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Field Monitoring and Automation using IOT in Agriculture Domain

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Abstract

Agriculture sector in India is diminishing day by day which affects the production capacity of ecosystem. There is an exigent need to solve the problem in the domain to restore vibrancy and put it back on higher growth. The paper proposes an e-Agriculture Application based on the framework consisting of KM-Knowledge base and Monitoring modules. To make profitable decisions, farmers need information throughout the entire farming cycle. The required information is scattered in various places which includes real time information such as market prices and current production level stats along with the available primary crop knowledge. A knowledge dataflow model is constructed connecting various scattered sources to the crop structures. The world around is getting automated replacing manual procedures with the advancement of technology, since it is energy efficient and engross minimal man power. The paper proposes the advantages of having ICT in Indian agricultural sector, which shows the path for rural farmers to replace some of the conventional techniques. Monitoring modules are demonstrated using various sensors for which the inputs are fed from Knowledge base. A prototype of the mechanism is carried out using TI CC3200 Launchpad interconnected sensors modules with other necessary electronic devices. A comparative study is made between the developed system and the existing systems. The system overcomes limitations of traditional agricultural procedures by utilizing water resource efficiently and also reducing labour cost.

*Keywords:*e-Agriculture; Knowledge Base; Monitoring; Ontology.

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1. Introduction

Farmers need agricultural information and pertinent knowledge to make knowledgeable decisions and to satisfy informational needs. In agriculture domain through the development of a knowledge management system, enquiries of farmers can be answered with the help of multimedia which is easily accessible.
The application of Information and Communication Technology (ICT) has proven for widening the opportunities to promote agriculture on several aspects and domains in developing countries. Technology has crossed hurdles by using wireless technology, networking, mobile etc. to overcome the utilisation of energy, power and cost consuming equipments which was helpful in the agricultural development. The development of ICT in various domains has driven substantial interest in rising investments by private sectors towards the growth of ICT in Agricultural research (Fredrick Awuor et al., 2013).

At present, the key issue in the current domain is utilisation of resources like man-power and water which is lacking in many parts of the country. There have not been any significant technological advancements being made in agricultural sector as compared to other sectors. Agricultural system needs to be monitored on a regular basis. The use of the developed framework is to reduce wastage by automating the entire agricultural system.

2. Background:

The major challenge identified in the current domain is to provide farmers required information and timely help. It is difficult to find knowledge to aid sustainable agriculture as it may not exist or rigorous to locate. Here, the web application is intelligent to come up with good solutions to enhance circulation and acquisition of information about sustainable agricultural techniques. The developed applications include Knowledge Management System, Agricultural Information Retrieval System, Expert Knowledge System and Agro Advisory System with Mechanism for sharing and reusing agriculture knowledge. Susan F. Ellakwa developed ontological system for multimatching and merging technique. The system used ASP.NET, C# to match entities of crops. XML was used for building system ontology. Here, ontology based information retrieval systems helps farmers by retrieving and integrating several information together to meet the information requirement of the queries. Precise user context information is provided to farmers with the help of a specific ontology [10]. Xiangyu HU et al. developed IOT application which embedded IOT-Radio Frequency identification, GPS and smart sensors used to transfer information from the field. The information was recorded using RFID and sensors are used to monitor the field. CGM modules are used to provide intelligence to the system [11]. Richard K. Lomotey et al. proposed a reliable distributed mobile architecture to provide farmers timely information. The proposed architecture was on the spray quality app from multifarmland perspective by constructing a three layered architecture with cloud hosted middleware. The above mentioned design enables farmers to access various information via Wi-Fi or 3G [2]. Ontology based application have serious drawbacks also. It mainly concentrates in developing a knowledge base to answer queries but failing to represent the full extension web semantics that can be used for the current domain.

