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MANAGING IRRIGATION NEEDS BASED ON SMART DECISIONS USING MACHINE LEARNING

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Abstract

Optimized utilization of water for agriculture is a big challenge in today's world. Internet of Things (IoT) based solutions along with machine learning techniques help in achieving effective utilization of waters in farming landspace. This paper presents sensor-based acquisition of soil moisture, temperature and humidity from the farm. Data are then stored in the server and clustered into two groups. Next machine learning based classification models like Naïve Bayes (NB), K-Nearest Neighbor (K-NN) and Support Vector Machines (SVM) are applied to decide irrigation need. The performance measures of the classification models show that K-NN classifier performs better than the other two classification models considered in this study.

Keywords:

Classification Algorithms, Decision Support Systems, Internet of Things, Machine learning Algorithms, Smart Irrigation

1. INTRODUCTION

The main problem affecting many parts of the world is water scarcity. This is due to the increasing population and fresh water demands. So, there is a need for water management especially in the field of agriculture. Advanced technologies based on smart strategies can help the framers in irrigation. In the recent years, Internet of things (IoT) plays a major role in every field of work. Reference [1] explains about the smart/precision farming using IoT. Data collected from the sensors deployed in the farms are stored in databases and are then analyzed to take decisions in smart irrigation systems [2]. Data mining techniques are applied in analyzing the crop type, soil and climatic data in order to plan the accurate yield estimation for the numerous crops [3]. Unsupervised clustering algorithms are applied in modeling and identification of irrigation station [4]. Classification models were developed to predict the wind drift and evaporation losses in sprinkler irrigation [5].

The main objective of the work is to regulate water supply on demand. This paper focuses on automating water supply by analyzing the air temperature, soil moisture and humidity using machine learning techniques. K-means clustering is applied to group the data into two classes namely needs irrigation and not needed. Classification model is built using NB, K-NN and SVM with the clustered data. This process is automated using the hardware setup built using Raspberry pi and Arduino Uno.

The rest of the paper is organized as follows: section 2 discusses the related work and Section 3 presents the proposed methodology. Results are discussed in section 4. Section 5 concludes the paper.

2. RELATED WORK

This section focuses on the works seen in the literature regarding the application of IoT in agriculture and application of machine learning in agriculture. The internet of things is a concept where every physical object is connected to the internet and is able to identify themselves to other devices. This is possible with the enabling wireless technologies such as RFID tags, embedded sensor and actuator nodes [6]. IoT plays a major role in field of agro-industrial, environmental and smart farming [7]-[9]. The method in [10] presents a wide range of wireless sensors used for designing wireless sensor networks in agricultural fields.

The following paragraph explains the application of IoT in smart farming. An automatic irrigation based on time temperature algorithm utilizes water effectively over manual irrigation [11]. An evapotranspiration (ET) controller is used for managing residential irrigation so that landscapes are irrigated based on plant needs and requires much less water loss over time-based irrigation scheduling [12]. The distributed wireless network system of soil-moisture and temperature sensors connected to a gateway unit handles sensor information and transmits data to a web application. A rule-based microcontroller system checks the threshold values of temperature and soil moisture and controls water supply [13]. A smart phone-based irrigation system that captures and processes digital images of the soil nearby the root zone of the crop, and estimates optically the need irrigation [14]. Cloud of things combined with thermal imaging is used for determining the relation between water status of the field and radiation emission to monitor irrigation [15]. A decision support system is developed based on the combination of the wireless sensor, actuation network technology and fuzzy logic theory to support the irrigation management in agriculture [16]. A weekly irrigation plan was defined by the agronomist based on various machine learning approaches using soil moisture sensor data. It was found that Gradient Boosted Regression Trees provided a best irrigation plan with an accuracy of 93% [17].

The following paragraph describes the application of machine learning in smart farming. The multi-sensor network system is used to collect the multi-dimensional information of the number of pests, soil, environment, ecological climate and meteorological factors were collected. Then K-means algorithm is used to group the damage into four levels: mild, moderate, moderately severe, and severe. The correlation coefficient and gray relational degree were used to find out the key factors between the number of pests and the multi-dimensional information and a BP neural network model were trained using the key factors. The results showed that the recognition rate of the pests was 96.7% [18].

