InFEvoS: Integrated Farming Evolution System

Tajinder Singh Sondhi, Awari Renuka Sambhaji, Sharmila Banu K

Abstract**:** ***In this work, we intend to propose a monitoring and expert support system, called InFEvoS (short for, Integrated Farming Evolution System), for increasing agricultural productivity by boosting resource utilization and assisting the backward section of farmers, with knowledge on better farming techniques. Our system accounts for different crop, soil, climate types, etc. and is scalable and sustainable, which was a big challenge. InFEvoS overcomes most of the drawbacks current systems encounter, especially scalability, and versatility.***

Index Terms**:** ***Agriculture, Precision Farming, Rural development, Internet of Things, Expert System.***

I. INTRODUCTION

Farming is one of the most traditional occupation in India. It is being practiced in India since the Indus Valley Civilization, which was nearly 2500 years ago. India is the second largest producer of agricultural products in the world and now is slowly getting converted into industrial farming from traditional one. Currently, the share of agriculture in India is about 6 to10 % (which keeps on varying) in the GDP of the nation. Due to no proper technologies in irrigation and less pass on of knowledge from one generation to other, India is experiencing downfall of the productivity in farming.

Though recently, the production of commercial crops has been increased and the farmers who have started using smart farming for commercial farming have become rich, but the majority of farmers (more than 60% population of the nation who contribute to farming) have no knowledge about it.

There are a large number of organic farms but all of them are struggling. Because the techniques have vanished with time and people have no idea about what smart farming is. And because of lack of knowledge, and less income, the farmers have started to give up farming. The rate of farm crisis has increased to 76%.

We did a survey of existing solutions to summarize what kind of issues different approaches face.

Merging Internet of Things with Agriculture is a quite popular technique. But there are various factors and approaches to this that make every attempt different. Jhao J. C. et. al. [1] proposed integration of control networks with information networks for IoT along with a remote monitoring system which utilizes the internet and wireless communications. Their data collection is aided by an information management system. Yan-e D [2] mentions the information management system as an important sub-technology of AIT (Agricultural Information Technology). Thus he gave a wider view to the information management system in his work. Jayaraman, P. P. et. al. [3] further enhance information management system by adding semantic enhancements, using an ontology, for better query processing and search optimization. It uses Phenonet-OpenloT Architecture. TongKe, F. [4] proposes an agricultural information cloud, where recorded data is processed, accessed, read and written via cloud itself. A User Interface enables access to this data which was recorded wirelessly. Nandyala C. S. et. al. [5] emphasize on energy efficient approach through GAHA (Green IoT Agriculture and Healthcare Application) which uses green clouds for computation. Baranwal, T. et. al. [6] have developed a monitoring system but instead of growth monitoring systems like others, this one is a security system which monitors pest, rodent, insect attacks. Thus the architecture is quite similar, but the type of sensors used, and their purpose is different than other systems.

With more and more advancements in technology in agriculture, the term 'precision farming' came into existence. Stafford, J. V. [7] showed us how precision agriculture is implemented in the 21st century, with the assistance of new sensors and satellite-based weather and terrain track. Gebbers, R. et. al. [8] have shown how to optimize production by combining sensors, information systems, enhanced machinery, and informed management, along with a case study on African Green Revolution. Pierce F. J. et. al. [9] suggests basic components of precision farming can be classified into two major divisions namely, the enabling technologies (computers, geographic information systems, global positioning systems, sensors, application control), and steps in precision agriculture (assessing variability, managing variability, evaluation of precision agriculture). Zhang, N. et. al. [10] gave an overview of worldwide development and status of precision agriculture technologies and aspects like natural-resource variability; variability management; management zone; impact of precision-agriculture technologies; etc. Baggio A. [11] presented the setup of the Lofar Agro project that concentrated on monitoring micro-climates in the crop field and gathered statistics on the wireless sensor network too for simulations. Adamchuk V. I. et. al. [12] provided us with information about the variability of different soil attributes within a field. These are essential for the decision making processes to increase the overall profit made from production of crop, improve product quality, and protect the environment.

