Data Fusion For Intelligent Decision Making in Agriculture Resource Management

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Abstract

The Agricultural Resource Management System (ARMS) is an information system that geographically permits farmers to classify their field and farm animals' for making services in terms of setting up resources, increasing their ecological Farm Plan, food traceability, and animal physical condition. It is a tough task of planning the agricultural resources and making use of them effectively such as farm construction, tools utilization, fertilizer processing, management amenities, and use facilities which adds to the production, training, and marketing of crops. Apart from the fundamental property sunlight, soil, and water, the seeds and animal breeds, and human Endeavour also should be given more priority as agricultural resources. On the other hand, Agriculture Management System is the administration website to assist farmers in achieving high productivity and profitability to furnish efficient agricultural procedures through online selling of products. In order to attain the benefits and profits through agricultural resources, the Data fusion technique is used to integrate data and knowledge impending from several sources to acquire exact outcomes remotely. The purpose of this paper is to construct an intelligent decision-making Data fusion algorithm for proficient agriculture resource management. In addition, the analysis of challenges of the resource management and solutions also are rendered by taking agriculture land's natural resources like water, air, and temperature level in winter and autumn seasons..

1. Introduction

The integration of multiple data sources to create reliable, precise, and valuable information is a challenging task in agricultural resource management. There are two levels of data fusion techniques namely low-level and high level data fusion that merge a number of sources of raw data to construct fresh raw data or vice versa by issuing classification and recognition activities accurately towards better decision making [1, 25]. The Communication bandwidth and improved decision accuracy can be achieved by decision level fusion. Besides, using Remote sensing data fusion, the integration of the information obtain through dissimilar declaration from sensors accumulation satellites, aircraft and ground platforms information regarding resources can be acquired[2]. On the other hand, the problems with agriculture farmers are handling climate Differences, soil corrosion, biodiversity failure, meet customers shifting experiences and opportunity, satisfying demand in quality and quantity, spend in farm yield, implement and be trained latest technologies and survive flexible aligned with global cost-effective aspects[26]. The other major challenges in modern agriculture are mismanagement, illiteracy, unawareness and unpredictable climatic conditions [3].

Generally, the way of worldwide farming enhancement has been hardly centered on extended productivity instead of complete combination of Natural Resource Management with food and nutritious precautions [4]. A comprehensive methodology is the best since it can address the troublesome issues related to the sophistication of food and other formats. To address the Different necessities that shape human existence, there is a need to have a common way to deal by using the individual ideas as a learning experience [27]. Further, environmental change, which is occurring during a period of expanding interest

for food, feed, thread, and fuel, can possibly irreversibly harm the common asset base on which farming depends [6, 7]. The connection between environmental change and farming is a two-way road as horticulture appends to environmental change in a significant manners and environmental change as a rule influences agribusiness in a hostile way [29]. Sometimes, extraordinary environment occasions like floods and dry seasons are probably going to be huge outcomes on the whole areas for food and the environmental change is influencing the delivery of plants, disturbing species, and pests and, the geographic reach [28]. The Sensors used in smart farming are recognized as agriculture sensors to present information which help farmers to supervise and optimize yield by become accustomed to moDIVy in the ecological circumstances. The agriculture sensors can be deployed on various parts used in the agriculture industry for observing the status of the natural resources through gathered information and controlled by remote wireless devices. The agriculture Sensors, advantages drawbacks and their uses are explained as follows.

The functions of agricultural sensors

- **Location Sensors:** These sensors are useful in determining latitude, longitude and elevation of every location surrounded by necessary region using help of GPS satellites.
- **Optical Sensors:** These sensors can make use of light to evaluate soil properties by which these can be installed on drones, robots and satellites to find out natural substance and humidity of the soil.
- **Electro-Chemical Sensors:** These sensors can be used in collecting chemical information of the soils by sensing the content of soil ions to give information of pH and soil nutrient intensity.
- **Mechanical Sensors / Dielectric Soil Moisture Sensors:** To assess soil compaction in the form of mechanical conflict, these sensors are used.
- **Dielectric Soil dampness Sensors:** Humidity intensity of soil by determining dielectric constant can be measured.
- **Air Flow Sensors:** To compute air permeability, these sensors are used.

