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Smart agriculture management system using internet of things

Kaushik Sekaran[1], Maytham N. Meqdad[2], Pardeep Kumar[3], Soundar Rajan[4], Seifedine Kadry[5]
[1,4]Vignan Institute of Technology and Science, India
[2]Al-Mustaqbal University College, Iraq
[3]G. H. Raisoni College of Engineering, India
[5]Department of Mathematics and Computer Science, Faculty of Science, Beirut Arab University, Lebanon

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ABSTRACT

In the world of digital era, an advance development with internet of things (IoT) were initiated, where devices communicate with each other and the process are automated and controlled with the help of internet. An IoT in an agriculture framework includes various benefits in managing and monitoring the crops. In this paper, an architectural framework is developed which integrates the internet of things (IoT) with the production of crops, different measures and methods are used to monitor crops using cloud computing. The approach provides real-time analysis of data collected from sensors placed in crops and produces result to farmer which is necessary for the monitoring the crop growth which reduces the time, energy of the farmer. The data collected from the fields are stored in the cloud and processed in order to facilitate automation by integrating IoT devices. The concept presented in the paper could increase the productivity of the crops by reducing wastage of resources utilized in the agriculture fields. The results of the experimentation carried out presents the details of temperature, soil moisture, humidity and water usage for the field and performs decision making analysis with the interaction of the farmer.

Corresponding Author:

Seifedine Kadry,
Department of Mathematics and Computer Science,
Faculty of Science, Beirut Arab University,
Beirut, Lebanon.
Email: s.kadry@bau.edu.lb

1. INTRODUCTION

Internet of things (IoT) is a term that enables us to utilize technologies, work together, communicate each other, provide real time data from sensors wirelessly for processing, and provide more valuable information for efficient decision making in the corresponding research field. IoT is dramatically a developing technology in application areas like health care, defense, industry, agriculture and so on the features of IoT are unlimited in such a way that it can be utilized for the development of civilization to make and lead a better life. To implement IoT one need to have a knowledge on research area with the hardware equipment's and possibilities with connection to internet for accessing the devices.

IoT is more like physical things connected to internet, communicate, and share data to each other which is smart devices, IoT is not a new idea but recent development in hardware technology made it popular [1] for implementation, U.S president provided a positive statement after Auto-ID using IoT in 1998 [2] there was a great encouragement and development in the field [3]. IoT with sensor networks provides a new device to interact and observe the real-time data in physical world [4] provided with automation and decision making process. Developing an intelligent system using IoT for agriculture could be able to monitor the crops growth and its environment [5, 6] even though collection of the raw data is important [7], the mining and analysis of the data is also considered to be essential task. Agriculture field products [8, 9] have several issues with IoT which can be solved and allow us to predict, monitor, and manage the cycle of agriculture products. In India agriculture is the largest livelihood provider with its enormous population [10] merely half of the population still relies on agriculture as income.

Our Proposed Architecture model consists of three different layers as 1) physical layer, 2) IoT layer, 3) Com-op layer, these layers act as the entire management system provided with consumer monitoring and automation services into it. The system has capability of managing all types of issues in agriculture like animal control, quality management, supply-chain management and so on.

