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Robot Technologies in Agriculture: A Review

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Abstract:
To meet labour shortages in different concerns of agriculture, the world is innovating various technologies to meet the demands for the increasing population. "Robots and AI would now be able to be utilized to direct non-institutionalized undertaking (e.g. natural product picking, specific weeding, crop detecting) recently held for human specialists and at monetarily possible expenses.” In this paper we shall discuss about various technologies including surveillance, mobile soil sampling, precision seeding and cloud based irrigation technology proposed specially for agricultural application. We shall elaborately learn about the various sensors, programming languages and micro controllers used for the robot locomotion and arm movement also. The main focus of introducing robots in modern agricultural trend is to effectively use natural sources and customize the amount of irrigation water as well as calculate exact amount of fertilizers required by the plant and the soil, reduce human errors and also physical presence of humans on the field.

***Keywords—** Agricultural Robot Technologies, Surveillance Robot, Soil Sampling Technology, Seeding Technology, Cloud Based Irrigation, Microcontrollers, Sensors, Relays.*

I. INTRODUCTION

To meet labour shortages in different concerns of agriculture, the world is innovating various technologies to meet the demands for the increasing population. "Robots and AI would now be able to be utilized to direct non-institutionalized undertaking (e.g. natural product picking, specific weeding, crop detecting) recently held for human specialists and at monetarily possible expenses.” Surveillance robot can also be mentioned as one such technology of mankind developed to replace human efforts in monitoring trespassers like wildlife and birds attack on crops. An automated application must act and re act powerfully to various structures and qualities of the earth, distinctive time subordinate conditions. By mimicking human aptitudes or growing them, robots defeat basic human imperatives incorporating capacity to work in troublesome horticultural situations over a diurnal cycle and can possibly lessen the effect of physically presence and hard labour. [1]

A. Present Agricultural Status

It is estimated that developments in agriculture will be the most effective tool to end poverty and to feed 9.7 billion people by 2050. [2] 2016 analysis found that 65% of poor working adults made a living through agriculture. [3] Regions having food scarcity problems will be at stake with decrease of crop yields due to climate change. 25% of greenhouse gas emissions are contributed by agriculture and forestry. With the ongoing trend of

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agriculture, water consumption is not less than 70% which also leads to unsustainable waste generation and pollution. [2] Although India's contribution of agriculture is only 17.5 % of the GDP (at current prices in 2015-16) it employs almost half of the workforce of the country. India ranks as the second highest producer of fruits and vegetables. 25% contribution in the total pulse production, being second in the world ,22% to the rice generation ranking 3rd in the world, 13% to the wheat generation. It also accounts to 25% of the absolute amount of cotton created, being the best second exporter of cotton. Annual growth of agricultural output over the past 10 years ranges 8.6% in 2010-11 to -0.2% in 2014-15 and 0.8% in 2015-16. Production of food grains in 2016-17 according to an estimate by Ministry of Agriculture of the country is estimated to be 272 million tons which is aimed to be increased to 300 million tons by 2025. [4]Many industries depend on agriculture indirectly to extract raw materials supply to produce the final product.

B. Crisis in Agriculture

Some of the major problems which concerns farmers in the process of cultivating crops includes destruction of plants by natural elements like high velocity wind, disease attack, heavy downpour, wildlife and birds attack on the crops, etc. Other artificial undesired phenomena include uncontrolled amount and traditional ways of using of pesticide, improper irrigation, etc.