Sanjay Chaudhary et al. presented an advisory system for cotton crop using cotton ontology, web services and Mobile Application Development Advisory system. Domain knowledge is maintained for answering farmer queries. The Architecture of the system includes five major components, the SQL database which holds the static information, the RDF knowledge contains data on cotton concepts, geographic data includes mapping the field in google earth or Carto DB and the RESTful services take care of the remaining components. There are several existing advisory systems developed in agriculture domain which includes: eSagu that incorporates advice from experts to improve farm yield and productivity. Agrisnet is web portal which provides appropriate knowledge about seeds, fertilisers with the help of scalable data bank. In KKP, the Karshaka Information Systems encloses info's on crop growth, market price and availability with general statistics. mKrishi is a mobile application helping farmers with visual and audio means to clear their queries of farmers. [7]

The systems developed in IOT and Cloud Computing emphasizes on reliable architectures to provide farmers timely information from the field over 3G or Wi-Fi. Offline communications are enabled over Bluetooth between farmers (Richard K. Lomotey, R. D., 2014). The developed systems intelligence is enhanced by a considerable margin by incorporating CGM modules over IOT. Use of sensors in applications of Cloud Computing and IOT are reliable but cumbersome to install, which makes it a major concern for the same. Relying heavily on technology like GPRS, GPS, 3G, Wi-Fi and etc., can be disastrous in the event of unforeseen crash. The above mentioned disadvantages make a serious setback in resolving the current challenging scenarios of the rural people in agriculture sector.

Nomenclature

ET_0	Reference Crop Evapotranspiration
T_{max}	Maximum Temperature of the day
T_{min}	Minimum Temperature of the day
T_{mean}	Mean Temperature of the day
R_{av}	Mean Sun-Earth Distance
R	Actual Sun-Earth Distance
K_c	Crop Factor
SAT	Saturation of Root Zone
PESE	Amount of Percolation and Seepage Losses
WN	Water Need
WLayer	Water needs to establish water layer
effR	Effective Rainfall
H	No. of Hours
D	No. of days

3. System design and Realization:

Data collection, monitoring and evaluation of the system results in determining which approach is effective and where these adaptations are most needed. Therefore, ICT engaged interventions in agricultural sector are more productive than the conventional methods. Technical and financial aids are vital need for the farmers to become adapt inclusive and effective method. These challenges can be addressed by ICT based information dissemination models to share knowledge improving productivity, social and environmental sustainability of farmer and farmer communities. The main sections of the architecture illustrated as knowledge base and monitoring system. Here, the main sections are elucidated in brief.

3.1. Knowledge base:

Knowledge Base is constructed to store vast complex structured and unstructured information to assist farmers or even an individual with no prior knowledge of farming. But finding right information in an appropriate manner is difficult where providing relevant knowledge should be distributed not only in an organised and complete manner, but also in absolute way. The knowledge based infrastructure allows adapting the changes in agriculture for a better extension and adding advisory services.

3.1.1. Realized Inputs:

Knowledge base contains information modules about farming techniques, market information, Crop structure and geospatial data. Farming techniques include the best practices in farming to attain maximum yield and comprises of pest and disease controls added with phase based farming methods. Market information include various cost info’s, sellers, dealers, warehouses, funds, credits, dedicated website, call centres, E-learning and market availability. Crop structure encompasses information about crop breed, crop factors, pest, disease information and soil nutrient requirements. The geospatial data is used to import the weather details and water table content helping farmers choosing their best suitable crop. It is also used for setting Field Map according to the location set by the farmer.

3.1.2. Knowledge acquisition:

Knowledge acquisition primarily refers to the process of obtaining, analysing, comprehending, and recalling information through the best of many existing reliable methods. Here, knowledge is acquired from reliable sources by establishing a model integrating farmers, agriculture agencies, Ministry of agriculture, Agricultural Universities and institutions along with Rest API services.

