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Supervised Learning System for Pest Disease Identification and Recommendations using Wireless Sensor Network in Agriculture Domain

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Abstract

Designing wireless sensor networks (WSNs) that will sustain for longer time have been a challenging issue. For achieving this, efficient utilization of available energy should be anticipated from energy-constrained sensors running autonomously for long periods. In the field of agricultural research, farming related activities, assistance to farmers using advanced IoT and sensor network technologies is a need of time. Initially this paper briefed about smartphone based application systems that forewarns the farmer about pests/diseases that can occur on the crop. The designed system assists farmers to foresee the crop disease using machine learning algorithm. The disease can be predicted based on the environmental parameters as soil moisture, temperature and humidity obtained from sensor node and other parameters like rain fall, evaporation rate and sun shine hour obtained from open weather map application programming interfaces. A prototype is developed using ultra low powered micro-controller with interconnected sensor's module. While comparing with the Arduino micro-controller based system, it was observed that the developed prototype system utilized less energy with effectively forewarned the farmers about crop diseases using Internet of Things (IoT). Thus it would assist the farmers proactively to reduce the losses due to crop diseases.

Keywords: Energy; Networks; Routing; Sensor; Wireless.

1. Introduction

Nowadays, due to recent technological advances, the sensor networks become most popular in various fields like industrial, agriculture, healthcare, defense, etc. Agriculture sector in India has been diminishing day by day which affects the crop production capacity. The utilization of advanced technologies is growing rapidly in agriculture domain to monitor the field. The cotton crop is one of the important cash crops in India that is cultivated on large scale that affects the Indian economy in so many ways. The crop yield had been diminishing due to pests' attacks and many farmers predicted it out of their previous experiences or expert assistance. There is the possibility of an inaccurate prediction of diseases, substantiating the need for latest technology.

Understanding of agricultural issues, farmers need to have relevant knowledge of the happenings at the surroundings for making fruitful decisions. In agriculture domain through the development of an information management system, farmers get assisted with the help of telephonic communication and helped with multimedia which is easily accessible. The various climatic conditions lead to pest attacks on the crop, leading to tremendous amount of economic losses to the farmers, which mostly is the outcome of unawareness regarding diseases and their preventions among farmers.

So there is a vital need to solve the problem in the domain and to design automatic system to spread awareness of the pest attacks on the crops among the farmers. It will help to restore crop's health and put it back on higher growth. This paper proposes an e-Agriculture cloud based android application framework consisting of soil health monitoring and considering environmental parameters that are taken from open weather map web APIs. The different modules of implemented system help farmers to make gainful decisions with needful information required throughout the entire farming cycle.

The proposed system spreads awareness of the disease attacks on the crops. Also it will forewarn farmers about the disease that can occur on their crops which will be detected by data collected from the various sensors. The proposed system got trained using machine learning algorithm to predict disease attacks and message farmer about the same.

2. Related Work

In one of the research, authors briefed about the current key issues in agriculture field to prevent crops infected due to pests. It also tells about the traditional methods like manual investigation, geographical information system etc. To overcome the disadvantages of these methods this paper proposes an IOT system using wireless sensor networks which are having high density, wide range, and strong dynamic characteristics, so it has become an effective method for collection and transmission of agricultural information [1].

The paper [2] highlighted a revolutionary technology that represents the future of computing and communications. Modern technologies can control the cost, maintenance and monitoring performance. Satellite and aerial imagery play a vital role in modern agriculture. Also the authors surveyed some typical applications of agriculture sensor monitoring network technologies using cloud computing as the backbone. The simple agriculture model was being addressed with wireless networks. This survey is used to understand the different technologies and to build sustainable smart agriculture.

In the research paper [3], authors provided the information about network architecture in agriculture along with the pest monitoring system. GPS technology is used to get the location of tagged objects and acquire the relevant information. For the transmission of information, wireless sensor networks (WSN) and GPRS/GSM are the mainly used network technology in the field of agriculture. The information platform of disease and insect pests monitor based system integrated all kinds of information such as the agricultural management knowledge, purchase, warehousing, delivery and retail. It also realizes the information interchange between different phases.

