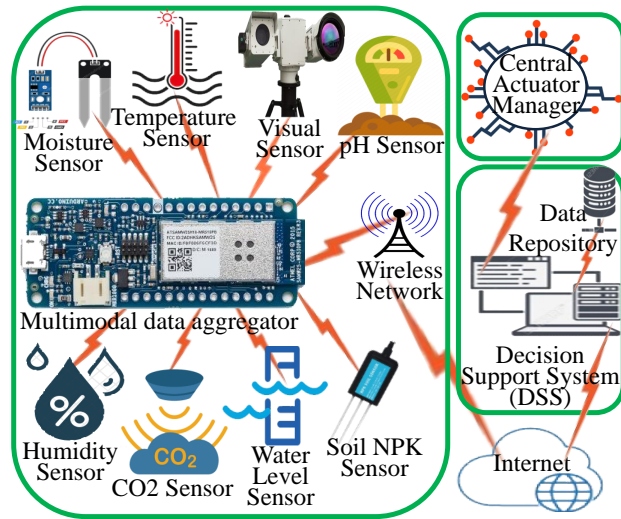

Fig. 2: Data acquisition system (DAS) for rose farming monitoring.

V. MyGreen: The Proposed Novel IoT-Enabled Greenhouse

Major parameters that influence the proper growth of rose plants and flowers in a greenhouse are proper control of environmental temperature, humidity, soil and environmental moisture, environment CO_2 level, water level, uv-light density, free from heavy dew. Along with these parameters, the visual health monitoring of leaf and flower, and proper supply of minerals, fertilizers and medicines is also equipotent as they make the plant healthy and productive. However, monitoring and maintaining these parameters pose certain challenges which are listed in Section IV. To handle such challenges, these things need to be automated as much as possible. For this purpose, we propose an IoT based framework as a mechanism of greenhouse rose farming automation (Refer Fig. 1). This IoT framework can facilitates the rose plants a favourable growth environment by providing soil monitoring, auto optimization of suitable environment, optimum irrigation, real time problem diagnosis, reduced harvest failure, remote controlling and management, and cutting down in operation cost.

Conceptually, the IoT framework consist of three parts: 1) Data Acquisition system (DAS): A set of Sensors for collecting real-time data from the greenhouse, 2) Central Actuator Manager (CAM): A set of equipment for performing different task

of the greenhouse and these equipment is handled by a set of actuators, and 3)Decision Support System (DSS): A decision support system is used to monitor and manage the resources.

A. Data Acquisition system (DAS)

In the DAS (Refer Fig. 2), in case of any deviation, an automation system is required to handle it immediately. For example, if the CO_2 level is above the upper limit (900 ppm) then it needs to open the ventilators and if the CO_2 level is below the lower limit (800 ppm) it needs to switch on the CO_2 cylinder. Similarly, actions can be taken for other parameters like, when the light intensity is not within the range of $440lx$ - $670lx$ then the roof top cover of the greenhouse can be uncovered or covered respectively, the dehumidifier can be set on / off when the ground humidity is not in the range of 55% - 65%, the warm air is activated when the temperature reaches below $17°C$ and the air cooler may be activated when the temperature reaches above $28°C$.

In any visual irregularity is detected in the rose flower or leaf, appropriate actions will be taken. The diseases can be detected through the visual sensors and by applying different machine learning modules. The algorithm classifies the specimen to any one of these 12 classes namely *normal, Aphids, Black Spot on Roses, Cercospora Leaf Spot of Roses, Crown Gall on Roses, Japanese Beetles on Roses, Rose Mosaic Virus, Powdery Mildew on Roses, Rose Curculios, Rose and Pear Slugs, Thrips on Roses, or others*. A Support Vector Machine (SVM) based classifier is used for classifying the specimens. A sample size of 40 from each class is used for training purpose and 10 samples from each class is used for testing the model. A overall classification accuracy of 91% is obtained on training data and 85% classification accuracy on test data. These diseases are controlled by applying any/some of these remedials such as *strong blast of Water* and *insecticidal soap* at appropriate time, *good air circulation*, and *spraying them with Bordeaux Mix or neem, applying baking soda or milk, cleaning the pruners between cuts with a dilute bleach solution* and *applying appropriate pesticides*. These remedial needs activating various equipment at appropriate time. Upon receiving the data captured through