C. Solutions to overcome the crisis

To overcome the crisis of agriculture, many new technologies has been developed such as feedback systems to investigate and predict in prior the growth of crops. [5]. Crops are monitored from time to time by capturing multi temporal and large scale remote sensing images. [6] In addition to the combination of both internet and wireless communication systems in monitoring tasks, information management system is also made to engage by taking the system into account to collect data for better analysis of the situations both external and internal. [7] The new mechanical biological system makes complex moral, administrative and social effects. [1]

II. ROBOT TECHNOLOGIES

Cultivation is an idea of utilizing new generation and the board strategies that utilizes all sort of information gathered about explicit areas and yield assortment. [8] The fundamental purpose for computerization of cultivating forms are reducing the time and effort required for performing traditional cultivation practices and to increase yield by proper investigation and calculating accurately the methods and required materials including water, soil and fertilizers. [9] Agriculture 4.0 will assume a vital job in worldwide cultivating, yet mechanized controlling frameworks, information application and portable stages are rare on ranches. [8] Structuring of farming robots is displayed dependent on specific methodology and certain contemplations of horticulture condition in which it will work. [9] Agriculture 4.0 is the joining of agrarian advancements, and present-day information advances bolster ranchers. [8] The accentuation in the advancement of self-ruling Field Robots is at present on speed, vitality productivity, sensors for direction, direction precision and empowering innovations, for example, remote correspondence and GPS. With regards to planning a robot for mechanizing these activities one needs to break down its thought into two contemplations which are horticulture condition in which robot is getting down to business and accuracy prerequisite in the undertaking over customary techniques. A universally useful self-governing automated control framework intended for agribusiness field applications has four center capacities: direction, identification, activity and mapping which are considered in the structuring as per application necessity. [9] Some robots are designed for observation tasks to monitor movements or any other factors as such around it. [10] Such robots are termed as surveillance robots whose fundamental

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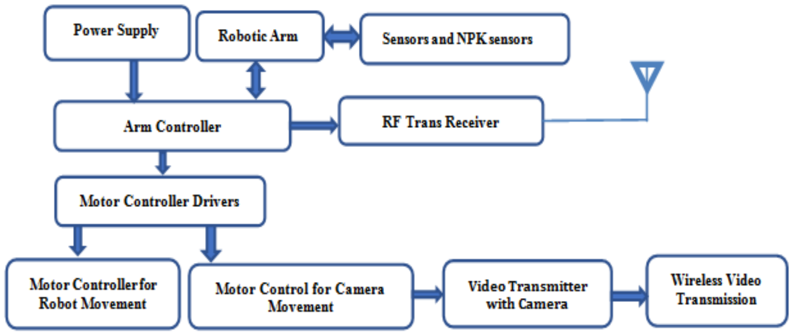
task is to monitor the environment around it including movements. It also becomes unavoidable to incorporate computerization and information handling techniques in present day irrigation system frameworks so as to enhance the water utilization. [3] Let us discuss various innovations which have been developed to improve agricultural practices.

A. Surveillance Robot



This robot is developed to monitor any form of movement around the main framework and the real time video of the environment around it can be viewed through a system. It finds its use in monitoring other parameters such as it helps in deciding the correct amount of fertilizer required, measures chemical quantities in soil. The framework is built with cameras, sensors, transmitter systems to perform its defined function. The main idea of this technology is to use less no. of nodes required to read the parameters. The system will measure micro parameters (NPK), temperature, locomotion, moisture, soil pH. [1]

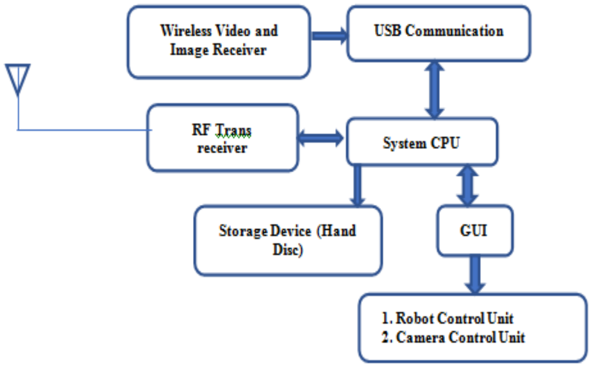
- **OPERATION**

ARM controller and DC motor control drives and manages the locomotive motion of the robot across the site. Sensors are mounted on an appropriate arm of the robot. The robot's motions are controlled with the aid of programs written to produce definite motions. Operator can take command from locomotive manager to control the motion of the robot. RF trans receiver is used to connect data between user and robot. Movable video camera (tilt possible right and left) is also placed on the main framework. CPU is used for graphical user interface and to store data at the front end. GUI is used to provide accurate parameter measurements together with real time video having high quality. [10]