2. RELATED WORK

Zhao et.al [1], proposed the integration of IoT (internet of Things) technology to real-time production of agriculture crops with remote monitoring and wireless communication using internet is proposed, a management system of information is also designed to handle the crops data for research purpose. Ning H. and Wang Z. [2] has differentiated IoT in two aspects namely Unit IoT and Ubiquitous IoT, where man's like neural model (MLN) is considered in unit IoT and a global integration of unit IoT is considered as ubiquitous IoT with this combination, a social organization framework model (SOF) is constructed for the relationship and development for future of IoT. Yane [3] have discussed about the methods of designing the IoT architecture for agriculture by employing Agriculture information technology (AIT) concept by analyzing the features of agriculture data. Zhou et.al [4] have presented a report of using sensor networks design on IoT in agriculture for monitoring the crops and the design is evaluated using the parameters like reliability, cost, interoperability and management to ensure the right design. Qian S., et.al [5] has proposed the concept of embedding the IoT applications with crops growth which make the system to be adaptive and intelligent, by experimenting on different fields. They also discussed about the challenges faced to develop an intelligent system. Bing F. [6] has presented a research on an intelligent based system on IoT with few technologies employed such as sensors, RFID, and so on, a decision based system is developed by managing and monitoring the plant environment. Bing F. et.al [7] has discussed about the devices used in IoT along with its architecture, services and protocols which is intended to collect the real time data and provide services to consumers. Wang C., et.al [8] presented the impact of cloud computing and IoT on the conventional system by taking diversification in to advanced system which deals with complexity and robust nature, they explained the ways of innovations to achieve the goal of IoT with automation. Lee M., et.al [9] has presented an IoT based agriculture productions to manage the supply chain demand and a monitoring system to analyze environment of the crops, with methods to carry out decision support. Tuli A., et.al [10] proposed a framework for modernizing the Indian agriculture system with cloud deployment named as "Agri-Assistant" which provide information regarding the agriculture and its methods for farmers in rural areas. Kiljander J., et.al [11] has proposed a novel architecture for IoT and pervasive computing that provides a huge potential to business in virtual computing platform and presented two principles for the architecture. Alam K. M., et.al [12] has discussed the enhancements of open IoT platforms on agriculture for validating, processing, study the crops growth from sensors and its environment to make efficient decisions.

Jayaraman P., et.al [13] presented the analysis by identifying the needs for agriculture based on the constraints or parameters like weather forecasting, crops farming, rural development, and market identification, relevant to the IoT perspectives and contribution of IoT towards poverty reduction. Kalezhi J., and Dlodlo N. [14] have discussed about the methods in IoT that reduces investments with top-down architecture principles especially suited for smart cities creation. Ganchev et.al [15] has proposed a distributed IoT architecture referred as DIAT (distributed internet-like architecture of things) which is used to tackle the issues such as security, heterogeneity, and so on and the service created for automation and decision making for multiple domains. Anand Nayyar and Er. Vikram Puri [16], presented the importance of IoT and smart intelligent networks,They presented the Smart farming techniques based on IoT and proposed a novel smart agriculture stick using IoT which monitors the crop growth. The Stick architecture presented in their paper keeps track of live data of temperature and soil moistures and monitors the environment by enabling farming techniques and increasing the overall yield and production quality. They used Aurdino technology to enable processing from sensors and live data feeds collected from Thingsspeak.com. Jiangfeng Cheng et.al [17] introduced about smart manufacturing basing on cyber-physical systems (CPMS), the key issues in CPMS include Industrial internet of things (IIoT) with the characteristics like automation, smart connectivity, real time monitoring and collaborative control. They suggested that 3rd gen and 4th gen mobiles does not meet the demands of CPMS in supporting high data rate, reliability, latency etc. They proposed the potentiality of 5G in promiting IIoT and CPMS. The characteristics of 5G technology could support IIoT and CPMS in manufacturing technologies with three types of application mode ie, enhance mobile broadband (eMBB), massive machine type communication (mMTC), ultra-reliable and low latency communication (URLLC). The challenges of 5G technology is also discussed.

3. PROPOSED ARCHITECTURE

In this section an Architecture is proposed as shown Figure 1 for smart Agriculture using internet of things (IoT) which provides numerous benefits such as effective and efficient management of resources, knowledge development, intelligent management, monitoring, etc.,

