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FRMA: Farming Resource Management and Analysis

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Abstract—Internet of Things with Cloud technology and Machine Learning with Big Data capabilities have emerged to help us improve productivity in agriculture. We review works which have carried out research on these technologies being applied to farming and their impact on agriculture. The works have been analyzed and categorized into the following categories (a) Internet of Things in intelligent farming; (b) Machine Learning in intelligent farming; (c) Applications of compound technologies in intelligent farming. The works reviewed will give the reader a comprehensive idea about how Internet of Things devices and Machine Learning are improving agricultural productivity and farm management. Machine learning algorithms process the data being collected by sensors to help solve many problems faced by farmers.

Index Terms—Intelligent farming, Digital agriculture, IoT, Machine Learning, Yield Prediction, Disease Detection, Cloud

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1. INTRODUCTION

Agriculture continues to employ over one billion people around the world. Its significance lies in the fact that everyone is a consumer of agriculture and farming, irrespective of whether one is employed in the sector or not. Despite this significance, globally, crop produce is not enough to sustain many in developing or underdeveloped nations. Therefore, consistent efforts are being taken to improve farm productivity and increase effort and resource efficiencies to maximize produce. Key players in recent advancements of farming technology include Internet of Things (IoT) and Machine Learning (ML), usually coupled together with cloud computing and big data frameworks. IoT can be described as a system of interconnected devices and objects, which can provide with unique identifiers transfer information over a network without any kind of human intervention. Moreover, in farming, it refers to a set of connected sensors, which are in turn connected to a controller, with the objective of collecting necessary data [1-3]. There are various sensors to collect data like temperature, pH, moisture etc. Machine Learning, on the other hand, refers to training machines to infer patterns and make predictions from large amount of data. Various ML algorithms exist to solve problems like distinguishing crops from weeds [4], predicting amount of fertilizers and pesticides to enhance efficiency in smart farming [5], irrigation management and decision support systems [6] etc.

While both these technologies often work hand-in-hand, specific configurations for any given farming depends mostly on the application of the technology. IoT plays a smaller role while ML and Machine Vision become essential components when the farmer wishes to distinguish between crops and weeds [4], ripe and unripe fruits [7] or diseased and healthy plants [8]. Alternatively, IoT plays a bigger role in cases where the farmer wishes to monitor all farm-related parameters [9].

In this paper, we provide an all-inclusive analysis of smart farming with latest technology. The first section covers research carried out which focused on IoT in smart farming, the second section covers research focused on ML in smart farming, the third section covers research in different applications of smart-farming and the final section provides some insight into the advantages of using technology in farming.

2. LITERATURE REVIEW

2.1 IoT in Intelligent Farming

Internet of Things has been drastically changing the face of modern agriculture Farmers across the globe have been using it to reduce waste and improve productivity of their crops [10]. Agriculture, in the past decade, has become more technology-driven and industrialized. Farmers are now shifting from the traditional farming practices to smart-farming, a phenomenon which utilizes modern ICT (Information and Communication Technologies) to improve crop quality and operational efficiency of agricultural farms [14]. The basic of an IoT based smart farming system is monitoring via multiple sensors and automation of multiple aspects of the same.

Across agricultural farms, farmers have been adapting to install sensors, and use them to measure a wide set of variables, like temperature, humidity, rainfall etc. Coupled with cloud-based monitoring and data management, farmer are now enabled to carry out smart analysis and planning for their crops, which leads to efficient usage of resources, along with increased output [13]. To effectively integrate IoT into everyday farming practices, there are some components, which have to be considered, for the Agri-IoT framework:

1. **Data Wrapper:** This module provides the user with a generic methodology to describe the characteristics of the sensory metadata and parsed sensory data.

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2. **Discovery Module:** This module ensures scalable integration and registration of all the devices and services in real-time. These devices can either be located in the same physical space or can be accessed from remote locations as well.

3. **Data Aggregation:** This module utilizes the concept of time series analysis and data compression techniques to reduce the size of the data received through raw sensory observations.

4. **Data Federation:** As the name suggests, it is the interface between the sensors, processing units and the users, providing them with necessary and legible details. This module locates the relevant stream of information, translates them into RDF Stream Processing (RSP) queries, evaluating them to answer the users' queries.

5. **Knowledge Base:** This module provides the user with sensory data, accumulated from the sensors across the agricultural farm(s).