Uses of Agriculture Sensors

- The sensors that can be installed in any weather equipments to offer information such as soil temperature at a variety of lowest point, air hotness, rain-level, leaf condensation, chlorophyll, wind track, solar emission, relative moisture, atmospheric stress etc.
- Agro based industries use these sensors to measure the effective utilization of agriculture resources.
- Agriculture drones use these sensors to spray insecticides and insect killer.
- These sensors are deployed in Solar based pumps to reduce the cost of electricity.
- E-fences that use these sensors to help in saving crops from animals.

Benefits of Agriculture Sensors

- Because of their ease to use and installation simplicity and cost effectiveness they are much with agricultural use, in addition to pollution warming.
- Since these sensors are made with integrated chip, it is easy to control them easily by remote access.

Considering above factual information bearing in mind, this research paper is aiming in developing a smart data fusion algorithm by utilizing the agricultural resources effectively. It is also intended that the major benefits of attaining high productivity through proficient Agriculture Resource Management.

2. Preliminary Studies

This section of this paper discusses the various research papers in data fusion techniques used in agriculture and also resource management algorithms for managing the resources effectively.

Bekele Shiferaw et al (2004) discussed the distinctive agricultural characteristics features, methodological complexity to inspect the strong points and flaws of a variety of impact evaluation methods on concerns like soil, water and bio-diversity management. Graef F, Schneider et al (2015) pinpointed the significance of counting dissimilar assessments and implementation possibility for rainwater harvest and management of agriculture in sub-moisture sections. Miguel A. Altieri et al (2005) presented the model of agricultural scheme developed by conventional farmers healthy modified to the restricted circumstances of the semi-arid environment, to produce continued capitulate. Nabavi-Pelesaraei et al (2016) studied all emissions in the agricultural area by using ANN technique that has competent of modeling crop production and overall GHG emissions with maximum precision. Malik, D.P. et al (2003) deliberated the making of appropriate crop outcome and security expertise. Fernando Lobo Pereira et al (2013) projected layered management formation for planning, coordination, and execution layers. Konstantinos Chartzoulakis et al (2015) talked about the implementation of sustainable water administration in agriculture, which comprises a multi-functional function in irrigation use, soil and plant follow-ups, water pricing, recycle of treated wastewater, farmers' participation. H. Hu and H. Yan (2018) explained a multi-sensor data fusion algorithm based on and the efficiency of this fusion algorithm is confirmed in the course of comparison to improve data compilation consistency and strength of knowledge agriculture scheme. Rodrigues et al (2009) projected a technique to review 6 data fusion algorithms based on the making of synthetic images that replicate real satellite images. From their comparative studies Wavelet IHS has an edge over other methods. Padilla et al (2019) modeled a supervised scheme of agricultural construction as a Data Fusion System to the calculation of harvest auction supported on relationship policies excavation in accessible sales data. Astrignanò et al (2017) evaluated spatial variability for the precision agriculture with the help of data fusion algorithm by comparing the partition and the soil properties as a part of agricultural management. Vallentin, C et al (2021) demonstrated the prospect of separating farming land into administration region by merging the transferable belief model with the experiences of farmers as precision agriculture.

Ming, Xin et al (2017) proposed a type of data fusion hue that has a capacity instantaneously carry out pixel-level fusion mechanism following the statistics collected from the sensors. The data fusion

algorithm based on Kalman filtering along with Zigbee wireless protocol to study intelligent monitoring, processing center, and administration and data investigation. Suyog Malviya et al (2015) focused on the studies of Multi-sensor data fusion applications for enhanced quality data analysis and processing in measurement and Analysis of precision agriculture by the various parameters of sensors. Zhou, Yi et al (2012) studied a life time of WSN in the background of data fusion algorithm under hostile environment in precision agriculture. Abdikan, Saygin et al (2012) studied the comparative assessment of fused data by using their existing proposed image fusion algorithms such as Ehlers, IHS, HPF, two dimensional DWT, and PCA methods. The parameters they used for their study were bias, correlation coefficient (CC), Difference in variance (DIV), standard deviation Difference (SDD), universal image quality index (UIQI) techniques for investigation regions "urban" and "agricultural". Feng Zhang et al (2020) analyzed the agriculture big data in terms of solving security issues in heterogeneous agricultural ant colony optimization algorithm (Big Data ACO) for a accurate decision-making and reducing instability of data fusion data. Andrei B.B. Torres et al (2020) proposed a high performance fusion algorithm to get better sensor accurateness, recognize objective proceedings, and create intelligent decisions by using three layers. Zou T et al (2017) projected in recognizing the sensor nodes concerned by actuator noise and decrease their amount of contribution in the information synthesis consequences.