Soil fertility level is predicted by analyzing soil information such as nutrient content, soil type, pH value, EC (Electrical Conductivity) value and soil texture and recommendations were offered for crop selection using C5.0: Advanced Decision Tree (ADT) classifier algorithm [19]. A hybrid heuristic methodology that combines Decision Trees and Genetic Algorithm was developed to model farmer's behavior on irrigation events [20].

An inference method based on data fusion technique called Dempster-Shafer inference for irrigation decision-making in oil palm supported on soil moisture and vapor pressure deficit data [21]. The outcome of system was inferring the crop state; regarding soil and plant water status, following the concept of site-specific agriculture and the results showed a 27% increase in the production of bunches of fresh fruit. Average wind speed, coarseness index and sprinkler spacing were used as input parameters to obtain the coefficient of uniformity values (CU) by employing the artificial neural networks (ANN), neuro-fuzzy grid partitioning (NF-GP), neuro-fuzzy sub-clustering (NF-SC), least square support vector machine (LSSVM) and gene expression programming (GEP) techniques. From the results it is inferred that the coarseness index has the lowest impact on modeling CU is sprinkler irrigation [22].

IoT has been applied in many fields and data mining applied on IoT data is becoming the promising area of research. This paper presents one such idea of using the sensor data to predict the need of irrigation using data clustering and classification approaches. This would help farmers in less water zone areas to regulate water supply and promote yield of agriculture.

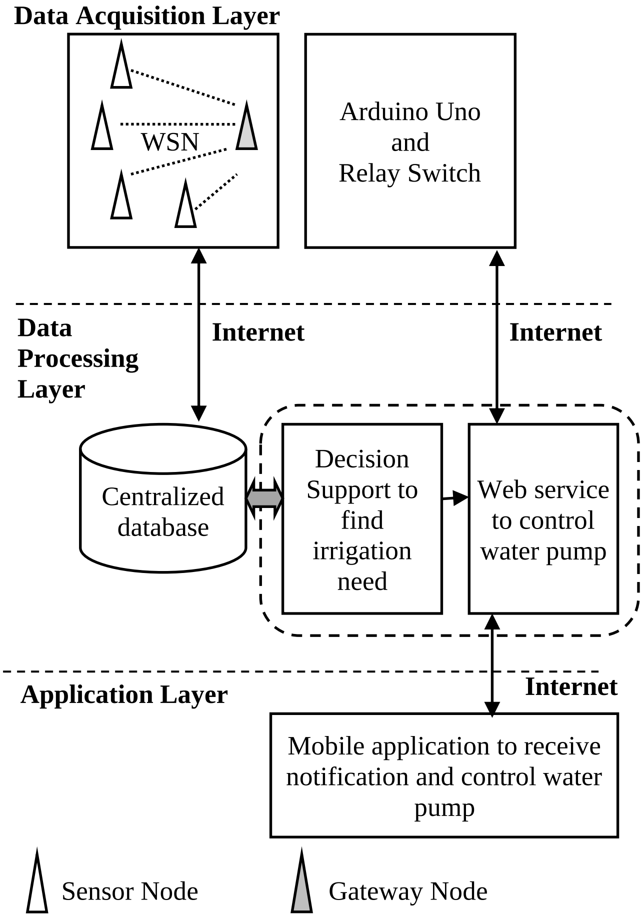

Fig.1. Architecture of the Proposed System

3. METHODOLOGY

The architecture of the proposed automatic irrigation system is shown in Fig.1. It has three layers namely, Data acquisition and control layer, Data processing layer and Application layer.