- **Data collected from Samples**

Following are the details about the various data collected after testing the samples using the built project.

a. Humidity:



PHs-220 humidity sensor is utilized to measure this parameter whose output is equivalent to the o/p voltage. Test samples at 20%, 90% generates 660mV and 2970mV respectively, i.e. 2.97V output. At the analog i/p (pin no. 35- AD1.2) of the ARM processor, the humidity o/p is connected. [10]

b. pH:

Voltage generated by pH electrodes (EC100GTSO05B) and transmitter (Alpha pH 500) are measured. The electrodes and transmitter acts as pre amplifiers with high i/p impedance providing high i/p gain of 16.7 to generate 1V/pH. Voltage range of 59mv/pH is generated by standard pH probe. [10]

c. Moisture:

Tensiometer is used as sensor for this particular purpose along with a transducer. Moisture Tension ranges from 0-100 Centibar for this sensor. It generates the following data – o/p:- 4-20mA, i/p power:- 12-24 VDC, max. current consumption 20mA. [10]

d. Temperature:

Sensor used for temperature detection of the site is LM 35 which has a linear scale factor of

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+10mV/ °C. Temperature is measured in °C, with an accuracy of 0.5 °C (@25 °C), fully rated at -55 °C to 150 °C and operates between 4-30V. [10]

e. Light intensity:

A photo sensitive resistor (here, LDR) is used as sensor. Light intensity is inversely proportional to resistance and directly proportional to potential. With change in light intensity voltage drop across LDR changes. Amplifier amplifies the potential change. [10]

f. NPK Micro Parameters:

Ion Selective Field Effect Transistors (ISFETs) is used as sensors to measure primary micro nutrients in soil. NPK micro sensors collects accurate spatial information, irrigation, fertilizer quantity required and produces the data to operators. [10]

- **Data Transmission System**

Wireless camera combined with a power source (having built in 2.4GHz video sender) with video transmitter (XC10A transmitting both video and sound) and receiver are used. VR36A (no audio receiver) is connected to a monitor within 100 ft range from the camera. Video signals are first converted to radio frequency (RF) by the camera and transmits them to the receiver connected to the monitor. These (RF) signals are converted to video signals by the video receiver and fed through cables to the monitor's video input slot. [10]

B. Mobile Soil Sampling Technology

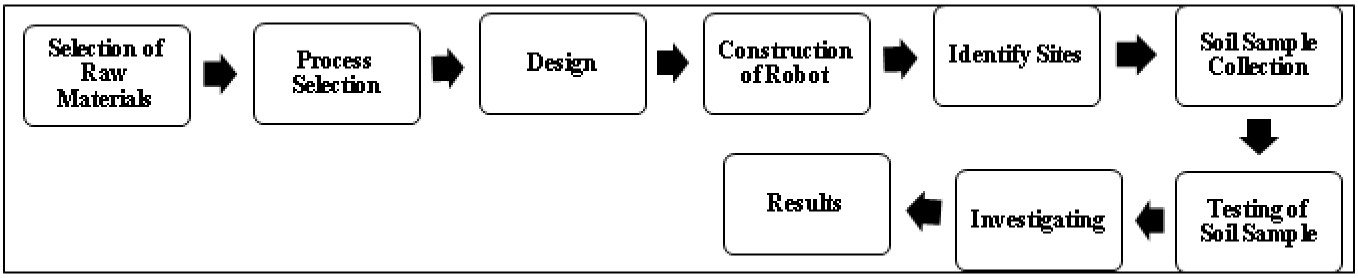

Fig. 2 Block Diagram of Proposed Soil Sampling System [8]