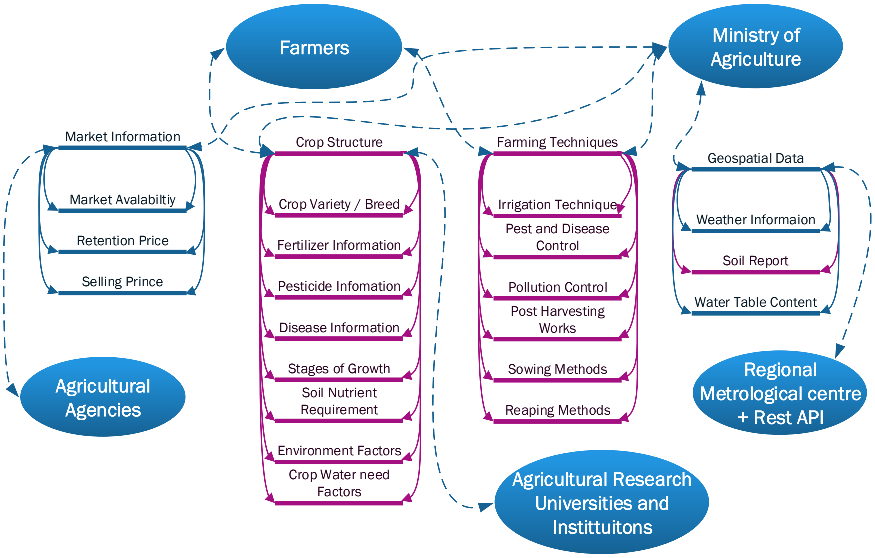

Fig 1. Knowledge acquisition model comprising crop structure.

3.1.3. Knowledge flow:

Crop Data Flow model is used for representing knowledge flow in a conceptualised network and to provide optimal information for adapting the changing climatic condition. The data flow module explains how the data flows from one module to another and it as well as explains how each module are interconnected. Fig. 2. depicts the working flow of the developed system at various phases.

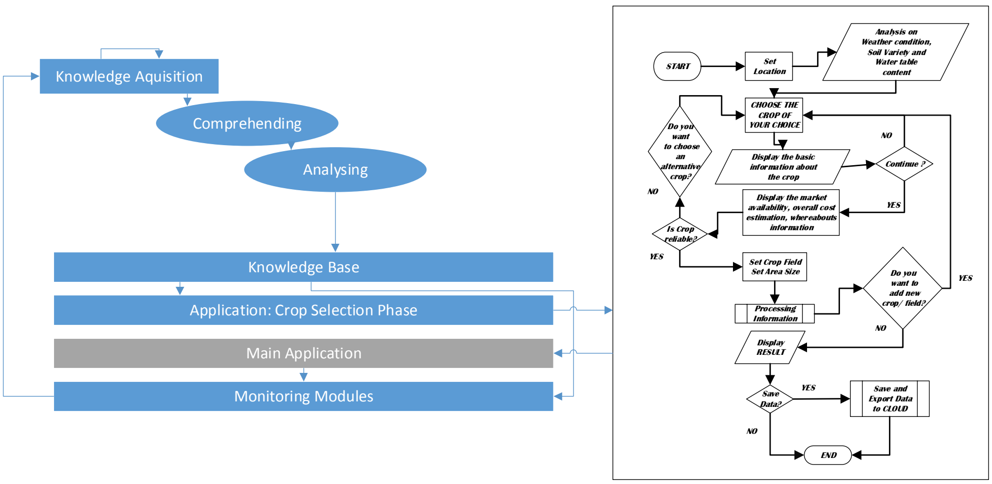

Fig 2. Knowledge flow model of the Application

3.2. Monitoring Interface:

3.2.1. Hardware Requirements:

TI CC3200 Launchpad and Arduino UNO board with Ethernet Shield is used to implement the monitoring modules. The following sensors and other peripherals are used to collect real time data from the field:

- DHT11 Temperature and Humidity Sensor.
- Soil Moisture Senor (KG003) - Output is high when there is deficit in soil moisture (i.e the field is dry), or output is low. Analog interfacing can be used for accurate output.
- Ball float liquid level Sensor-Output is according to liquid level or ball raise.
- Magnetic Float Sensor for water level indicator- The float sensor is a device used to detect the level of liquid in the tank. Float sensor is an electromagnetic ON/OFF switch.
- BH1750 Module Digital Light intensity Sensor / LDR resistor.
- A Four Channel Relay Board (5V) for switching AC/DC is used to trigger a AC motor (220V) to operate the valves.
- L293D H Bridge (Wide Supply-Voltage Range: 4.5 V to 36 V) which is a typical motor driver that allows DC motor to drive on either direction.