The authors in their research described the way that communication technologies and intelligent context-service system provides autonomous decision without human interactions. They used LoRa WAN technology and compared it with ZigBee network. Also the paper presented the design of smart communication system manager used as low cost irrigation controller which can get controlled remotely by mobile phone. There exist many additional sensors and devices which could add new and useful features to the agro-system if they could only be integrated with it. They aimed to make more efficient multimedia platform to determine the most efficient decision to manage and monitor their agricultural fields, especially for fertilizing tasks [4].

The work presented by authors in [5] is the result of a preliminary analysis to realize an integrated microwave system for weed seed bank depletion. An overview of the main sub-systems was given along with the prototype realization. The paper presented a general preliminary overview of a system connected to communication infrastructure in order to improve agriculture. The core of the system was the weed seed bank depletion by means of microwave based heating solution. The microwave technique was supported by a vision system, which would be used both in visible and infrared bands according to different crops in order to maximize its efficiency and a GPS based localization system. All the parameters to program and control the proper working of the systems, as well as measured data, was available with a specific application, making the whole system perfectly integrated in the world of Internet of Thing (IoT). Some technology solutions are addressed and some possible choices to realize each section are reported. The description of the whole system is reported as well.

3. Design and Implementation

In agriculture, each kind of diseases and pests is considered to be harmful to plants and has a abundant adverse effect on agriculture. Therefore, the IoT based system is designed to help and reduce the frequent use of insecticides and fungicides. Also to predict when the pests appear in order to lower the appearance of pests. The forewarn and monitoring system of agricultural disease is divided into four different categories such as sensor node for acquisition of monitoring information, intelligent data processing modules as a weather station, prediction modules, user application, web-server and wireless communication technology. Weather stations gather and forward real time weather information. The designed system uses local weather forecast data for cumulative temperature in next 48 hours.

The humidity, temperature and soil moisture data are taken from sensors attached to sensor node and other required rest of the environmental parameters like rainfall, evaporation rate, sunlight and wind speed which are responsible for causing diseases in crop fields are taken from open weather map web APIs [7]. The various machine learning techniques are applied to data sensed from environment through sensors. The results obtained by this algorithm are useful for farmers to take decision about disease conditions in advance for further implantation in the crop monitoring system. The following figure 1 shows the implementation framework of the designed system.

This system consists of ESP8266 NodeMcU module which is the main part of the system used for interfacing purposes. Three different types of sensors are used for measuring soil conditions and levels of water. These three sensors are namely RHI-112A humidity sensor, YL-69 Soil Moisture sensor and Davis 6470 stainless steel Soil temperature sensor probe. All these sensors are interfaced with NodeMcU. The Support Vector Machine based regression system is implemented for identification and classification of pest diseases.