3.1 DATA ACQUISITION AND CONTROL LAYER

Data Acquisition and Control Layer mainly has the IoT components placed in the agricultural field. It has two components one to gather the data and other to control the motor. Wireless Sensor Network with ZigBee technology [23] is implemented with sensor nodes having three sensors viz., Soil moisture sensor, humidity sensor and temperature sensor. The output of these sensors is read by Raspberry pi connected to ZigBee for sending data to Gateway Node that will send the data to the server using web service. In the control component, a water pump is connected to a relay switch that is controlled by Arduino Uno node. The node is controlled by the web service that is triggered by the classification model. The web service is written in PHP and is hosted on Apache web server at server machine.

3.2 DATA PROCESSING LAYER

Data processing requires three components viz., centralized database, decision support model to predict the irrigation need, web service to control the water pump. The steps followed in this stage are shown in Fig.2. The data read from the previous layer is sent to the server and stored in the MySQL database. Decision support to predict the irrigation need involves two steps. First, there is a single time clustering of data done using K-means clustering. K-means clustering [24] is a partition-based clustering algorithm which partitions the given data into K-specified groups. In this work the records are grouped into two groups namely “need water” and “not need”.

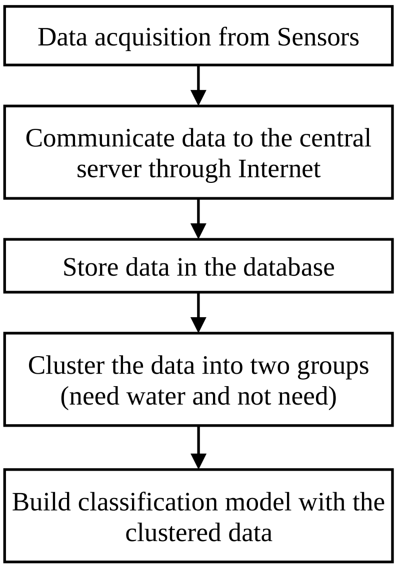

Fig.2. Flowchart of decision support process

In the second step a classification model is built using any one of the classification models such as Naïve Bayes classifier (NB), K-Nearest Neighbor (K-NN) and Support Vector Machine (SVM). NB calculates the probabilities for every attribute and selects the outcome with highest probability. K-NN is a lazy learner. Similarity between the new data sample and available data are calculated. K nearest neighbors is chosen and the new data is assigned the class to which it is most similar. SVM is a discriminative classifier where the algorithm uses the labeled training data and constructs an optimal hyperplane which categorizes the new data. The built classification model is used in decision making for irrigation need. The steps followed in this stage are presented in Fig.3. A web service has been developed to start and stop the water motor. This web service developed using PHP sends signal to Arduino-Uno to control the relay switch to start/stop the water motor. It also alerts the user when there is need for irrigation.

3.3 APPLICATION LAYER

In Application Layer a mobile application runs in the user's smart phone. When the web service alerts the user, the message is displayed stating the irrigation need of the field and motor automatically started. The mobile application also provides the user to control motor manually. In this case the mobile application sends information to web service which in turn controls the relay switch connected to Arduino Uno.