3.2.2. Software Requirements:

Energia MT is an open-source electronics prototyping platform which is a modified version of wiring/Arduino IDE for the Texas Instruments is used to write embedded c code, compile and execute them.

1.6.8, an Arduino programming environment is used for writing code in the Arduino programming language to instruct the Arduino.

Blynk is a Platform with iOS and Android apps to control Arduino, Raspberry Pi and the likes over the Internet. It's a digital dashboard where a graphic interface for any project can be built by simply dragging and dropping widgets.

3.2.3. System Architecture:

Modules of Monitoring Interface:

The Monitoring phase comprises of application’s main abilities and functions. From the knowledge base, the user interface is allowed to use decision making system, knowledge assessment on farming, and other systems.

- Reminder: It is used to remind the farmer on the schedules of reaping, fertilizer spraying, pesticides, and on irrigation timings. It notifies the user on daily basis based on the input parameters from the knowledge base through an automated SMS notification.

- Monitoring Plant Growth: The stages of growth from the knowledge base is used to calculate the corresponding phase of growth. The height of the plant is found out using the mapping outline image of that plant and this height is used to predict whether the plant is meeting the requirement or not.

- Irrigation Planner: It makes a set of plans to irrigate various section of field in a pattern to get profitable yield. It also displays the information from field as dry and irrigated fields as monitoring prospect. Based on the estimation of crop water need, rotational or continuous flow is planned to irrigate the field.

- Crop Profit Calculator: It is used to calculate profit for the farmer by giving inputs on year of growth, selling and retention price.

- Calamities check: The irrigation plan and the field set is changed according to the weather forecast which is acquired from Yahoo weather API. It is also used to monitor unusual activities in the field like immediate firing, etc.

- Problem Identifier: This identifies the problem when there is misdirection in irrigation system, motor problem. It approximately identifies where the problem has occurred. For example, in the case of no power supply, there is no use of giving commands to the peripherals whereas the user should be notified about the power problem.

- Calculation of Water need: The amount of water need for meeting water dissipation through evaporation and transpiration is defined the crop water need (ET_c). The crop water need is subjected for a uniform crop, disease free, active having favourable soil conditions. Shortly, Evapotranspiration estimates the total amount of water plants consume for a quality growth corresponding to the local weather condition and phase of the plant cycle [3].

  Algorithm framed for estimating water need [4]:

  1. Calculate ET_0:
  Here, Hargreaves and Samani (1985) evapotranspiration equation is used to calculate the ETo:
  $$ETo = 0.0023 * \sqrt{(tmax - tmin)} * (tmean + 17.8) * ExTR;$$
  Calculating Extra-terrestrial radiation [5]:
  $$ExTR = 1367 * (Rav / R)2$$
  $$(Rav / R)2 = 1.00011 + 0.034221 * cos(o) + 0.001280 * sin(o) + 0.000719 * cos(2o) + 0.000077 * sin(2o);$$
  o = 2πn / 365 radians.

  2. Crop Factor is to be determined (Kc) based on the stages of the growth.
  3. Et(crop)= ET_o*Kc.
  4. Calculate SAR (H2O to Saturate the root Zone).
  5. Amount of percolation and seepage losses (PESE) based on the soil type is to be determined.
  6. Determine the amount of water needed to establish a water layer: WLayer based on the stages of the growth.
  7. Calculate Effective rainfall of the region based on annual rainfall. (effR)
  8. Calculate Crop water need: $WN = Etcrop + SAR + PESE + WLayer - effR.$
  9. Calculate Continuous Flow and Rotational Flow.
  $$Contflow = (WN/8.64) * hectaresize.$$
  $$Rotflow = (24/H) * (7/D) * contflow.$$

- Optic Monitor: Sunlight is the perfect balance of wavelengths necessary for plant growth, but use artificial light can also be used to help plants along. Grow lights are used to stimulate plant growth where there is no sufficient sunlight or in places where daylight hours are less. This application is mainly used in winter regions/months to enhance the plant growth. Here, the daylight is monitored by Light Intensity Sensor and when it goes below the threshold value, the supplemented light is used to stimulate the plant growth.