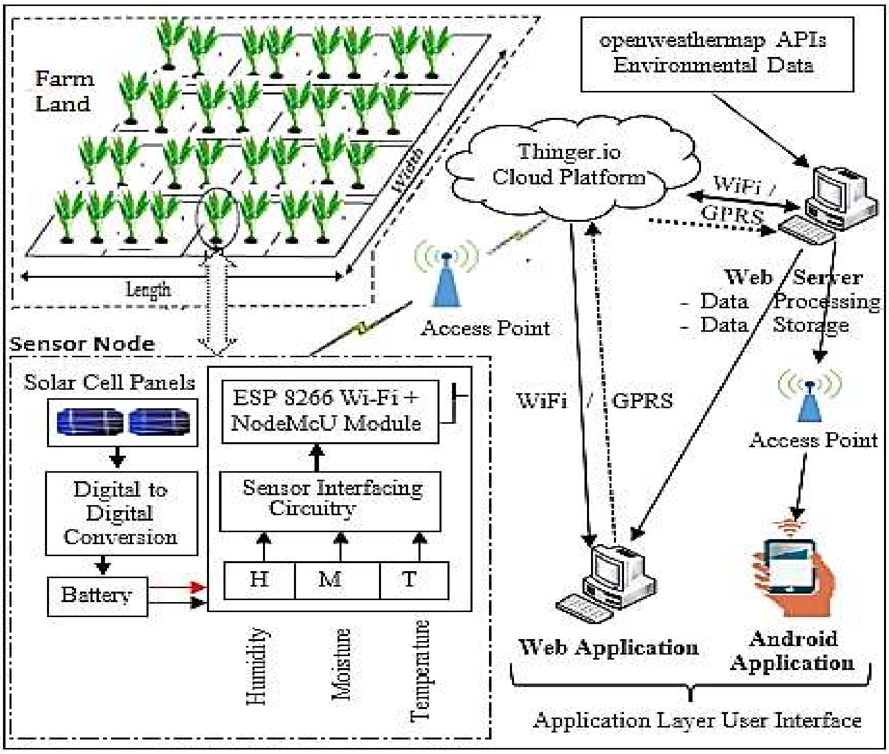

Figure 1. Implementation framework of IoT enabled Smart Agro System

Support Vector Machine (SVM) is a supervised machine learning algorithm that is used for both classification and regression challenges. However, it is mostly used in classification problems. In this algorithm, each data item is plotted as a point in n-dimensional space (where n is a number of features that are considered) with the value of each feature being the value of a particular coordinate. Then, the classification gets performed by finding the hyper plane that differentiates the two classes very well as shown in following figure 2.

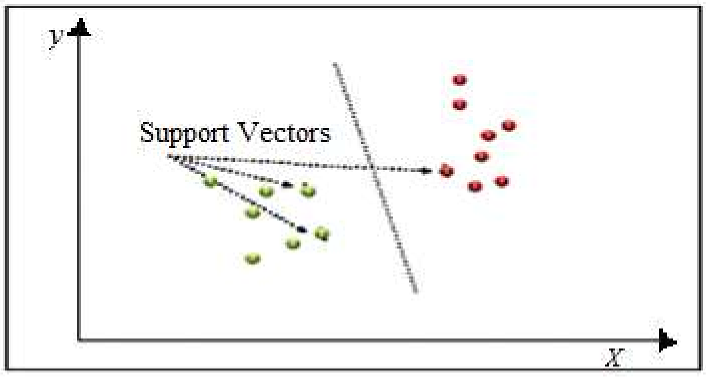

Figure 2. SVM Classification

Sensor nodes are laid on targeted farmland areas to get real-time data and collected environment signals are treated as a source of information. The data collected is stored in a database. The sensor technology is used for data acquisition and is mainly focuses on to capture part of the existing data. Also it can be used to correlate and synchronize, analyze these data elements and finally, carry out a responsive activity without user intervention. After processing, a disease that can occur will be identified or predicted, if disease occurred then a farmer gets informed with message in his local language informing the same and guided for corrective actions. This system is a low cost effective system that will boost the production of crops in agriculture and will lead to fewer losses and a happy farmer.

The farmers who are users of system should be able to register themselves by installing a "Fore Warner" web application and request. The sensor Node hardware module will get installed on farmer's farm.

The Administrator will manage all backend functionalities through a website. The farmer is able to do the following functions:

- Make new registration with device Id
- Login into system with valid username and password
- Add crop details
- Monitor the field and view result

The Administrator can do the following different functions:

- Get detailed entries of registered farmers
- Manage database records
- Control all network functions

The multi-target regression algorithm is used for implementation of this system which will fit parameters like Maximum Temperature, Minimum Temperature, Maximum Humidity, Minimum Humidity, Rainfall, Evaporation rate and Sun Shine Hours (SSH) and predict the pest value of the disease if a value greater than zero occurs then a logic called predicting logic will be used which will then predict if the disease actually occurs using the threshold value for disease. This logic will give accurate results for the pest prediction.