Soil test samples are broken down to decide the creation, qualities or supplement levels of the dirt. The required data can be obtained with high accuracy and with a very effective cost using robot developed with this technology. Soil property data can be obtained from the site utilizing the device's locally available frameworks, empowering ranchers to react to sudden changes progressively. After the introduction of answers for soil inspecting and stockpiling arrangements, the center plan of the referenced soil examining robot is portrayed. The versatile robot has is designed to have 6 wheels with an onboard hanging system. The soil examining device is put locally available and comprises of a pipe with customized fold plan on its finish, to keep the soil inside, saving entire cross-segment. This robot will be "a research center on wheels". Versatile stage will look at tests on site and stores the information in the base. [8]

- **Design**

The device gathers the soil test. It is a single part coupled to the robot. MS pipe is used as inserting base, which conveys the heap during the procedure, finished with a centre drill. The supplement is a straightforward PVC pipe. The MS pipe has an all-encompassing through which the inside (the ground layers) can be viewed. Two sensors are used to check temperature and moisture proceeding onward two guides driven by DC motor connected to a screw. The development permits taking soil from certain depth beneath the ground with noticeable layers. A variolation is also utilized to guarantee partition of response powers from the stage.

The framework is designed to be hanging to carry loads underneath 23 kg while maintaining a lightweight body. All the wheels can be lifted to 40 cm while the remaining wheels still contact the ground permitting free swingarm activity because of

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differential mechanism. The differential itself depends on a plain bearing on with an aluminium profile coupled to two threaded rods on each end. This system additionally gave the third purpose of help of the edge. To improve driveability, considerably more, the centre arrangement of wheels are moved around 5cms comparative with different wheels to the outside. [8]

- **Test**

Soil sampling mobile platform under operation on soil with a significant level of ferrous content. The soil test was conducted in different soils of Europe and North America. Solidness and viability of the driller is tested. It was tried on materials from loose as well as hard soil subjected to different conditions. The normal profundity of the boring was 15cms. A temperature sensor and a moisture sensor are utilized. The two sensors were appended to the drill sampler. In this situation, the robot was controlled from the base station commanded using python programming language. Research facility area accumulates all deductively fascinating tactile estimation. The administrator controls the meanderer by a joystick with various catches. Each has relegated capacity and explicit activity. Sample report of the soil generated on 11/08/2018 examined at site Drumheller, Alberta, Canada (ambient temperature: 28°C at atm. Pressure: 1024.20hPA, longitude: -112.752986°, latitude: 51.470856°, orientation: 344°, wind speed: 14Km/h heading 315°) under rover orientation -2°(x), 5.92°(y), 344°(z) are 9.85°C temperature and 5% humidity. The information from sensors are put away in the created report. The report comprises of an exceptionally exact area of the overviewed site, current environmental situations, and primer test outcomes. The administrator can decide and choose actions for gathered information for nearness of any noteworthiness to the research and can choose if gathered material is reasonable for further investigation or not. The new updated version is furnished with an all-new stockpiling instrument permitting assortment of various contaminants from studied sites. [8]

C. Precision Seeding Function Technology

Increasing productivity of yield by treating every specific crop according to their particular needs using precise techniques of cultivation is the aim of the present agricultural scenario. This study will portray an agricultural robot designed especially for seed sowing which works at defined depth and distances between crops and their rows according to the type of crops by providing accurate navigation. For seeding, robot must be capable to move linearly even on rough terrains of the field, appropriate sensors must be selected considering working ambience. [9]

- **Working**

This technology is employed to dig soil up to a certain appropriately specified depth, burry seeds into the soil and pour water into it. Sensors detects the amount of completion of sowing seeds by detecting the area under the compound of the field. After the detection of first row the robot will turns at 90° to its left and it covers the distance between two rows of crop and for second row, the robot will turn at 90° to its left to continue sowing. Once the second row is done, the end is detected and then root will turn at 90° to its right and covers row distance and again turns at 90° to right. Further, to cover a third row. The robot will execute the sowing of crop rows by turning to its left and right. [9]