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Water is a precious resource. Using water wisely with minimum wastage can have a significant impact on agricultural productivity. This can be achieved by choosing the appropriate irrigation method for the respective crop. Marouelli W. A. et. al. [13] tested sprinkler and drip irrigation in the organic tomato for single crops and when intercropped with coriander and found some interesting results which will help us grow coriander better in our project. They recommend sprinkler irrigation during the initial phase of coriander production in order to improve germination rather than drip irrigation and get a better yield. Agrawal N. et. al. [14] developed a smart drip irrigation system but one of its drawbacks is, it is expensive because of the Raspberry Pi and ZigBee used. However, Polak P. et. al. [15] propose an extremely cheap way to make a drip irrigation system, but it is not smart. We are going to infuse these two and make our own low-cost smart drip irrigation system, to conserve water.

Use of sensors for remote monitoring also requires a power source. Since units are wireless, we chose Solar energy for power as it is clean and available in abundant. This is evident from the works of Somov A. [16]. This idea is also supported by Haight R. et. al. [17] who mentioned how photovoltaics could power sensors inside building and in the environment. Since our approach is marginally different, we intend to use power distribution and charging circuits along with the solar panels.

Once the data is collected and stored, it is followed by analytics and decision making which is one of the most important parts of our system. These tasks are usually performed by what we call the "expert systems". Liao, S. H. [18] mentioned different types of expert systems, along with their methodologies and applications, observed over a decade from 1995 to 2004. These specific to only agriculture were elaborated by Jones P [19] in his work. Plant R. E. [20] developed project CALEX. A general purpose shell program that, when coupled with domain-specific program modules, provides a software package that can be used by consultants, growers, pest control advisors, and other managers for overall agricultural management decision support. Yialouris, C. P. et. al. [21] developed an expert system for detecting tomato diseases. It contained data and inference rules in the form tables making it efficient to store, build relations, classify and operate on. Harrison, S. R. [22] proposed several metrics for validation of an agricultural expert system. We have information on how to generate test cases and have different tests for subjective validation, statistical tests, appropriateness aspect tests, sensitivity analysis, etc.

In this era of deep learning, people have tried again and again to imitate human intelligence in machines, by trying different approaches. Krupakar H. et. al. [22] focused on reviewing the computational methods used to determine Evapotranspiration and its implications. They compared the efficiencies of several different data mining and machine learning methods. Kamilaris A. et. al. [24] proposed a survey of 40 research efforts that employ deep learning techniques, applied to various agricultural and food production challenges, and compare and contrast them on the basis of the specific models and frameworks employed, the sources, nature and pre-processing of data used, and the overall performance. Time Series Analysis using Recurrent Neural Networks is a powerful approach to predict patterns, as mentioned by Zhu N. et. al. [25], and has been used in many agricultural areas, such as land cover classification, weather prediction, soil moisture estimation, etc.

The main problems (gaps) identified from the survey are:

- Many approaches enhance one or two aspects of farming, but are unable to address all.
- The environments for performing experiments were rigid.
- Rigid environments led to the solutions applicable only those specific conditions.
- Inflexible approaches reduce scalability.
- Many efficient solutions proposed aren't economically viable.
- More inclination towards automation rather than assisting farmer.
- Decision systems do not consider the present scenario but use historical data.

To solve these issues, and present a generic affordable, scalable, sustain-able, all-purpose solution, we propose the InFEvoS (Integrated Farming Evolution System), which combines positive features of several smart farming techniques and try to overcome their drawbacks.