- **Multi-target Prediction**

For a feature vector *x*, predict accurately a vector of response *y* using function *h* (*x*):

$$x=(x_1, x_2, x_3, \ldots, x_p) \xrightarrow{h(x)} y=(y_1, y_2, \ldots, y_m) \quad (1)$$

The main challenge is to appropriately model target dependencies between targets.

- **Marginal and conditional dependencies**

$$P(Y) \neq \prod_{i=1}^{m} P(Y_i) \qquad P(Y \mid x) \neq \prod_{i=1}^{m} P(Y_i \mid x) \quad (2)$$

marginal (in) dependence ≠ conditional (in) dependence

The following table 1 shows a sample data set which is used to train the prediction module. The dataset consists of various parameters like pest value, maximum temperature, minimum temperature, relative humidity, rainfall, wind speed, sunshine hour, evaporation, disease, and city. This dataset is used for training the SVM classifier model. This data set is taken from Central Research Institute for Dryland Agriculture (CRIDA) website [8] which is an ISO 9001 certified.

Table 1. Sample Dataset for Disease Prediction Module

Pest value	Max Temp. (°C)	Min Temp. (°C)	Relative Humidity 1 (%)	Relative Humidity 2 (%)	Rain Fall (mm)	Wind Speed (kmph)	Sunshine Hour (hrs)	Evapo-ration (mm)	Disease
0	26.1	9.6	66.6	27.9	0	3.5	4.3	3.3	No disease
0	28.6	10.9	75.4	33	0	2	4.6	3.4	No disease
0	30.8	15.3	69.4	26.7	0	3.7	5.1	3.9	No disease
0	29.6	14.2	75.7	27.7	0	4	6.1	4.3	No disease
0	28.5	11.4	68.3	26.1	0	3.7	6.8	4.3	No disease
0	29.7	17.3	60.6	25.3	19	4.5	6.1	3.9	No disease
0	31.7	16.5	74	36	0	3.5	6.9	4.6	No disease
0	34.3	18.9	68.7	31.3	4	4.1	7.4	5	No disease
0	35.1	18.2	53.1	22.6	0	5	7.5	6.2	No disease
0	36	18.8	79.3	44	0	3.7	7.7	6.5	No disease
0	35.4	19	62	31.1	0	4.8	6.2	6.5	No disease
0	38.8	20.4	62.6	24.9	0	3.8	7.6	8.3	No disease
0	39.2	22.9	56.4	21	0	4.4	7.5	8.9	No disease
0.02	27.5	23.3	77.9	49.9	198	1.1	5.7	2.3	American BollWorm
0.32	29.6	23.5	85.3	68.9	56	2.2	5.7	3.1	American BollWorm
0.18	28.3	23.1	89	75.9	54	1.1	5.7	3.2	American BollWorm
1.52	32.5	22.9	88.9	83.3	0	3.4	4.8	4.9	American BollWorm
1.5	34.6	23.1	92.3	79.6	7	1.3	6.3	5.4	American BollWorm

4. Observations

The efficient communication framework for wireless sensor networks helps to transfer data accurately in IoT applications. The new approach based on the idea of sharing a dynamic cryptic credentials ensures security to sensor based applications without increasing communication cost for wireless networks with minimal energy consumption.

The system monitors the changes in the environmental conditions like temperature, humidity, rainfall, wind speed, sun-shine-hour etc. The pest/diseases which affect the crop mostly requires given environmental conditions to be in specific range for a pest to attack the crop. The humidity, moisture and temperature values are collected through sensors i.e. the real time data to detect the possibility of pest attack. The detection of crop disease along with disease name and its occurrence is getting identified by monitoring farm field conditions based on the parameters mentioned in table 1. Different supervised learning algorithms can be used to do this kind of classification like Decision Tree (DT), Artificial Neural Network (ANN), Bayesian Network (BN), k- Nearest Neighbors (kNN) and Support Vector Machines (SVM) algorithms. Metrics points that shows efficiency SVM over all others can be given as below;

Accuracy (A): precision of the classifier in predicting a value.