- Well Dry Check: This module is used to check whether the well is dry by getting the input from the soil moisture sensor node, it notifies the user when the value goes below the threshold limit and the user can respond for which corresponding action can be performed like filling the well by turning on the motor.

- Field Dry Check: Similar to the last module it uses soil moisture sensor node, that notifies the user whether the field is dry or not.

- Identify the soil type and soil deficiency: Every soil has its own water holding capacity. On comparing the real time data with predefined sets of values in the knowledge base, soil type can be identified and if the calculated soil capacity differs to a larger extent from the predefined data then it can be said, the soil is deficient.

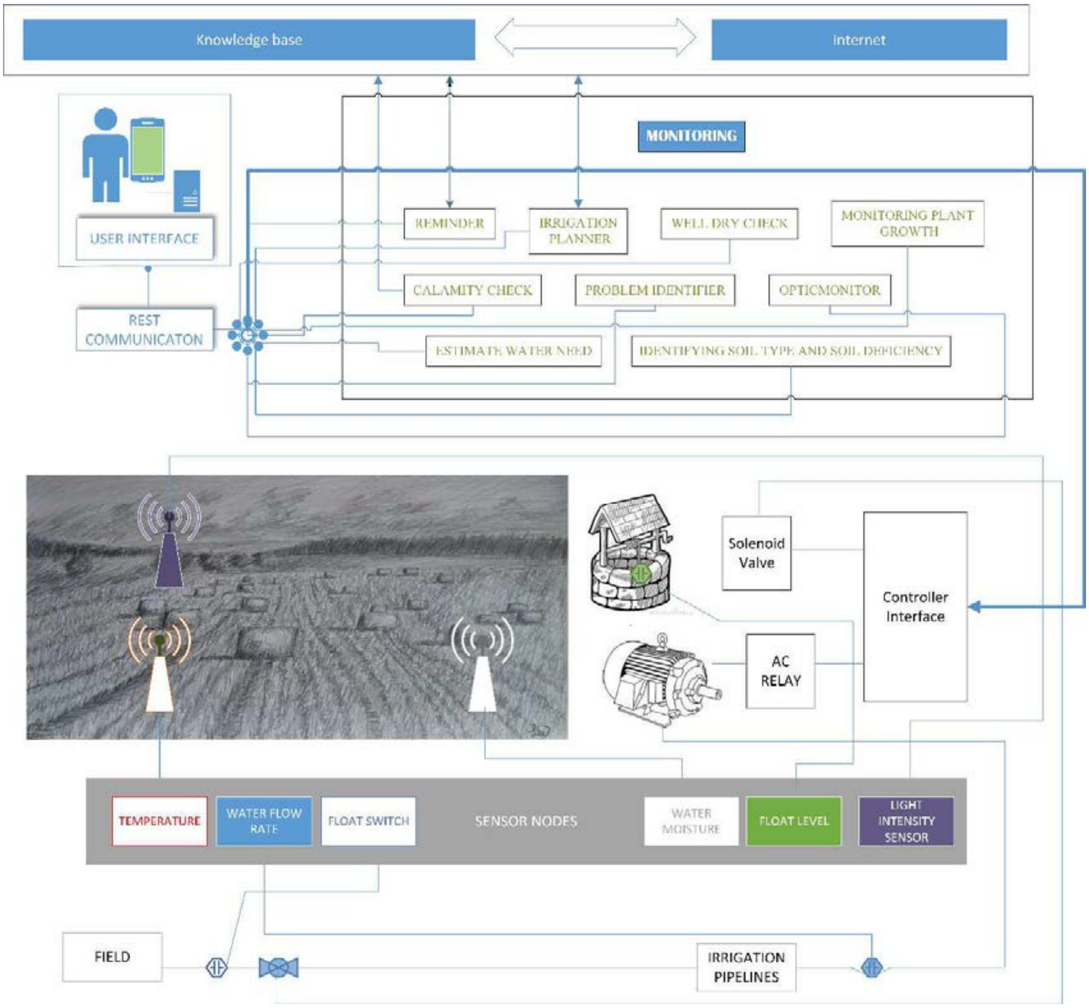

Fig 3. Architecture of e-Agriculture Monitoring module

4. Discussions:

As discussed in Background section, Internet of Things based developed systems are not reliable due to reliance of 3g or Wi-Fi communication modules. Search enquires are not helpful to that extent because it is unable to cope up with farmer's poor knowledge and also these are developed to serve particular group crop or region. In the case of user centered ontology, only a set of farmers of that context can gain knowledge whereas it cannot provide all necessary information. Advisory system lacks the procedure oriented approach and cannot construct the complete ridge between farmers and computers. It needs a group of experts working behind to answer the farmers' queries. Here the proposed system overcomes constraints as the automation of this system is programmed to function even in offline mode also. The system can be easily rebuilt or replaced in the worst case scenarios. In the traditional farming methods, water need is not constrained. But the system overcomes the setbacks by calculating the water need using Evapotranspiration which reduces the water usage. The framework designed, instructs the farmers to carry out activities in regular intervals based on the crop life cycle by replacing the existing systems like KB Management, Advisory and Expert Knowledge Systems. Here, a comparative study has been made which discusses about various system's cons and pros [6,7,8,9].

Table 1. Comparative study between developed and existing systems.

	KM-System	Agro Advisory System	Expert Knowledge System	Agricultural Information Retrieval System	Knowledge Management System Development	IOT Monitoring System