On the other hand, Nayyar et al (2016) proposed a novel Smart IoT based Agriculture Stick assisting farmers in attaining the real time agriculture data as efficient environment monitoring. Ayaz et al (2019) highlighted the challenges of wireless sensors and IoT in agriculture parameters, like soil grounding, crop position, irrigation and pest finding. Panigrahi et al (2020) proposed a Smart IoT based Agriculture Stick in receiving real time Data of Temperature, Soil Moisture, etc and other factors for resourceful environment monitoring to perform elegant farming and boost an overall yield. Jash Doshi et al (2019) proposed a methodology that is able to generate communication on diverse stages to inform farmer about real time data to obtain essential follow-ups as a smart farming. Chetan Dwarkani et al (2015) focused to create strategies and techniques on the capacity that acts an important role in farming activities. M. R. Mohd Kassim et al (2014) offered real-time information about the terrain, yield and software procedure management of the precision irrigation system for making use of fertilizers. K Asha et al (2016) proposed a method that uses effectively IoT and Cloud data with the purpose of taking accurate decisions for the farmers aiming at good productivity. Suporn Pongnumkul et al (2015) methodically assessed the review to use mobile phones that employs built-in sensors of mobiles to give agricultural clarification so as to take the required follow-up things.

From the preliminary studies, it is learned that there have been many research oriented articles with regard to the combined usage of technologies called IoT, Cloud computing and ANN techniques with data fusion algorithms for smart cum precision agriculture. But the challenges and issues in collecting real time agriculture data and fusing them for taking the decisions intelligently are the tough things. The existing data fusion algorithms have been good enough to integrate the agriculture data but compromising the heterogeneously environment as well as multiple data fusion DIVficulties in integration.

3. Proposed Intelligent Decision Making Data Fusion Algorithm

This section explains the Proposed Effective Agriculture fusion algorithm. The following pictorial representation in Figure 1 illustrates a smart Agricultural environment, in which the parameters to be monitored are climatic condition, moisture of soil, growth of crop, nutrition level, temperature of the land area and water level. The conversion of a normal agriculture area in to smart agriculture area is done using proposed data fusion. By means of an accurate decision that can be taken to take necessary steps in the form of controlling the agriculture resources effectively.

The Proposed Agriculture setting up Architecture comprises three important parts namely power from solar, deployed sensors and IoT platform. The data captured by the sensors will be collected, fused, processed followed by analysis before taking decision appropriately.

3.1. Deployment of Agricultural sensors

In the proposed agricultural environment, several sensors have been deployed to sense and gather the agricultural data that are finally needed to integrate by the proposed data fusion algorithm which is shown in figure 2. By doing so, the conditions of the resources of the agricultural field are being monitored continuously for the follow-up things to be done from the remote place by the farmers [11]. The deployed sensors are connected by IoT for further effective association with the data analysis and decision making of the environmental resources status. The IoT and AI techniques have been used here with the integration of data using the proposed data fusion algorithm for best decision making.

Multi sensor Data Fusion Environment: Sensors with Different agriculture variants have been used to provide information that are capable in monitoring and optimizing growth level of plants, land water stage, humidity stage, soil category and temperature point of the agriculture ground as per the varying environmental factors [19]. These sensors inspect by penetrating the soil and records resistive forces before sending them to the central node for further data integration and data fusion [12].

Data integration: The data integration process does the mixture of information collected from a variety of resources like soil databases, temperature figures, humidity information, water stage statistics, and Crop Growth records throughout diverse climate circumstances by multi-sensors[18].