II. PROPOSED INFEVOS SETUP

Network and Cloud Model

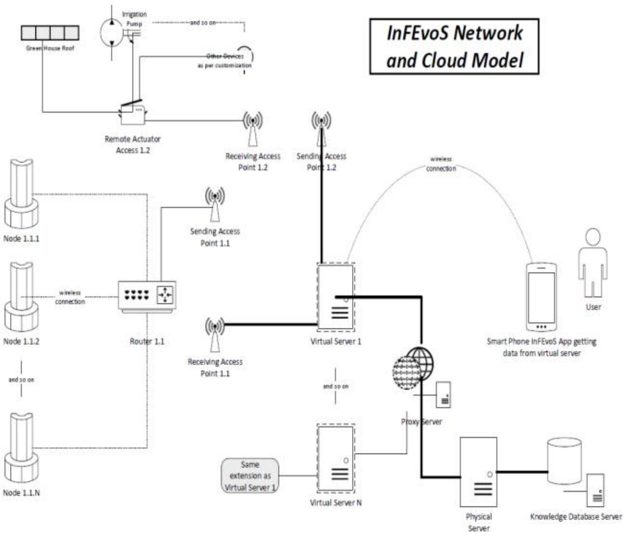

Fig. 1 InFEvoS Network and Cloud Model

Fig. 1 demonstrates the InFEvoS Network and Cloud Model, where each and every 'Node' of the Wireless Sensor Network (WSN) is connected to a router, which further connects it to the Internet. These Nodes, collect data and send them to their corresponding Virtual Server Instance, sharing common Physical server. The role of the Proxy server here is to hide the actual physical server in order to prevent cyber-attacks. The Virtual Server does the job of regulating and managing information and resources. It records all data from sensors in real-time, them summarizes them. This Summary is then cross-validated

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with 'Field Rules' provided by Physical server through the Proxy server and 'Field Knowledge' provided by Knowledge Database Server. The process output is then executed by informing the farmer the corresponding information and sending action details to the Remote Actuator Access. For example, if moisture levels are lower than required values for a particular crop, sown in a specific soil type, under specific circumstances, then evaluate for how much time and with how much water the plants should the plants be irrigated, then inform farmer on smartphone app, about this irrigation event and activate pump from remote actuator access.

The hierarchical naming structure of (Virtual Server Instance).(Sending/Receiving Access Point).(Node Number) enables to keep track of each and every single Node and its flow of information, to the server. Similarly, (Virtual Server Instance).(Sending/Receiving Access Point).(Device Number on Remote Actuator Access) enables remote controlling of several other farming peripheral devices, as per need.

Node Design and Physical Server

In Fig. 2, the Node Design is presented with 5 main sub-modules. Since each Node is operated wirelessly and is an independent functional unit, it is important to see if we account for all failures. The main part of the Node is the NodeMCU, which is a S.O.C. micro-controller with the ESP8266 Wi-Fi module. Presently, the NodeMCU is low-power 3.3V operated but the sensors are 5V operated, thus to rectify this, we have voltage boosting circuits.

Powering these Nodes wirelessly is achieved by making use of freely available natural solar energy. Solar panels power Node and charge battery during the day time, via charging circuit. This charged battery becomes the power source during the night time for the Node. Sensors record reading that the NodeMCU interprets and transmits. There is a wide variety of combinations of sensors to choose from which vary as per requirement, thus there will of different models on these "Nodes", with different combinations of these 5 major sub-modules.

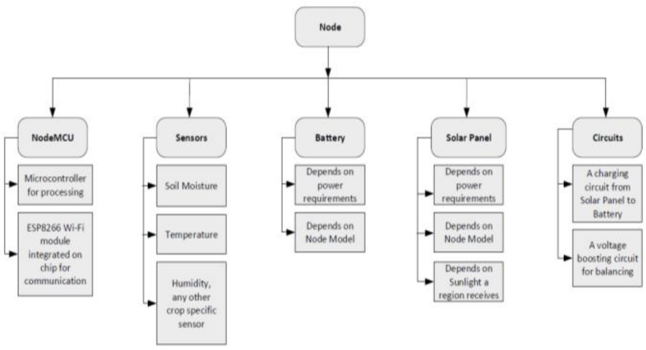

Fig. 2 Node Design

The Physical Server is the one which keeps track of rules of farming which are associated. For each query of Virtual Server, via a Proxy server, which asks 'is the current trend summary normal or some action is needed', the Physical server runs a set of rules derived from the expertise of humans in the field of agriculture. Then responds with a generic action (eg: watering is required), which is made specific by the Virtual server as it contains user specific details (eg: how much to water). The rules are processed in a hierarchical nested fashion, very similar to how data is arranged in the Knowledge Database Server. This makes responses highly efficient. To further boost the speed, multi-threading can be implemented for each user in a virtual server instance.

Knowledge Database Server Design and Example Result

This was the most challenging part of our research. A conventional database approach where we have a two-dimensional table with a lot of joins with other tables is not at all appropriate for such a dynamic system with so many parameters to handle.