Knowledge Base	This contains crop parameters like crop and field details acquired from various sources	Its design is based on the advices needs to be given to the farmer	Knowledge repository was created supporting first order logic to solve the complex nature of the concepts	Knowledge base was created as to retrieve or extract information from the web.	Knowledge base is designed in such a way that can evaluate user centered context.	Monitoring systems include knowledge about geospatial information.
Group of people working behind	No	Yes	No	No	No	No
Monitoring System	The field is monitored real time based on the knowledge base to increase the yield and reduce man power.	No	No	No	No	The system is designed in such a way to reduce man power.
Technique Used	IOT and Cloud Computing.			Semantic web retrieval.		IOT
Efficiency and Reliability	More efficient because offline monitoring is also possible.	Reliable since people working behind the system.	Not reliable because, it can't serve to farmer's knowledge.		Efficient to provide all knowledge on user centred.	The more we dependent on the internet cloud leads to a more catastrophic event when it crashes.
Disadvantages		Advisory systems lack the procedure oriented approach. It can't build the complete bridge between farmers and computers. It needs an expert group of people working behind to answer the queries.	Search queries help the farmers to get the desired result and it is not sure of the intensity of the result.	Multi Matching retrieval process is difficult.	It also developed on user centered which suits only for a particular set of farmers which are categorized on a subject like over crops or region.	It increases greater complexity by over reliance of technology like GPRS, GPS, 3G, Wi-Fi and others. Next hurdle is downtime of cloud is possible.

5. Conclusion:

Farmers need help during different stages of crop growth and the guidance should be given at the right time. Farmers are suffering a lot economically, socially and politically. Various challenges in agricultural domain are identified and an architecture was framed meeting the above mentioned challenges. Knowledge base is structured with various crop details which speak about knowledge acquisition, flow, various input like market availability, geospatial data and weather prediction. Monitoring contains modules like remainder, monitoring plant growth in various stages, irrigation planner, crop profit calculator, calamity check and problem identifier. Evapotranspiration method is used to calculate the water need of a plant per day with devised algorithm's help. A comparative study was made between various application available with current developed system taking various aspects into account like knowledge base, monitoring modules, efficiency and reliability.

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