A SMART DRONE FOR ENSURING PRECISION AGRICULTURE WITH ARTIFICIAL NEURAL NETWORK

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Abstract

The smartness in agriculture can be built through incorporating technologies like wireless sensor network, cloud computing, artificial intelligence, big data analytics and internet of things (IoT). Field/Crop management, irrigation control, water management and nutrient management are the few solutions that driving the smart farming. The unmanned aerial vehicles (UAVs) facilitate the field and crop monitoring solutions without any environmental disturbs. The drones in correlation with crop management and field analysis, estimates the factors like chlorophyll content, leaf variation index and vegetation index to make a decision about the healthiness of the plant as well as land. The proposed approach is planned to yield accurate, cost-effective and multipurpose drone into the place. The imaging techniques of camera and its efficiency are inherently analyzed and applied in design to make accurate and timely decision. Further the images received from the sensors are processed with artificial neural network models to optimize the performance of the system. By feeding intelligence, the spraying task of the drone can be automated. The efficiency of the proposed intelligent model is evaluated against most popular artificial neural network (ANN) algorithms experimented in existing works like naïve bayes, K-nearest neighbor (KNN), support vector machine(SVM), decision tree and random forest.

Keywords: Agricultural Drones; Artificial Intelligence; Internet of Things (IoT); Precision Agriculture; Wireless Sensor Networks.

1. Introduction

Agriculture is one of the major element predicts the economy of the country. Recent internet survey stated that the contribution of agriculture in gross domestic product (GDP) is increased to 19.91% in the duration of 2020-2021. Also it is mentioned that the India's contribution in agriculture is higher than the world's average share in the domain.

Though everyday technologies are booming, still our farmers in rural area depend on contemporary mechanisms. The major activities of farming like land preparation, seeding, fertilizing, irrigation and harvesting are highly demands forecasting of weather, healthiness of field and crop. The traditional setting requires man power and machineries to carry out these tasks, in turn increases the cost of cultivation. The economic survey

published on 2018 confirmed that labor force for agriculture would fall up to 25.7% by the year 2025. As a result confined with that report, farmers in rural areas are started to migrate their occupation.

In general note, precision agriculture or farming is managing the farming activities much controlled way in yielding better productivity of crops. The developed countries started using current technologies like Internet of Things (IoT), big data analytics, cloud computing, artificial intelligence and software applications to enable precision agriculture[Bhakta et al. (2019), Valluri and Sharma (2020), Akhter et al. (2021)]. The challenges associated in achieving precision farming employing the advanced technologies listed are as follows:

- Lack of knowledge on modern technologies
- Poor acceptance rate in adopting to newer technologies, as still have believe in older methods
- Wrong perception over costs of practicing the technologies

Forecasting weather and the continuous monitoring of the growth of crop, field and equipment bring promising increase in its productivity. In aligned with that the proposed work aims to design a drone that monitors the field, crop growth and weather condition of specified region regularly. It is also planned to incorporate the spraying seeds and water automatically responding to the observed conditions from the connected devices in role.

2. Related Work

The deep investigation with interest in revealing the role of IoT is carried out [Farooq et al. (2020)]. The article captured the possible applications, sensors to be used, protocols for communication along with the challenges in applying the same. An exhaustive survey on significant contributions of researchers in bringing smart farming by adapting IoT as one of the major enabling technology is conducted [Raneesha Madushanki et al.(2019)]. Also [Ayaz et al. (2019)] put forth remarkable effort in obtaining the contribution of IoT in agriculture. It is also enlisted the appropriate sensors to be used with various activities of farming from sowing to harvesting. A smart solution to monitor the crops adapting to IoT is implemented [Doshi et al. (2019)]. The IoT device is designed in a way to monitor through assessing the field health like soil moisture level, nutrients value, humidity and temperature.

An IoT platform to monitor the soil health using a control box is built [Muangprathub et al. (2019)]. Using association rules in data mining technique, analysis the data received from soil moisture sensor, it predicted the time for watering the plant through an alert provided to the farmer via a mobile application. Furthermore it discussed the role of unmanned aerial vehicles (UAV) and its applications in agriculture. The authors [Daponte et al. (2019), Gurappu et al.(2021)] proposed a survey over the techniques available for precision agriculture. The use of drones with cameras and its possible applications in this domain is also elaborated.

An unmanned aircraft, i.e. a drone for facilitating the field health analysis is designed [Ipate et al. (2015)]. The drone is equipped with appropriate sensors to capture the field as well as crop health and enclosed within the quad copter frame. An agriculture robot in a way to envision the precision farming is developed [Saheb et al. (2017)]. The main component of the robot is the drone. The drone is redesigned to spray seeds over the field. The nozzle design is found to be insufficient to handle the different varieties of crops. The proposed design is able to handle only maize crops with minimum seeding capability. Also the balancing factor of drone while seeding was not addressed. [Rao Mogili et al. (2018)] after his exhaustive survey on agricultural drones and its applications, developed a drone to effectively monitor field and spray pesticides to reduce the harmful effects imposed to the labors while doing so. [Shaw et al. (2020)] devised a drone to spray disinfectant accommodating a payload of 6 litres. The drone adopted the octocopter frame which has eight arms in order to support the payload specified.