the visual sensors and applying the machine learning algorithms, the affected plants are detected and appropriate action is suggested by the DSS. From the visual sensors, the growth of unwanted plants in the environment can also be observed and and upon detection, the DSS will take proper action. Upon receiving the data, the DAS sends it to the DSS. Further, the DSS analyses the data and take appropriate action through a actuator management system which is described in Section V-B.
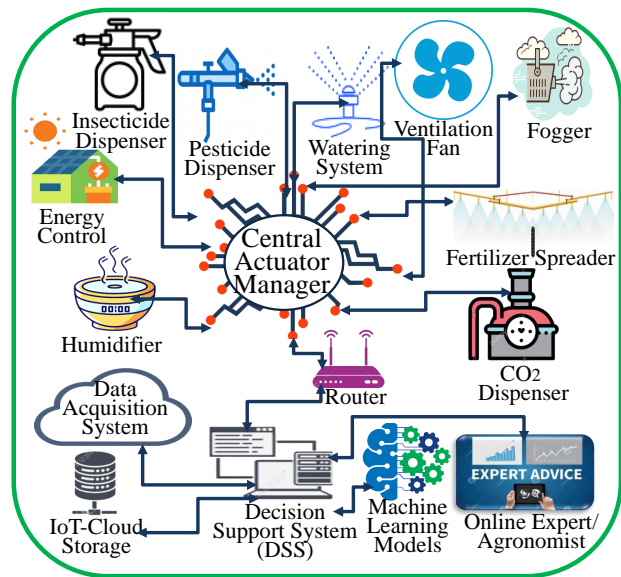

Fig. 3: Actuator Management System.

B. Actuator Management System

To automate the equipment, parameter received such as water level, CO_2, mister, humidity, temperature, uv-light, are associated to separate actuators for every action. Further, all actuators are connected to a Central Actuator Manager (CAM) (Refer Fig. 3). The CAM take instructions from the DSS and act accordingly by activating or deactivating or controlling the actuators. The action is taken immediately if any disease is detected. This action may be a i) Rule based action defined earlier or ii) Action suggested by machine learning models, and iii) Expert advice (expert advice are recorded in the repository). In case of rule-based action, the CAM automatically activate / deactivate the actuator based on the rules decided by the DSS or by the agronomist a priori. However, in case

of expert advice, the decision on actuators to be activated is decided by considering the suggestions from DSS, previous outcomes in similar situations and experience of the manager.

The mister and dehumidifier can also be controlled (start / stop) through this dashboard only. The dashboard also shows the amount of nutrients and water as per the suggestion of DSS. It also helps in observing the current status of a plant or the nearby plants using the optical CMOS magnifier. The magnifier takes the values of the plant's row and column as input and help in monitoring the plant's status by picturing it. The dashboard takes numerous inputs and upon clicking on the submit button, it makes the necessary changes and sends the data to the repository for further use. Once, there is enough labelled data available, the agronomist will use a machine learning approach to obtain better accuracy over the results.

C. Decision Support System (DSS)

The DSS acts as the main operating system of our proposed IoT enabled greenhouse rose farming system.

Broadly, the DSS governs six major components of the proposed IoT enabled rose farming namely i) Rule based designed engine, ii) Central Actuator Manager (CAM), iii) Machine Learning Models, iv) Experts or Agronomist,v) Greenhouse workers, and vi) Data Repository. Here the DSS is not only act as a resource allocator but also as a resource optimizer. Data fetched periodically from the data sever are given as input to the rule based designed engine. The data received may be a regular data for which the rules are predefined by the DSS and accordingly the instructions are send from the DSS to the CAM. For example, starting of the water pump when the water level is below the defined range, starting of de-humidifier in case the humidity level is more than the thresh hold. However, the data received may not be a regular data like change in the climate condition, flower / leaf affected with disease, or any other abnormal conditions for which no clear predefined rules are framed. These data are passed to a machine learning module to obtain the required solution. But, for some instances it might happen that the machine learning module fail to find a solution (for a new

disease or for a change in climate). In this case, the information is automatically passed to an expert / agronomist who uses the information received from the DSS and data from the repository to suggest the correct decision. So, the DSS acts here as a service provider. The CAM after getting the instruction, activates the required actuator to take action.

In addition to this, based on the information available through visual sensors, the DSS analyses and prescribes the appropriate amount and time interval of supplying water, nutrient, and / or pesticides to the rose plants (Refer Fig. 4). The correct proportion of the nutrients is decided by the expert / agronomist by looking into the plant's health, climatic condition, soil parameters, temperature, humidity, and plant disease (if any). The values can be set manually through the dashboard in the greenhouse based on the user requirements. It is to be noted that the medicines will not be sprayed over all the plants, instead, it will only be sprayed over the plant diagnosed with the disease and the plants which fall within a radial distance of $1m$. The following system eases the traditional problem of covering all plants and helps in feeding the plants with medicines at the prescribed time intervals.
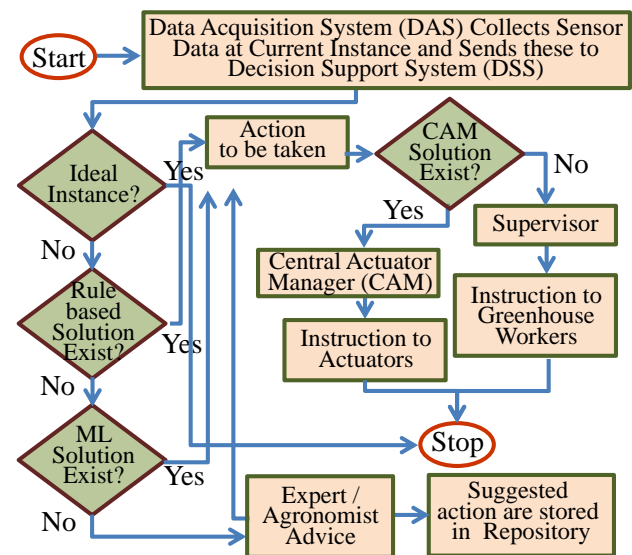

Fig. 4: Decision support system (DSS) working flowchart.