Tolerance to noise (TN): ability of the classifier to handle erroneous data in the training process.

Speed of learning (SL): speed of learning of the classifier.

Speed of classification (SC): speed of the algorithm in classifying a new instance.

These metrics can have values between 1 and 4, with 4 being Excellent, 3 Good, 2 Average, and 1 Poor. The results obtained are presented in figure 3 as shown below.

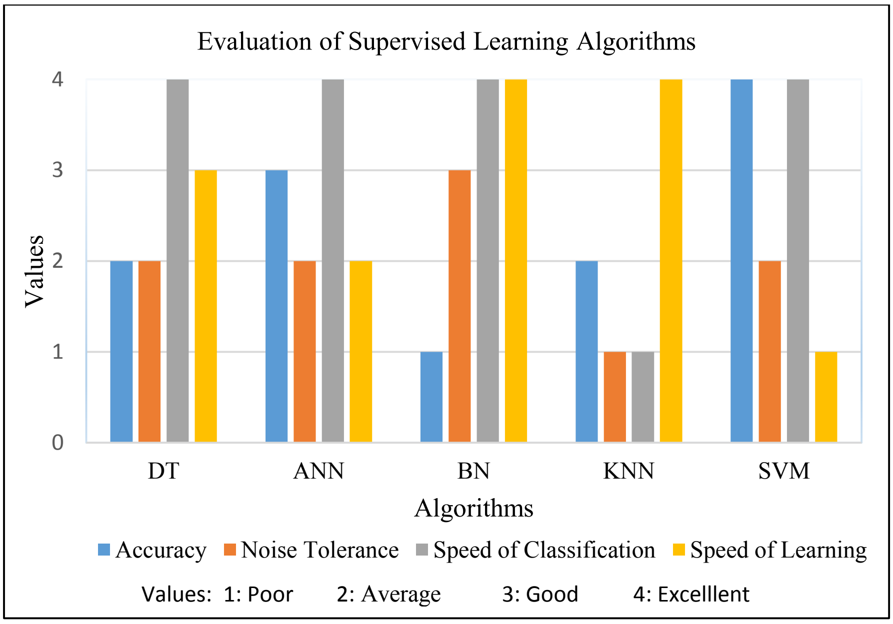

Figure 3. Evaluation of Supervised Learning Algorithms

This IOT based system by considering soil temperature, moisture, humidity, and other abiotic stresses along with SVM classification is also evaluated for different kinds of crops and for probable diseases that can be caused.

The following figure 4 shows the relationship among temperature, humidity, moisture and other environmental Parameters for the prediction of American Bollworm (Larva) Disease related to cotton crop. The machine learning algorithm predicts the appropriate disease based on the training datasets and the input parameters provided to it.