For instance:

1. Region
   a. Area Polygon Tuples
      i. Point 1
         1. Longitude
            a. …
         2. Latitude
            a. …
      ii. …
   b. …
2. Time
   a. GMT
      i. Year
         1. …
      ii. Hour
         1. …
      iii. …
   b. …
3. Climate
   a. Avg. Daylight
      i. …
   b. Temperature
      i. …
   c. Humidity
      i. …
   d. …
4. Soil
   a. Texture
      i. …
   b. Type
      i. …
   c. Macro-nutrient levels
      i. Nitrogen
         1. Max
            a. …
         2. Min
            a. …
      ii. …
   d. Micro-nutrients
      i. …
   e. …
5. Crop
   a. Crop Name (scientific)
      i. Variety
         1. …
      ii. …
   b. Crop Name (local)
      i. …
   c. …
6. Inter-Crop
   a. Main Crop Name (scientific)
      i. Variety
         1. Inter-Crop 1
            a. …
         2. …
   b. …

Fig. 3 Multi-Dimensional Database Design

There are 6 major dimensions to handle, which is constructed with a linked chain-like nested data structure. They are: Region, Time, Climate, Soil, Crop and Inter-Crop, in order. The order is important as it increases specificity and reduces the variability of precise farming related information need in the fastest possible way. Each dimension has its own parameters (like columns of a table) in a highly nested fashion. A sample instance structure is given in Fig. 3.

Getting the right settings would involve, fetching a right point in this hierarchically nested 6 dimensional space. This ensures all the possible situations have been covered and the retrieval process is also fast and durable. Adding new information to this structure is also convenient. All these make such a design fit for our purpose, and offers way more flexibility than the conventional database.

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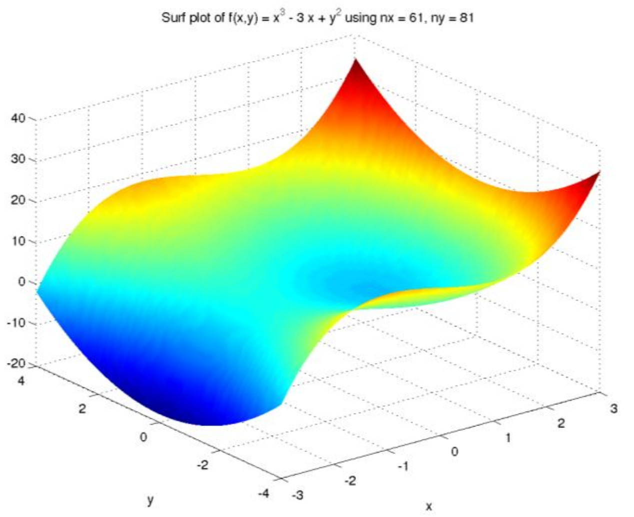

Fig. 4 Surface Plot 3D

For simple understanding, we demonstrate by taking example of a 3D space which would be easy to visualize, as shown in Fig. 4. So in a 3D surface plot, all of the variables X, Y, Z are inter-linked to each other through a constraint (a surface function). Because of this constraint, for a point, if a parameter varies (say X), then since the point moves only on the surface and cannot leave it, both Y and Z might vary together because of it. In higher dimensional data, which are inter-linked, this functional constraint that changes other values too is extremely useful, especially for the field of agriculture. This would enable expert systems to suggest decisions which are based on conclusions derived from checking far more factors than before.

III. CONCLUSION

Our proposed system has following advantages and benefits:

- Increased agricultural productivity with the help of technology.
- An architecture, generic enough to fit most crop, soil and climate types.
- The architecture is scalable and sustainable.
- Assist farmer with real-time insights of cropping trends based on recorded data, via InFEvoS smart phone app.
- Achieve better resource utilization by reducing resource wastage, especially of water, by automated irrigation.
- Aid expert system decision making severely by using constraint based multi-dimensional database architecture.

InFEvoS has several useful possible applications and there are many open ends to the architecture. More advanced technology found in near future can be integrated easily. Load balancing on virtual servers and optimized codes can give a severe performance boost for a real-time system like InFEvoS. Over-all, this system better, beneficial, smart, durable and productive.

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