Data Fusion: The Data fusion has statistics resulting from multi-sensors resources, connected to the agriculture systems and sensors deployment that helps farmers in making decision about the status of temperature, humidity, water, Crop Growth and Soil. In the process of multi-sensor data collection, multiple multi-sensor network nodes collect the state information of the same monitoring object [13]. Due to the dynamic characteristics of the multi-sensor, it is necessary to fuse the same kind of data and make corresponding correction to obtain a more reasonable data [20]. There will be an assumption that there really are n multi-sensors as overall, and the interpreted data of them at a assured moment is $x_i, i = 1, 2 \dots n$. As per the fuzzy logic presumption, data interpreted of a multi-sensor can be regarded as a fuzzy set [21]. Further, the comparison stuck between the two fuzzy sets can be assessed by the closeness degree.

At the k moment, the calculation formula of the distance degree of multi-sensor i and j observation figure $x_i(k)$ and $x_j(k)$ is as follows:

$$a_{ij}(k) = \min[x_i(k), x_j(k)] / \max[x_i(k), x_j(k)] \quad (1)$$

When $a_{ij}(k) < \text{the preset threshold } M$ and is measured that $x_i(k)$ and $x_j(k)$ are not alike, and $a_{ij}(k) = 0$ can be acquired.

At moment k, the steadiness among multi-sensor i and other multi-sensor interpretation is $r_i(k)$ and the procedure for data fusion is as follows:

$$X(k) = \sum_{i=1}^n w_i(k) x_i(k), i=1,2,\dots,n \quad (2)$$

Where, $W_i(k)$ stands for the weight, and $N_i(k)$ signifies a cluster of non-negative Numbers. Due to

$w_i(k) / w_j(k) = N_i(k) / N_j(k)$ subsequent to the normalization processing of $W_i(k)$, the concluding fusion outcome of all the multi-sensor observation data at the k^{th} sampling can be achieved as follows:

$$x(k) = \frac{\sum_{i=1}^n N_i(k) / x_i(k)}{N_1(k) + N_2(k) + \dots + N_n(k)} \quad (3)$$

Data preprocessing: The effectiveness of characterization in the agriculture can be achieved by a variety of sensors by their data sensing, computation and communication. The data preprocessing starts by preparation of data that includes data cleaning, integration, transformation, and reduction [14]. In these, cleaning routines are used to seal in absent ideals followed by smoothing noisy data, recognizing peculiarities, and then correcting data contradictions [22]. In addition, Data implementation is the process of combining information from various causes of logical data accumulation. Finally, Data preprocessing can efficiently progress the feature of data mining and decrease data mining duration in agriculture part [17]. Data preprocessing plays a vital role as the transformation of raw data into an understandable format is done here.

Data Analysis and Decision making: In an agriculture dataset, the implementation of a training set has been build up as a model; at the same time as a validation set is to authenticate the model made. From the validation set, the data points have been taken out [15]. The first pace starts by switching ANN above a learning process to a running process based on the trained and test data before running. Secondly, the similar training data immediately used in the whole system to scrutinize the error rate is done [16]. Finally, comparing the Artificial Neural Network output with the expected result from the data has been undergone.

In ANN, the weighted associates permit data to go between layers (water, soil, humidity, temperature and crop growth) through it, where the sensor allows information from preceding level and estimates a a regression coefficient of all its net inputs (T_k):

$$T_k = \frac{\sum_l^n (W_{kl} y_l + b_i)}{\sum_l^n (W_{kl} y_l + b_i)} \quad (4)$$

Here, n is considered as input contributions, w is the weight of the connection between the sensors used. On the other hand and l, y is the input from the sensor node l, and bi is bias values of the nodes .In this instance, the sensor node productivity Pi, a relocation function ri is then applied to the weighted values of the sensors.

$$P_i = r_i (T_k) \quad (5)$$

The dataset after that can be “learnt” by training set and testing set. The process of learning is described as the procedure of modifying the data identified with the transfer functions among cells while contrasting ANN response to observable values [23]. The Back Propagation (BP) approach is often used to develop a feed-forward neural network to eliminate inaccuracy, where inaccuracy is the discrepancy between the desired outcome and the goal values in this activation.