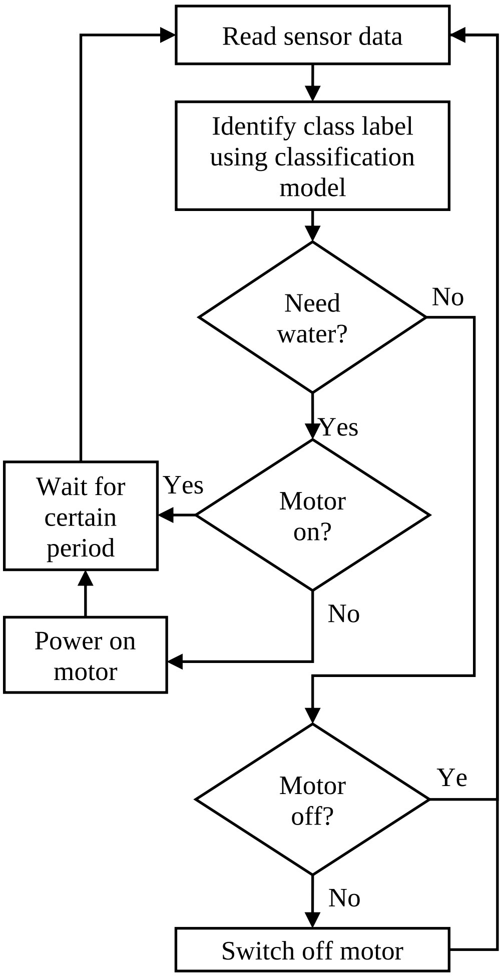

Fig.3. Flowchart to control the relay switch

4. RESULT ANALYSIS

The main aim of this paper is to provide a decision support system that automatically triggers water supply to the field when needed. This is achieved with IoT and the data mining model applied to the collected sensor data. The data acquisition node was setup in a small garden of our organization. The collected data is sent to the server over internet. The server used in this setup has Intel i7 processor with 3.40GHz, 4GB RAM and 500GB disk storage. The database to store the received data, the decision support model to process the received data and the web service to control the relay switch runs in the server machine. An android mobile application runs in the android based smart phone of the user. The user receives the notification and can also manually control the motor through his/her smartphone from the place where he/she is. The performance metrics considered to evaluate the classification model in the decision support process are precision (Eq.(1)), recall (Eq.(2)) and accuracy (Eq.(3)) [25].

$$\mathrm{Pr}\,ecision = \frac{TP}{TP+FP} \quad (1)$$

$$\mathrm{Re}\,call = \frac{TP}{TP+FN} \quad (2)$$

$$Accuracy = \frac{TP+TN}{P+N} \quad (3)$$

where, *TP* is the True Positive, *FP* is the False Positive, *TN* is the True negative, *P* is the total number of positive samples and *N* is the total number of negative samples. In this work positives refer to "need water" and negatives refer to "not need".

The experiment shows that the use of IoT and decision support with data mining model enables automatic supply of water to the field when required. The proposed approach would simplify the work of the user from going to the farm to on the motor when he is out of station. Also, the user can control the motor manually, which would help him during necessary situations. The developed system reduces the manual work of the user and helps to irrigate the field only on need thereby water is used efficiently in the required amount. The proposed system utilizes a machine learning based data mining techniques where the system learns from the previous historical data to take decisions of the new data. It avoids fitting only thresholds to the smart irrigation systems.

Table.1. Comparison of Performance of the Classifier

Classifier	**Performance metrics**	
NB	Precision	88.86
	Recall	86.84
	Accuracy	86.45
K-NN	Precision	92.16
	Recall	90.11
	Accuracy	91.05
SVM	Precision	90.01
	Recall	87.03
	Accuracy	89.11

The Table.1 describes the performance measures of NB, K-NN and SVM classification algorithms. The Fig.4 shows the comparison of accuracy of the classification algorithms considered in this study. It shows that K-NN classification algorithm gives the high accuracy compared with the other classification models. From the results it is observed that, K-NN classification algorithm produces more accurate results. Since K-NN is lazy learner, it does not build a model. It takes all the available data for similarity calculation. So, K-NN algorithm could be used for the decision support task to decide on the irrigation needs. It helps the farmers to irrigate the field on time and also use the water in effective manner.

5. CONCLUSION

The main occupation in many countries is agriculture. The important factor contributing life to agriculture is water. There are many places in the world where there is scarcity of water. In order to efficiently utilize the available water for agriculture, the paper presents a novel method which uses IoT and data mining techniques. Sensor data are read and communicated to the server through internet. The decision support system predicts the need for irrigation and triggers the relay switch through a web service. The user is also notified with the status of irrigation and could also manually control the motor from a remote place using the mobile app through internet. Many farmers are still applying the traditional methods of irrigation system. With the development in technologies, smart irrigation systems were developed using rule-based approach. Rule based systems sets a threshold which the system checks to switch on/off the motor. The proposed system utilizes a machine learning based data mining techniques where the system learns from the previous historical data to take decisions of the new data. It avoids fitting only thresholds to the smart irrigation systems. The system intelligently decides the need of water for the field and automatically switches on/off the motor thereby saves the manual work and time of the farmer. In future, the water level in tanks and wells could be taken for consideration to off the switch to avoid burning of the motor.

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