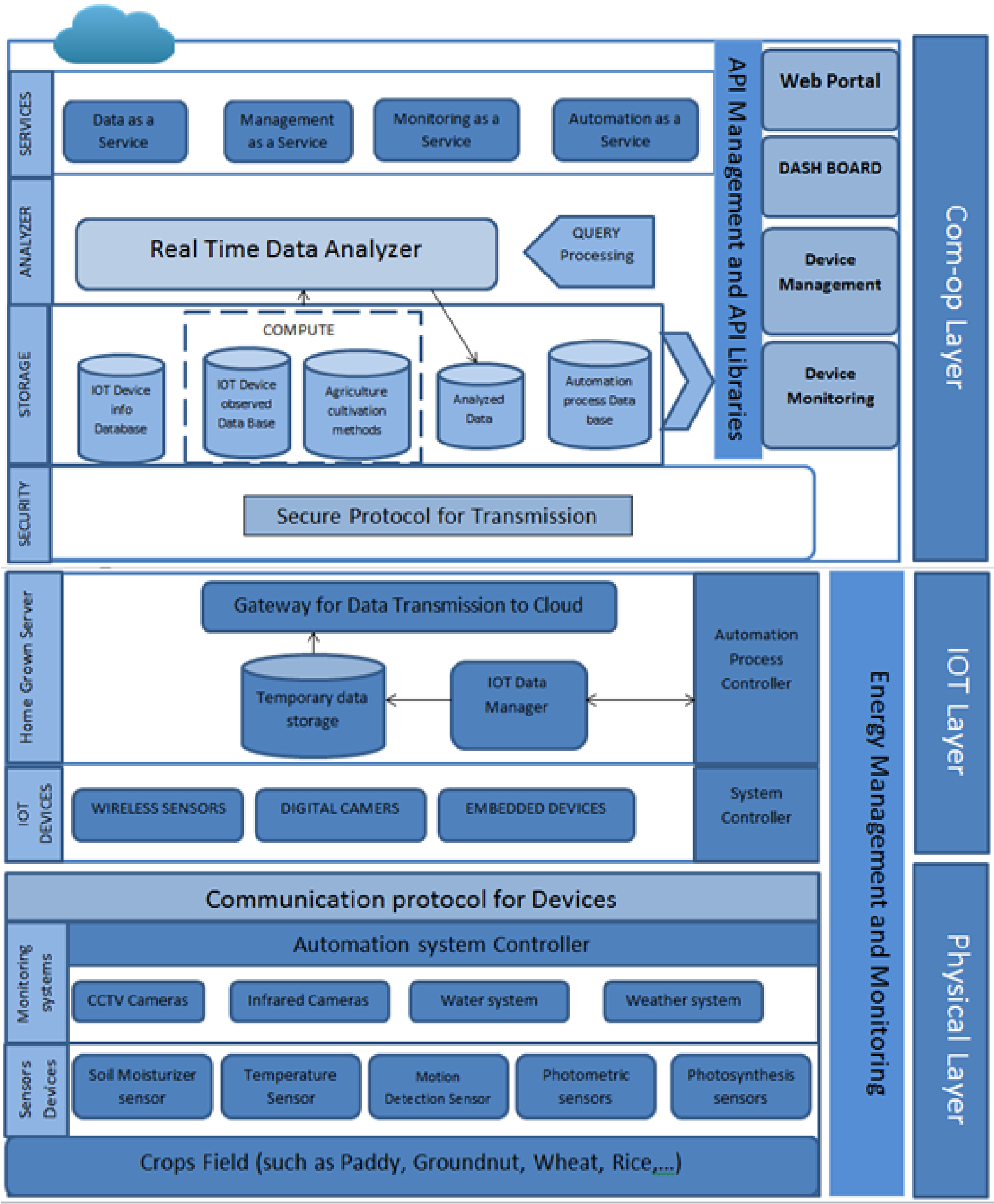

Figure 1. Smart agriculture system architecture

The architecture [18-25] is divided into three layers namely:

a. Physical Layer
b. IoT Layer
c. Com-op Layer

– Physical layer

The physical layer is a layer of automation to control the smart agriculture system. The automation process controller has sensors and control monitoring system. It is designed to manage and control the sensors and also performs monitoring of system devices. The sensors used in the process of automation are soil moisture sensor, temperature sensor, motion detection sensor, water level sensor, and photosynthesis sensors. This sensor comes under IoT devices which are subparts in IoT Layer. These sensors are intended to check the moisture level of soil, amount of water required for the crop, temperature of the plant, environment and detection motion of the species. The CCTV cameras, infrared cameras, water system, weather monitoring systems were used to monitor the automation field. The underlying communication protocols helps us to provide automation by serving as an interface between any two or more devices based on real time data.