3.2 Proposed intelligent decision making Agricultural Data fusion algorithm

The fusion of multi-sensors data will render in improving the accuracy of predictions by a range of properties. The flowchart for the proposed intelligent decision making Data fusion Algorithm is explained shown in figure 3 as follows:

Here, the intelligent decision making is specified owing to the reality that, in comparison to the tree-based technique, three scenarios occur in the proposed scheme, and the level of significance is within the specified parameters. Parameter significance is within the range i.e., decision to be taken)

- Parameter significance is out of the range i.e., necessary steps to be taken)
- Parameter significance is not available i.e., wait till getting the value)

In the Table 1, the Constraint Definition and their implication are specified.

Table 1
Constraint Definition

Feature	Normal value	Present value
Temperature data	N-T	P-T
Soil data	N-S	P-S
Crop growth data	N-C	P-C
Humidity data	N-H	P-H
Water level data	N-W	P-W

4. Experimental Results And Outcome

The experiment is done using Network Simulator 2 with the simulation parameters of smart data fusion algorithm. The simulation environment starts with the formation of sensor nodes under IoT environment in the agricultural field. Every sensor has its own characteristics to collect the data and further follow-up processing before the data fusion inference takes place [24]. categorize to maintain the reliability of the proposed system, extended observing outcomes are obtained. The two seasons have been taken in to account simulation studies of the proposed work namely Autumn and Winter for the duration between the months June-July; Sep-Oct and Sep-Oct; Dec-Jan respectively.

Air temperature observation: Based on the outcome in Figure 4 and 5, Variance in air temperature between day and night, also described Day/Night Variation (DIV) patterns are observed. The temperature at its peak level is noticed in Figure 3. DIV impact holds numerous significances and initially, DIV impacts have been associated to stand expansion and values of DIV approximately 25-35°C are confirmed to grant the finest plant growth, while DIV impacts between 15°C and 25°C illustrated a short connection to the foreseen results.

The most favorable temperature level for the cultivation of paddy is between 20°C and 35°C. It is also learned that exposure to cold temperature have an effect on all phonological phases of paddy will poorer grain production. Hence, the minimum temperature must not set off below 15°C as germination cannot take lay under that hotness. From the air temperature data in the season autumn and winter, it is inferred that in autumn the paddy growing are more prominent, as the DIV was lesser than 25°C.

Soil temperature monitoring: From Figure 6 and 7, it is studied that the difference of soil temperature for autumn and winter, results the identical pattern along with air temperature data that corresponds to them. It is also noted that temperature level stand between 18°C and 24°C for autumn and from 10°C to 22°C for winter.

Humidity monitoring: The Figure 8 and 9, depict the disparity of defined air humidity for autumn and winter. It is observed that the saturation occurrence has been equally normal in both seasons which have relation to the forecast of the rainfall when the humidity of the air arrives at 100%.

Water level monitoring: The Figure 10 and 11, depicts the Difference of relative water level for autumn and winter. It is understood that the requirement for water usage is equally regular in both seasons. Further it is identified that there is a relation to the prediction of the rainfall and the utilization of water level.

Crop Growth monitoring: The Difference of relative crop growth height level for autumn and winter has been depicted in Figure 12 and 13. It is observed that the growth in crop in height has been equally normal in both seasons. The crop growth is connected to the forecast of the rainfall, water level, temperature and humidity.

4.1 Analysis of Various Sensor Data using intelligent Decision Making Data Fusion Algorithm in Agriculture Environment

The previous visual illustrations have not exposed the deficiency of a few information in terms of the information's diversity. The specimens were not available at certain times of the day has been missing along with every day data. The Table 2 illustrates the samples that have been collected in time intervals for autumn and winter.

Table 2
Sample data used in autumn and winter

Sensing Hours	Duration (In Days)	Autumn (In Days)	Winter (In Days)	Cumulative Samples Used
6,12,18	65	35	30	212
4,8,16	55	20	35	186
2,10	4	1	3	14

The lack of data may decide various issues relating to the accurate decision but the proposed, intelligent Decision Making Data Fusion technique could provide advantages like as the responsibility activated by the information space can be alleviated. Since the variables used here are air temperature and soil status level for the assessment of the specimens obtained to make the surfaces store their ideals in order to be away from the data to be missed out by the system by chance. According on the results of the study, the proposed Intelligent Decision Making Data Fusion technique, the relationship between the variables is depicted in the figures 14, 15, 16, 17 and 18, 19.