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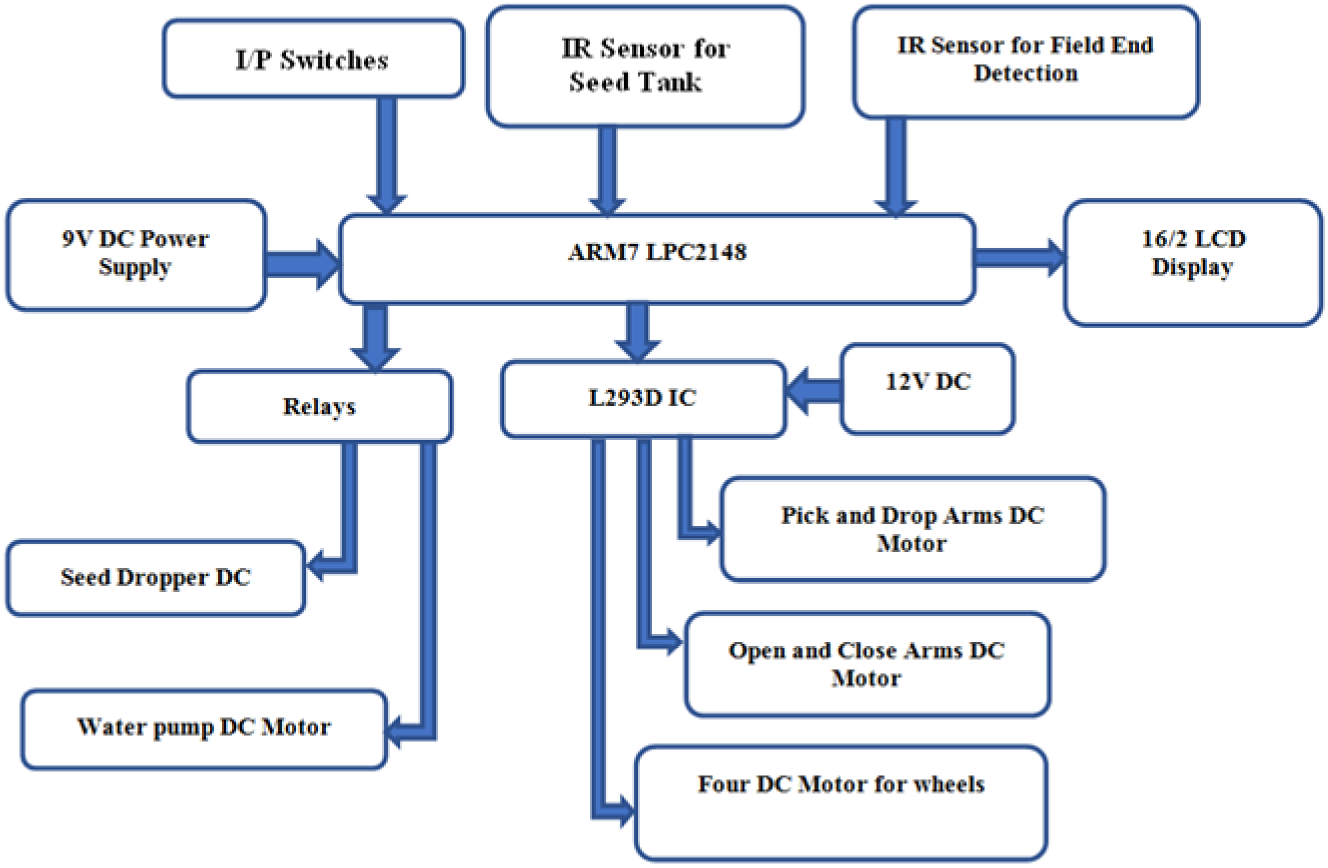

Fig. 3 Block Diagram of Proposed Seeding Technology [9]