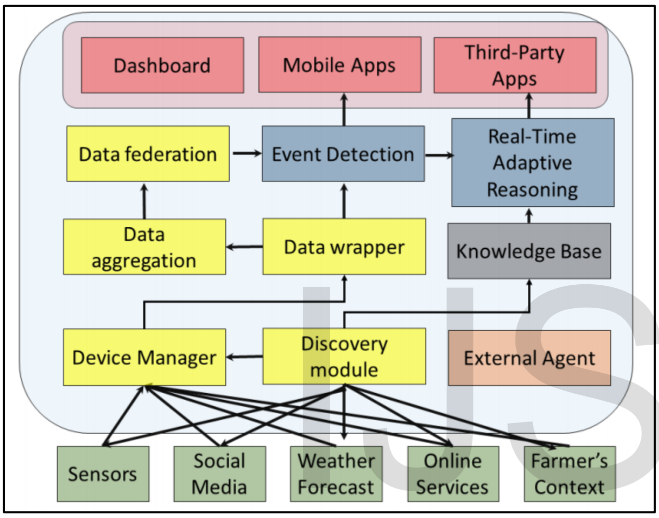

Figure-1: Agri-IoT Framework [12]

These are some of the components of the proposed Agri-IoT framework. A cohesive and systematic architecture of the framework will allow for maximized operational efficiency and output. Some of the advantages of using IoT in agricultural practices are:

1. Efficient water management.

2. Continuous land monitoring.

3. Effective crop monitoring.

4. Increase in crop sales in global markets, due to better health of crops.

5. Increased productivity, reduced manual work, and efficient farming.

2.2 Machine Learning in Intelligent Farming

Data in ML generally a stockpile of cases. Generally, an individual case can be described by using one of the following feature(s):
1. Nominal (enumeration)
2. Binary (**i.e.** 0 or 1)
3. Ordinal (**e.g.** A+ or B−)
4. Numeric (integer, real numbers etc.)

The performance of a*ny ML model or algorithm can be* measured by using any performance metric, which utilizes multiple mathematical and statistical models. Towards the end of the learning process, the trained model is used to classify, predict, or cluster new examples (testing data), from using theknowledge which has been obtained from the training process.
ML encompasses many dif*ferent types of algorithms like* supervised, unsupervised and reinforcement learning. Each category of algorithms has multiple algorithms. The most common ones have been elucidated below.

Regression: It is defined as a supervised learning model which predicts the value of a dependent variable according to the independent variables. There are many types of regression algorithms: 1) Linear regression; 2) Logistic regression [17]; 3) Ordinary least squares regression [18] are most used. Regression can easily predict the crop yield given farm, soil and weather parameters -[19] where the aim has been to find indicators about a field's heterogeneity, which were best-suited to be used for the task of yield prediction.The sub-task was one of multidimensional regression – predicting yield from the past and in-season attributes. Another study [20] compared the performance of four different regression models in soil organic carbon (**OC**), total Nitrogen (**TN**) and moisture content (**MC**) prediction. The soil samples in question were collected from a field situated in Premslin, Germany, dated August 2013, right after the harvest of wheat. The authors carried out the process of regression on the collected data and concluded upon the accurate prediction of soil properties that can optimize soil management.

3. APPLICATIONS IN INTELLIGENT FARMING

Smart or intelligent farming spans over multiple smaller applications of compound IoT and ML technologies such as yield prediction, plant disease detection, produce grading and segmenting, and optimizing farm parameters.

3.1**Yield Prediction:** Predicting the yield from a farm land has a lot of significance. While it can help farmers plan their livelihoods and their future course of action, it can also help governments or agriculture-related bodies to grade farms, keep logs on individual yields, and help them decide better on which farmers to provide with assistance or waivers.

A Fuzzy Cognitive Map (**FCM**) model was developed by the authors of [22], which consisted of nodes which have been linked by directed edges, where the nodes represents the primary factors in cotton crop production in consideration, such as soil. texture, organic matter, pH, soil nutrients like K, P, Mg, N, Ca, Na and cotton yield, and the directed edges demonstrated the cause–effect relationship between the properties of the soil and the cotton field indicators. The proposed method has been analysed for over 360 cases, considered for over three years (2001, 2003 and 2006) in a 5 ha experimental cotton yield.

The achieved success rates of 75.55%, 68.86% and 71.32%, respectively for the years referred, in estimating/predicting the yield between two possible categories (low and high). In another study [23], authors compared the performance of counter-propagation artificial neural networks (CP-ANNs), Supervised Kohonen Networks

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(SKNs) and XY-fused Networks (XY-Fs) for predicting the yield of wheat, from a 22 ha field located in Bedfordshire, UK. The study was carried out for a single cropping season. The overall accuracy calculated for SKN was 81.65%, for CP-ANN 78.3% and for XY-F 80.92%.