– Automation process controller

The IoT devices receive the input from the sensor and monitoring devices of the physical layer. The home-grown server uses the IoT data manager which receives the real time data from the system controller. It stores data temporarily in a local server. The gateway sends data to the cloud to analyze the data and initiates the proper service. The Com-Op layer receives the real time data from the IoT layer through a well-defined security channel depending on the data received, a particular service will be chosen.

– IoT layer

The IoT layer is the layer where the data from the physical field is collected and sent to further processing in the Comp-op layer. In the IoT layer, a system controller is present where the IoT devices are connected to the system controller for example physical local system collects data from the devices and transfer through the local server to main cloud server using this system controller. The IoT devices alerts every second, notifies every changes and sends data to the controller. The devices mainly used in the automation system are wireless sensors, digital cameras, and embedded devices. The home-grown servers are used as a local server. It is the part of automation process controller in which the home-grown servers contains IoT data manager information which collects data from the devices and stores in the temporary storage. The data is then forwarded to the cloud to process the data via gateway used to transfer data from local to the main server in the cloud.

– Energy management and monitoring system

The energy management and monitoring system is used for controlling the energy, power resources used in the automation process so that power can be reduced and saved in order to make automation more efficient. In this part of the system, the automation process controller can be coded to control the power source which is connected to the all devices in the process of automation. The power sources are either turned off or reduced when there is non-utilization of sensors or capturing devices to save electricity and make automation more efficient.

– Com-op layer

In the com-op layer the security level protocols are used to transfer data securely with in the cloud services. It acts as a Storage area for many types of data to store which can store every processed data and data to be processed. The analyzer is the main process system where the data are processed and basing on the result, the further process are decided and prepared for execution. The services are the full power processes that are created for the client who decide to do what should be done when certain notifications and warning and alerts are being given from the cloud services.

– Real time data analyzer

The Real time data analyzer will be connected to the databases and compute the data that is observed from the real time and stored cultivation methods and derive the results to be stored in the analyzed data. The data collected from the crop cultivation field will be compared with the database information of traditional method of cultivation and according to the data which is resulted from the comparison, the message will be sent to the client dash board and decision will be made.

The five databases of Storage area in the cloud are included such as;

– IoT Devices information DB

It stores the data about the devices that are installed in the field and provides the status of the device whether it is active or not can be identified easily and restoration of the devices can be done, every basic and essential information about the devices are stored and updated in every day of the field process. The database is maintained the details of sensor name, sensor id, sensor status, date, time, and configuration of the sensor.

– IoT device observed data DB

This database stores the real time observed data which is communicated by IoT data manager from IoT layer and helps to process and monitor the crops observed data for further analyze. The data that are collected from the various sensors and monitoring devices are stored in the database. Data from monitoring system can be stored in the database as videos, pictures. Details from the sensors like sensors status, water level, weather system details can be stored for decision making purpose. The observed data may be a signal, text, video and picture.

– Agriculture cultivation methods

It consists of a huge set of crops cultivation methods and fertilizer information; this helps to take decision about the crop automation process. It consists of details about crops cultivation essential things about the need of a particular crop to be planted and developed. For the crop development and good yield of the crop, the details of soil type, soil contents, minerals needed, fertilizers to enhance process of growth.

– Analyzed data

This database stores the processed data from IoT and Agriculture cultivation methods, derived structure data for the customer usage. With this data, the further need of a crop is predicted to provide for the automation field like water supply, fertilizer supply, control systems. The historic data is used for further crop and automation process.

– Automation process database

It consists of data about the automation occurred in the field and history for further analysis. This database acts as the backup database of the IoT devices information database, traditional essential cultivation methods database, and analyzed database and additionally we store he automation process occurred details in this database.