Design

ARM attached with a microcontroller is designed as the main framework block. By operating the input switches, input (crop type) is given. Output of the chosen crop and error is displayed on an LCD (Liquid Crystal Display). Seed tank is used for the purpose of storing the seeds and water tank is used for the purpose of storing the water and both are connected. For dropping the seeds, rotating wheel mechanism is used which is actuated by DC motor. Water is pumped using a directional control pump. A sensor is coupled near seed tank to control the amount before starting the sowing operation. Another sensor is also used to measure the size of the field. This system does not use a feedback element ,i.e, no output is measured or compared with the input or crop type but input is directly given to the system. Two V shaped arms are used in the robot whose motions are provided by DC motors. A motors controls the transverse motion of an arm and another motor is for regulating the opening and closing of the other arm. Opening releases the soil previously held to cover the pit used for sowing which was done by the closing of the arm. The wheels are run by 4 motors and the arms and wheels are connected to L293D IC which enables them to rotate in both cw and ccw directions. Relay switches are connected to both the motors provided for water pump and seed sowing. [9]

Test

Sample test of this robot was carried out on damp soil and the displacement of the robot was compared to an optimally predefined distance. The test was carried out on four different types of crops namely cotton, maize, soybean and wheat separated by a distance of 15cm, 12cm, 7cm and 5cm respectively between two crops and essentially the crop rows were separated by 60cm, 45cm, 50cm and 25cm

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respectively. The result of the test generated a difference of 4cm-8cm ,i.e, 12cm,9.5cm, 6cm and 5cm (for the crops in sequence as stated above) between practical and theoretical distance of two rows while that of the difference of theoretical and practical distance between two crops was found between 2cm-3cm, i.e, 53cm, 38cm, 42cm and 21cm respectively for the same crop sequence. [9]

D. Irrigation Technology

This technology is introduced to control the level of water automatically. Water level in a trough is continuously measured by a sensor and irrigation time is calculated using reduction in water level for a specified time duration. The process is started by powering electric valves using a microcontroller board. Few sensors are employed to sense the temperature and a wireless connection is setup to retrieve data. This system was tested on a crop field and compared to traditional practice this system achieved 90%. The system was used for cultivation of strawberries. [3]

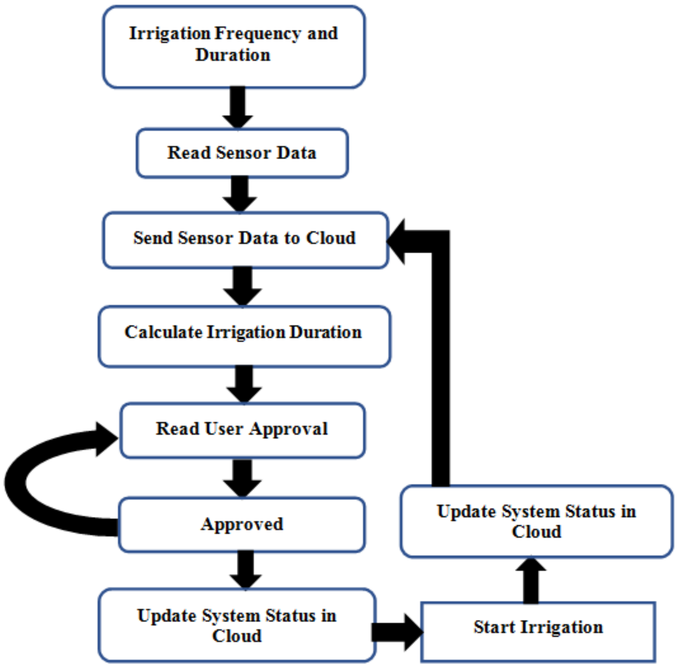

Fig. 3 Block Diagram of Proposed Irrigation System [3]

- **Design**

The duration of irrigation is calculated using the equation:

$$t = \frac{E_{pan} * k_{cp} * p * A}{q * n}$$

where,

E_{pan} = cumulative free surface water evaporation at irrigation interval (mm)

K_{cp} = plant-pan coefficient,

P4 = plant cover (%), a parameter related with area of plant leaves,

A = field area (m)

q = flow rate from the emitters,

n = number of drippers in the field. [3]