Figures 14 and 15 represent the air temperature vs. soil temperature for the same period of year in autumn and spring. It can be seen that the lowest Air Temp' Vs. Soil Temp' observed in winter is 33.78 percent, which was reported in March, and the highest Air Temp' Vs. Soil Temp' reported in fall is 53.98 percent in December.

Figures 16 and 17 stand for the Humidity vs. soil temperature for the same period of year in autumn and spring. It can be seen that the lowest Humidity vs. Soil Temp' observed in autumn is 27.12 percent, which was reported in March, and the highest Humidity vs. Soil Temp' reported in fall is 42.08 percent in January.

Figures 18 and 19 signify the Humidity vs. Water Level for the same period of year in autumn and spring. It can be seen that the lowest Humidity vs. Water Level observed in winter is 39.34 percent, which was reported in March, and the highest Humidity Vs. Soil Temp' reported in fall is 48.03 percent in December. In winter and autumn, data on basic factors such as air temperature, humidity, soil temperature, and water level were recorded. The variance in soil temperature led to the discovery that the variations in both

seasons are comparable to their corresponding air temperature data. Furthermore, by keeping track of relative soil humidity and temperature, because it was discovered that the observed constraints were not gathered simultaneous time, a data fusion technique was employed to seal in the spaces and offer a overall perspective of the scheme's activity. It was demonstrated using data fusion that:

- By figuring out how to calculate an estimate value for air temperature, you'll be able to calculate an estimated assessment for soil temperature, and likewise.
- The estimated assessment of the soil relative humidity can be obtained by determining the approximate value of the air relative humidity.

5. Summary Of Contribution

Multi-sensor data fusion is the course of action of merging interpretation from various sensors to offer a healthy and absolute picture of an agricultural location. The paramount contribution of the proposed Data fusion technique discovers extensive application in numerous areas of agricultural field in the form of object recognition, environment mapping, and localization. As, Data fusion helps in joining together several resources of data to create more constant, exact, and constructive information than that presented by every individual data source. Furthermore, the characteristic assessment level sensor fusion here extends in helping for the classification of detection actions to attain bandwidth and enhanced decision precision in terms of communication. Thus the proposed smart data fusion algorithms has been proven to be more reliable and robust in the agricultural environment by reducing human work, effort and money wistfully but without compromising high productivity in crop or plants.

6. Conclusion

This paper presented the design and development of intelligent decision making Data fusion algorithm for efficient resource management for Agriculture. The proposed sensor fusion algorithm merges sensory data that, when properly synthesized, help in reducing uncertainty in machine perception by combining data from multiple sensors through the data constraints such as soil temperature, humidity level, water level, air temperature in Autumn and Winter to consistently monitor the plant growth. The objective of using Multi-sensor image fusion inquires about uniting interpretation from diverse images to get hold of more implication than can be consequential from only one sensor. The proposed smart data fusion algorithm makes the normal agricultural data in to smart data by using best feature extraction and preprocessing techniques in terms of merging several interpretation views. The experimental outcomes illustrate that the implementation of the proposed intelligent decision making data fusion algorithm has been proven as an efficient one by its potential in analyzing the data fusion methodology for heterogeneous agriculture environment of paddy field. It is also proven that the proposed data fusion method efficiently suitable and reliable in reducing the human energy but utilizing the agriculture resources effectively to increase the yields.

Declarations

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Figures

Figure 1

Proposed Agriculture Architecture

Figure 2

Data fusion flowchart for agriculture

Figure 3

Proposed intelligent decision making Agricultural Data fusion algorithm

Figure 4

Figure 5

Air Temperature Sensing in winter

Figure 6

Soil Temperature Sensing for Autumn

Figure 7

Soil Temperature Sensing for winter

Figure 8

Humidity Monitoring for Autumn

Figure 9

Humidity Monitoring for winter

Figure 10

Water Level Monitoring for Autumn

Figure 11

Water Level Monitoring for winter

Figure 12

Crop Growth Monitoring in Autumn

Figure 13

Crop Growth Monitoring in winter

Figure 14

Air Temp' Vs. Soil Temp' in Autumn

Figure 15

Air Temp' Vs. Soil Temp' in winter

Figure 16

Humidity vs. Soil Temp' in Autumn

Figure 17

Humidity vs. Soil Temp' in Winter

Figure 19

Humidity vs. Water Level in winter