3.1. Services

The four major cloud [26-30] oriented services for the data are provided such as:

– Data as a service

Data will be provided from the database to the client dash board who owns the automation system which was effectively planted in the crop field. Information about all the devices, systems, processes are meant as data and the data are provided to the client to perform the efficient automation processes.

– Management as a service

The basic and advanced control system for devices connected in the field for the automation system process with control buttons and sliders button perform automation. Client can control the process and devices according to their decision.

– Monitoring as a service

It provides a basic video widget for monitoring the field by recording them by CCTV cameras, infrared cameras. Also, videos can be viewed that was recorded and stored in the observed database in the client dash board. The process can be known which are ongoing in the automation field. Water monitoring system and weather monitoring used to know the water level in the facility and prediction of weather environment. Therefore, this service provides a better monitoring process.

– Automation as a service

A full configured automation system will be controlled by the client mobile phone which has automation dash board installed in it or can be used to control automation through dash board. Dash board is the web API facility for client to control, manage and monitor automation.

3.2. Crop monitoring framework

The crop field is a starting phase to grow the crops, the land has to be fertilized well before seed the land, loosening the soil makes the way to seed, the seed gets chance to hold the grip of the sand and watering it will start the growth. From the watering the sensors placed in the field monitor the soil moisture, humidity and temperature of the environment. The growth level of plant starts and the watering level are measured with soil moisture based on the need, the water provided to crops. Each level of crop growth is monitored and automated with the sensor readings from real time data. Up to the harvesting time the crops are well grown and fertilizers help it to grow in a healthy way to provide an efficient analysis to the farmer. In Figure 2 the crop growth framework is designed with different growth methods of crop.

3.3. Pseudo code

```
DENOTION:
Procedure soil_sensor (moisture_level, minerals level [])
Begin
If(moisture_level<required_level)
Then Call Procedure water_auto ();
ENDIF
If(minerals_level<reqmin_level)
Then call Procedure fertilizer();
ENDIF END
```

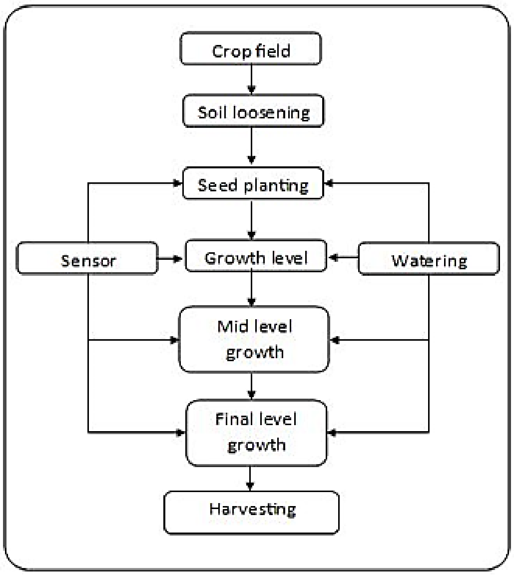

Figure 2. Framework for crop growth and monitoring

4. EXPERIMENTAL RESULT

4.1. Testbed

The experimentation is carried out to analyze the methods used, the sensors are installed in the crop field and the parameters like humidity, temperature, and soil moisture are monitored. The setup includes a laptop with Ubuntu 14.04.03 operating system connected with arduino IDE, a humidity sensor as shown in Figure 3 and a soil moisture sensor as shown in Figure 4. The analysis is performed on the fields like Paddy, sugarcane, banana, and groundnut. The readings from the sensors recorded are shown in Table 1.

Table 1. Soil moisture reading

Sensor value	Soil status
1000-1023	Dry
700-999	20% water content
400-699	50% water content
100-399	80% water content
0-99	100%water content

Figure 3. Humidity sensor

Figure 4. Soil moisture sensor

4.2. Methods for cultivating crops with results

The experimentation is carried on the fields like paddy, groundnut, banana, sugarcane, in this section, the methods of cultivations with respect to groundnut and banana field is presented. Groundnut production is the second highest production in India, the cultivation of groundnut is basically two types:

- Manual system: traditional cultivation.
- Based on rain.