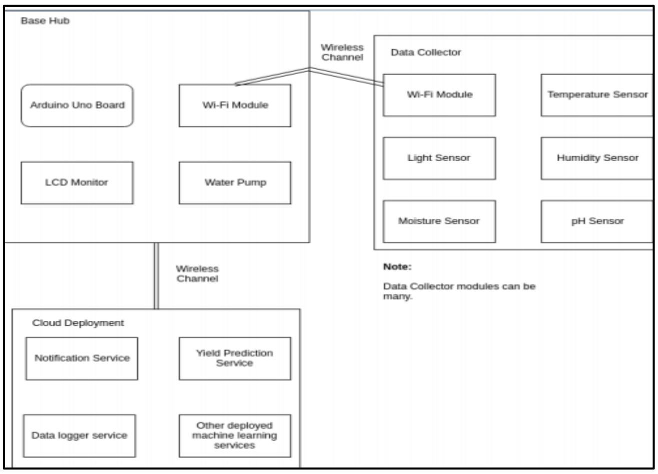
3.2**Disease Detection:** Detecting plant diseases early can save farmers a lot of damages. This can help them resort to the best measure to eliminate infected crops and protect the rest of the produce. The process of detecting diseases involves steps like image acquisition, image pre-processing, image segmentation, feature extraction and classification. Furthermore, multiple methods are used for the detection of diseases plaguing plants, which uses the images of their leaves [24]. Also, segmentation and feature extraction algorithms prove to be useful in the detection of plant diseases.

3.3**Weed Detection:** Identifying and separating weeds is a labour-intensive job that can be simplified manifold by using technology. [4, 25] apply digital image processing to distinguish between crops and weeds. This process has become quicker with the advent of CNNs which can extract features on their own and can detect borders between weeds and crops with high accuracy.

4. METHODOLOGY

In this section, the details of the methodology will be specified which we are proposing. The main component of the proposed architecture is a hardware kit which would be placed in thefarmlands at various positions. The purpose of the farming kit is to collect localized real time data. This data would consist of certain particular parameters which would be used to train the prediction model. These parameters include humidity, temperature, soil moisture, sunlight intensity, soil pH level and the GPS location. Accordingly, the hardware kit will consist of the respective sensors which can detect and track the relevant data in their immediate locality.

Furthermore, since the farm size can be very large, or a particular farmer might own multiple farms, the farming kit will consist of multiple child nodes which would connected to a central base hub present within the farm area. The networking of the child nodes and the base hub would be done such that each farmer can own only a single base hub while having multiple child nodes consisting of the above mentioned sensors. All the child nodes would relay their sensed information to the base hub in real time through a local area network. The base hub in turn would pass on this data to the remotely located cloud server.



The cloud server has two parts mainly. The first is the database and the second is the hosted script or API for facilitating the prediction model. The database is required to store all the information which is sent by the base hub. Before, it in the database, the incoming data first needs to be cleaned and formatted so that the data coming from different farms can be stored in a uniform manner for further usage. Once the data has been stored, it is given to the machine learning model for the training of the prediction model. The machine learning model essentially consists of deep artificial neural networks and is implemented in two separate stages. The first stage would be the ANNs corresponding to each individual farmer so that the predictions generated by them are personalized and specific to the needs of that particular farmer. The second stagewould be a consolidated neural network which is trained by the global data generated from all farms in order to generate an overview of the conditions of the whole area. Other than the data collected from the farming kits, the cloud database would also store additional information gathered from government portals such as types of crops, crop price rates, crop consumer demand, pesticide rates etc. The data collected from the farming kits are correlated with the publicly available agricultural information by the neural nets to predict outputs such as which crop is to be grown and in how much quantity.

Also, other agricultural resources such as pesticides, water, manure, herbicides and seed quantity is optimized based on the farm size, weather conditions, resource availability and market value. These outputs generated would be displayed as a weekly report to the farmer informing them of the quantity in which they need to buy future resources and also the amount of money which they would require for the purchases such that the cost of all the predicted resources remain within the farmer’s budget. Once the report is generated, it would be accessible by the farmers in their respective login through a mobile or a web application whose backend is connected to the cloud server.

Besides providing assistance to the farmers, the proposed application also aims at helping and improving the agricultural governance of India. Therefore, all the information collected by the farming kits is made publicly available from the cloud database so that it can be used by government organisations as well as NGOs for facilitating grants as well as technical support to the farmers based on the performance trends of their crop production and the resulting income. The main challenge for creating such a public database is ensuring the security of the stored data so that its authenticity and accuracy remains intact. To facilitate this, the base hub provided to the farmers would be associated with a hash code which is generated randomly during their registration. Every time the base hub sends information to the cloud server, the base hub ID and the sent hash code would be compared with the previously stored user records to ensure that the data is being sent by a genuine source. In addition to this, the data stored within the cloud database would be stored within Merkle trees which is a type of data structure that maintains a hash of the data being stored, in a chronological order by the consolidation of the hashes of the previously hashed data. Due to this data structure, the data records become immutable and uniformly consistent such that even though the records are available publicly, they can't be manipulated by a malicious entity.

Thus, the methodology applied in the proposed smart agricultural system benefits the farmers at a personal level through guided reports, as well as aggregated level by enhancing the agricultural governance of the whole region.

5. Conclusion

While a fair amount of work has already been done in the field of smart agriculture, the main difference between our proposed idea and the pre-existing ideas is the current smart agriculture infrastructures help in making decisions related to the present conditions whereas we plan on making a system that can make predictions about the future or the next season of cultivation which allows the farmers to better optimize their assets. Also, the proposed application also serves as a standardized public utility with a wide scope of practical usage for many agricultural purposes.

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