The different units used in this system and their purposes are discussed below:

a. Power Transmission Module:

A transformer and solenoid are employed. The transformer reduces high AC voltage to a lower optimum value. 24V AC is sufficient to open the valves. The controller unit controls the switching of the valves. [3]

b. Information Collecting Module:

Sensors to monitor water level and other environmental parameters are used and connected to a microcontroller board. The water level is measured continuously to monitor the evaporation of the water in the trough where the water level sensor is fixed inside the trough. The environment sensor senses temperature, humidity and pressure in the site. A trans receiver allowing, is used to transmit these parameters to control internet connection. Calibration is necessary for efficient usage of the water level sensor. To achieve accuracy, empty trough is filled with water and the output voltage reading from the sensor is recorded for every certain volume of increase. Calculations of voltage pairs from the above data is done using least square method. [3]

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c. Wireless Connection Module:

A clock and trans receiver are used for this purpose. A microcontroller board is used for processing data from the modules and releases required commands. The instant reading of local time and date are done .This information is required to initiate irrigation. The transceiver module receives measured data. Internet connection is done using GSM/GPRS module, SIM900 (SIMCom, Shanghai, China) and a set of AT commands are attached to it to read data related to sensor, valve information, intervals of previous operation and further sent to a cloud service. [3]

d. Investigation Module:

It is used to monitor the current system status, including water level, duration of last irrigation, valve position and ambience of the site. The system waits for approval of irrigation schedule and initiation of the process by the user. [3]

- D.2 Test

Two tests were performed at two different sites, one where cultivation is done conventionally, and the other one at a site where automatic drip irrigation was installed. Both the sites were divided into four sub sections each for different irrigation duration each to analyse the required parameters. Therefore, four irrigation treatments are applied with assigned water amount 0.5, 0.75, 1.00 and 1.25 times the trough evaporation (Epan) respectively. The data was measured at the site having 1009.39hPa atm. pressure at 21.76°C in the presence of 64.58% humidity in air. The initial water level taken was 127.32 mm with 1st & 2nd valves closed and 3rd & 4th valves open. Valves 1,2,3 & 4 were operated for 30, 45, 60 and 75 minutes respectively for 7 consecutive days and the amount of water level data was collected which was found to give a 13.5 mm reduction in the water level from the commencement of operation (recorded water level = 144.25mm) to the final day of analysis (final water level = 130.80mm). This technique of irrigation employed at the site has given no negative impact on the strawberry plants and therefore is fit to be in continuous use.[3]

III. CONCLUSIONS

Huge perceptions after examining and analysing calls attention to that introduction of robots could build generation productivity. Gathered examples give exact information of supplement providing limit. [8] The technologies to be developed must be relatively cost effective with improvised speed, accuracy in operating, less fuel consumption and human effort compared to the previous technologies. Farmers must be best benefitted by the technologies the millennials develop for them. [9] The surveillance technology is highly durable with more flexible platform, longer lifetime and more sensitive. No. of nodes used is reduced and various micro parameters are easily measured along with temperature, humidity, moisture, pH. [10] By employing drip irrigation system, we can now use only the adequate amount of water required for irrigation after precise calculation contributing directly to less consumption of water on earth. This way the field and plants will be saved from the certainty of drought stress and excessive irrigation that may cause various fungal and bacterial diseases in plants. [3] Seeding technology helps in detecting the area of land that can be effectively utilized for a particular plant. This technology allows us to choose accurate appropriate distance to be maintained between two crops to ensure good health and growth of the plant without deteriorating soil health of the site. [9] A very important feature common in all the technologies discussed above is its remote-control ability which serves a great advantage in this modern world of busy schedules. Another undeniable characteristic feature is the precision provided by these technologies which has helped in reducing faults caused due to human errors.

IV. Future Scope

Satisfactory accuracy and performance of the various robots discussed above can be improved by effectively redesigning the methodologies currently used for them by employing mechatronics, modern controllers and advanced information systems.

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