In both systems, the process of cropping, fertilizer, pesticides, water used are same with minor variation in water quantity. The cultivation of ground nut, needs the period of 105-115 days. For cultivation, the field is selected based on soil, water condition. As an experimentation, one acre of sample work field is considered. As an initial step, the field will be cleaned and soil is mined so that upper layer which helps the cultivation to yield more. This is the first method in the cultivation. In the next level, the water supply is provided to the field for loosening the soil. For one-acre field, approximately 25-30 kgs of groundnut seeds will be taken. Later, the seeds will be drawn in the field and water is supplied at the rate of 2000 liters each time. The crop starts growing after 10-15 days in next 10 days, after crop development, the field should be cleaned.

The fertilizers namely Potassium, Complex, Neem, and di ammonium phosphate are used for cultivation of groundnut approximately 80 kg are utilized per crop. After 40 days, the process of soil grouping process is done which leads to yield more crop and quality of ground nut is also increased, this process is also called as mannu anaipu (soil grouping). The process of soil grouping is nothing but grouping the soil at the stem of each plant. Water is supplied at the medium level and in a slow rate so that plant wont be decayed. Finally, after 110 days approximately all plants grow well and the time for harvesting crops from the field will be done. After harvesting, crops will be separated and both groundnut and their separated plants will be ready for market. The process of IoT process and its advantages towards agriculture is discussed in this section. Soil sensors were used to measure soil moisture, materials and minerals in the soil. By deploying this sensor in the field, the information about the particular soil is obtained and further processing is carried out. The information given by the sensors can help us in decision making process. It reduces the money investment in fertilizers utilization. Water quantity sensor used to detect quantity of water in the storage area so that we can use efficiently. Water flow control sensors used to control the flow of the water supply. The wireless communication sensors are used to communicate with the main board for processing and storing data. Passive Infrared (PIR) Sensors also known as motion sensors used to detect head signals and send information to the main board. By using temperature sensor, the temperature of the day is sensed and according to that we can control water supply to make efficiency. The readings are shown in Tables 2 and 3. The graphical representations of moisture level recorded for groundnut crop is presented in Figure 5. The graph presents the moisture level recorded from sensors for 12 milliseconds.

Table 2. Humidity and temperature value

Humidity	Temperature
50%	33.00 c

Table 3. Sensor values for groundnut

Milliseconds	Moisture sensor reading
1	678
2	673
3	670
4	667
5	665
6	663
7	660
8	659
9	657
10	647
11	646
12	643

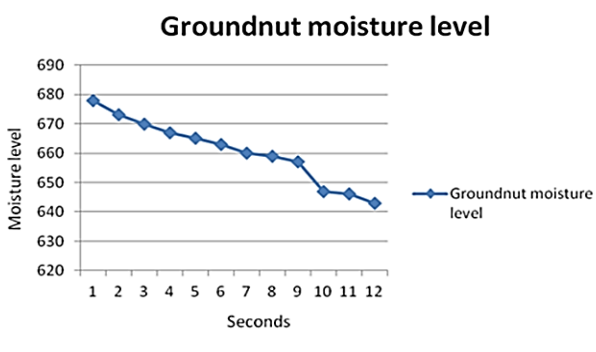

Figure 5. Moisture level for groundnut

Banana cultivation*:* another crop used for the experimentation is Banana. Banana is one of the famous cultivation products there are different types of bananas. Every type is unique in taste and in size. Prepare the field and mine the soil for plantation. Each plant should leave 1-meter distance. For one acre nearly 1000 plants are required. The banana cultivation season is December and January and lifetime of the banana cultivation is about one year. The water supply is provided weekly once or 6 days once according to the soil moisture information obtained using soil sensors. Day by day the banana plants will grow. Natural fertilizers like Neem, cow dung, ashes of wood etc. Over water supply can lead to plant rotten, approximately 2000 liters of water supply should be provided each time. Phosphate is the essential element in faster growth with high yield.