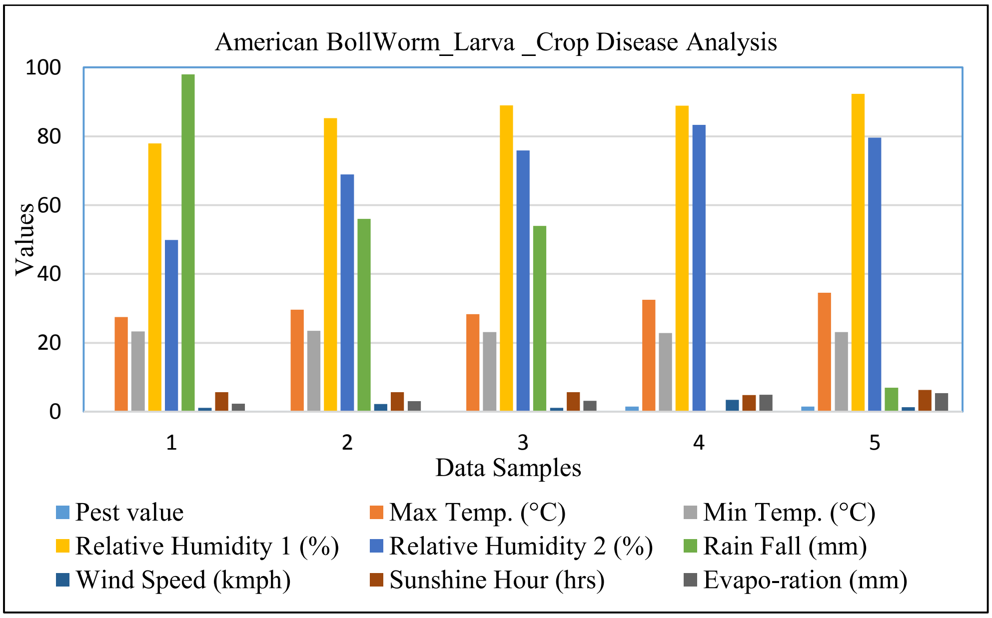

Figure 4. A relationship between temperature, humidity, moisture and other environmental parameters for prediction of American Bollworm (Larva) Disease

Support Vector Machine (SVM) method proposed by Vladimir Vapnik for classification and regression problems can also use to predict the severity of the fungus called rice blast, which attacks rice crops. Used training data were collected between 2000 and 2004 [14]. However, they compared SVM with other approaches. These approaches as Conventional Multiple Regression (REG), Generalized Regression Neural Network (GRNN) and Back

Propagation Neural Network (BPNN). Mentioned algorithms are applied to obtain results to calculate the absolute percentage error (APE). It is observed that SVM is the most accurate in predicting the severity of rice blast with %APE equals to 36.69. Similarly other algorithms presents results as GRNN with %APE equals to 46.37, REG with %APE = 65.44 and BPNN with %APE equals to 52.27.

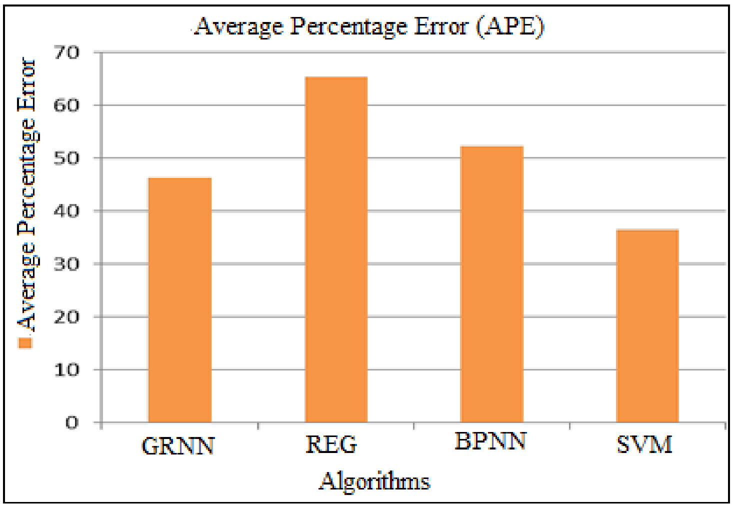

Figure 5. Comparative Analysis of Average Percentage Error (APE) of different algorithms for predicting the severity of the fungus Pericularia oryzae

5. Conclusion

The system is going to perform prediction on real-time data sensed by sensors which will reduce hectic image processing task and can be used to predict pests and diseases that may affect their crop by using machine learning algorithm. Also according to temperature and humidity when the infection rates are high, the system alerts the end user (farmer) in their native language. In addition to this, beforehand it also notifies the control timing of the harm caused by the cumulative temperature. It will reduce the burden of farmers by preventing them from manual monitoring of the field.

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