The DSS also provides interface for communication and interaction with human actors such as greenhouse workers, supervisor, and experts through app notification and SMS as and when

required. Supervisor also observe the current status of a plant or the nearby plants using the `optical CMOS` magnifier. The magnifier takes the values of the plant's row and column as input and help in monitoring the plant's status by picturing it. The supervisor monitors the status of all sensors and actuators through a dash board on a screen in real-time using an interactive interface. Decisions such as changing the status of some of the actuators or selecting the amount of insecticides or pesticides to be applied is sometimes needed to be taken by the supervisor. Although automation of greenhouse rose farming needs less human labour, however, some ground works such as planting, weeding of grass, bending, cleaning, de-budding, loosening the soil, etc. requires human involvement. These are carried out by greenhouse workers. Some of these jobs need to be done periodically and some are event driven (such as unwanted grass is observed by visual sensor and grass cutting task need to be activated). The jobs of the greenhouse workers are controlled, scheduled and actively monitored by the DSS. The remainder of the same are given from the DSS and the supervisor of the greenhouse periodically updates this status to the DSS. The DSS also provides interface for communication and interaction with human actors such as greenhouse workers, supervisor, and experts.

VI. A CASE STUDY VALIDATION OF MYGREEN

The major benefits that can be gained from the proposed IoT enabled rose farming are: the significant reduction in cost of production, drop-in death rate of plants, accuracy of detecting the diseases in plants, quick response time to take measure for remedies, and effective use of resources like minerals & fertilizers by minimizing the over/lesser dose. Among the above, cost and precision of accuracy for detecting diseases in rose plants are two major advantages as it highly affects the business. The prototyping of the proposed automation model was implemented in a sub part of 1000sqft area of original greenhouse of 2.5 Acre. The recorded result for a year is analyzed and presented in Fig. 5. The various costs (c) involved in a greenhouse rose plantation can be categorized as cost for labour, installation of hardware for automation, regular periodically check-up, maintenance, and recurrent

cost. From this we can conclude that: i) The cost involved in labour using the proposed IoT framework is greatly reduced because of the automation for various operational units. ii) The cost involved in installing the hardware for the proposed IoT framework is quite large but it is almost zero in the trivial method. However, this cost is only a one-time investment. iii) For the rest three costs like regular periodically check-up, maintenance, and recurrent cost, the proposed IoT based method incurs quite less as compared to its counterpart.
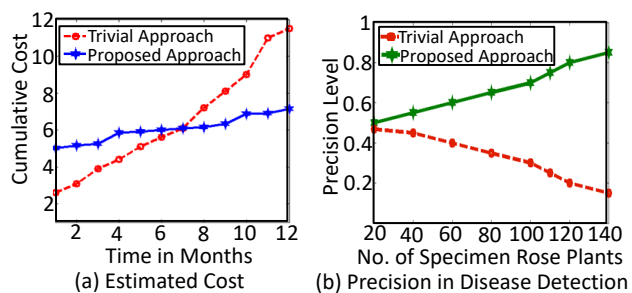

Fig. 5: Experimental Results.

Therefore, over the time, the cost involved in proposed IoT based frame work is quite less as compare to the cost involved in trivial method. Although the IoT based proposed approach incurs some cost in maintenance from time to time when required but still the total cost is significantly less than the trivial method involving human labour. This is being presented using a graph in Fig. 5(a). Similar observations can be seen while considering the precision of accuracy in detecting the diseases in rose plants. Although the precision is almost the same for a smaller number of rose plants like 20, but with an increase in the number of rose plants, the accuracy level decreases in trivial farming methods. On contrary, the proposed IoT framework gives better accuracy with an increase in the number of samples. This is because with the increase in samples, the dataset becomes rich and the learning rate increases, yielding better accuracy and prediction for detecting diseases in rose plants. This is being presented using a graph in Fig. 5(b).

Along with the cost and level of precision, the death rate of plants declines significantly because of early detection of diseases in the plants and taking necessary action for the same in time. Effective use of fertilizers, minerals, insecticides and pesticides

is another major advantage as the exact amount of doses are applied to the infected and nearby infected plants only (not the entire greenhouse) in IoT based approach. This prevents overdose or death of medicines or fertilizers or minerals on the plants.

VII. Conclusions

The IoT enabled automated system described in the paper helps in increasing the productivity of rose plants inside the greenhouse along with the cutting of the unnecessary costs. The investment done in these IoT devices is also not very large as compared to the expenditure through the manual process. The IoT enabled process not only gives accurate pieces of information but also lowers the burden of manual work by automation. It mitigates the traditional load of data gathering, refining, and determining the accuracy percentage. With technology in hand, the new methods of making a field or greenhouse sustainable is far better and a much lot accessible. MyGreen can be integrated with other sustainable IoT solutions to build stronger backbone for smart cities and smart villages [6].

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