Fertilizers used for banana are enzymes, micro nutrients, mida. For every two weeks, the dry branches and leafs need to be cleared. Banana tree consists of water consistency. Every part of the banana tree will be useful like plant stem, leaves, fruits, flower, inner stem. The Water supply can be controlled using water control instruments with help of water level sensors. More ever banana trees are little weak in catching soil or earth through root of the tree so heavy winds may affect and destroy the whole cultivation. The sensors used in the process of cultivation process are Chemical Sensors, weather sensors, air flow sensors, flow sensors, level sensors, safety sensors, safety switches, CCD (Charged Coupled Devices). Every sensor is used in every process of the cultivation. Through IoT, the agriculture can be enhanced and developed to and save the future. Table 4 provides the humidity and temperature, Table 5 and Figure 6 present the impact of moisture in banana tree, recorded for 12 milliseconds using the soil sensors, temperature sensors. The interface designed for our proposed work is given as follows. The options provided in this framework includes the crop cultivation methods, electronic devices activation, Moisture reading, temperature readings Figure 7.

Table 4. Humidity and temperature for banana

Humidity	Temperature
57%	37.00 c

Table 5. Moisture sensor level

Milliseconds	Moisture sensor level
1	400
2	402
3	406
4	407
5	408
6	409
7	410
8	412
9	413
10	414
11	415

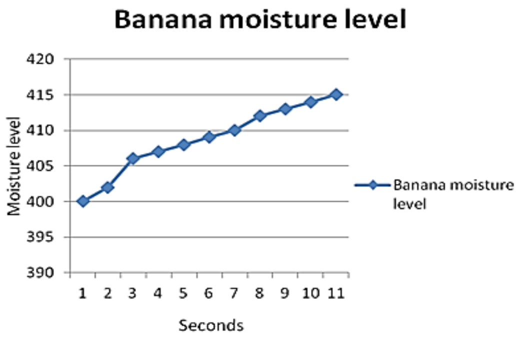

Figure 6. Moisture level of banana

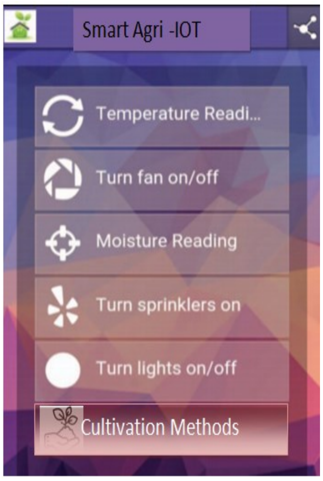

Figure 7. IoT Application in android frame work for smart agriculture

5. CONCLUSION

An IoT system Development for agriculture could resolve many real-time issues by increasing the quality and production management which enables the farmers to access huge amount of results from the real-time data from the crop field. Three layers in the architecture are connected with cloud where all the data are uploaded, processed and accessed with API libraries and the devices are connected. Methods for cultivating crops are provided as a process flow explained from the start of seeding to crop yielding. The experimentation is carried out on crops of groundnut and banana and the readings of different sensors are collected and placed in cloud to integrate with IoT for the purpose of automation and efficient decision making process. The system is managing efficiently and effectively. The Architecture proposed in this paper, could provide a base for implementation of smart agriculture system using IoT. The layers used in this architecture is intended to store, manage and monitor the crop growth details and also provide the efficient decision making for the process of fertilizers utilization, water supply and plantation of crop basing on the data collected from the sensors connected to the ground of the field. The work proposed has been tested on Live Agriculture Fields obtaining the accuracy rate of upto 98% basing on the data feed.Provide a statement that what is expected, as stated in the "Introduction" chapter can ultimately result in "Results and Discussion" chapter, so there is compatibility. Moreover, it can also be added the prospect of the development of research results and application prospects of further studies into the next (based on result and discussion).

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