The exhaustive studies in order to portray the machine learning methods in smart agriculture are carried out [Liakos et al. (2018), Priya et al. (2018), Sharma et al.(2021)]. Mobile application for E-agriculture is designed empowering with machine learning algorithms [Adebiyi et al.(2020)].In [Balducci et al. (2018)] tested the effectiveness of machine learning algorithms in precision agriculture. The data retrieved from field sensors are evaluated with various machine learning algorithms like neural network (NN), decision tree and KNN. The neural network based approaches outperformed others in this study. The promising predictive efficiency of random forest is addressed [Jeong et al. (2016)]. A multimodal design for precision agriculture is proposed and the effectiveness of machine learning algorithms are exercised [Garg et al.(2021)].

3. Proposed Drone Design

The UAVs or drones are of two types: fixed width and multi-rotor (provided with multiple arms typically 4-8 that eases the lifting function and improves the load capacity). The drones are equipped with smart sensors like camera in order to detect the liveliness and quality of crops and fields. In existing system, an agricultural drone is accounted to be costly and used for the following purposes:

- To monitor the health of the crop or field

- To spray pesticides in order to alleviate hazardous effects absorbed by the labors

The IoT based smart farming solution enables a paradigm shift in contemporary farming cultivation into proactive services. Through predicting the conditions of land, crop and weather in advance, the farming activities are streamlined into a right track. This in turn increases the productivity of the crops, meets the feeding rate of growing population.

The proposed system is planned to offer remarkable effort to field and crop health tracking using a portable drone designed with automated capability. The farmer located from anywhere can access the drone. The significant contributions of the proposed system are discussed in the following sections.

3.1. *Effective Design with Eight Rotor*

It involves the design of field network in acquiring the health of soil and images of drone in assessing the quality of the plant. The drone is designed to have eight rotors in order to increase the capacity and coverage [Shaw et al. (2020)]. Also it is equipped with multispectral camera to obtain deep insight and high resolution of images. To incorporate multipurpose, the two different designs of nozzles are used. Flat fan type of nozzles can handle spraying liquidated fertilizers and water on demand. But a novel design is required to move with seeding and is scheduled to design in this work. The 2-Dimensional (2D) drawing and computer aided system design (CAD) for the proposed drone is presented as Figure 1.

(a)   (b)
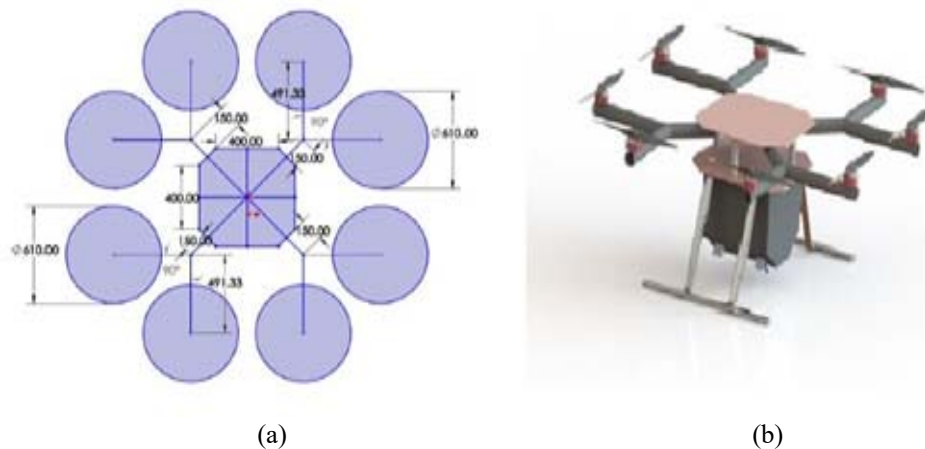
Fig. 1. Proposed drone presenting a) 2D Drawing and b) Simulated Design with CAD Software. (Source: Shaw et al. 2020)

The equations associated with calculating the thrust force of the drone surface is given as Equation 1 and the linear motion aligned with thrust and gravity is expressed as Equation 2.

$$T=\sum_{i=1}^{4}T_i=K\begin{bmatrix} 0 \\ 0 \\ \sum w_i^2 \end{bmatrix} \qquad (1)$$

$$m\ddot{x}=\begin{bmatrix} 0 \\ 0 \\ -mg \end{bmatrix} + R \bullet T + F_D \qquad (2)$$

Where R is the rotation matrix which is a cosine transformation matrix given below as Equation 3.

$$R = \begin{bmatrix} c(\theta)c(\psi) & s(\theta)s(\psi) & -s(\theta) \\ c(\psi)s(\theta)s(\varphi) - s(\psi)c(\varphi) & s(\psi)s(\theta)(s\varphi) + c(\psi)c(\varphi) & c(\psi)c(\varphi) \\ c(\psi)s(\theta)s(\varphi) + s(\psi)s(\varphi) & s(\psi)s(\theta)c(\varphi) & c(\psi)c(\varphi) \end{bmatrix} \quad (3)$$

To formulate the field sensory network, the appropriate choices of soil moisture, temperature and humidity sensors are selected and integrated with the microcontroller. The circuit design for the same is captured as Figure 2 as below.
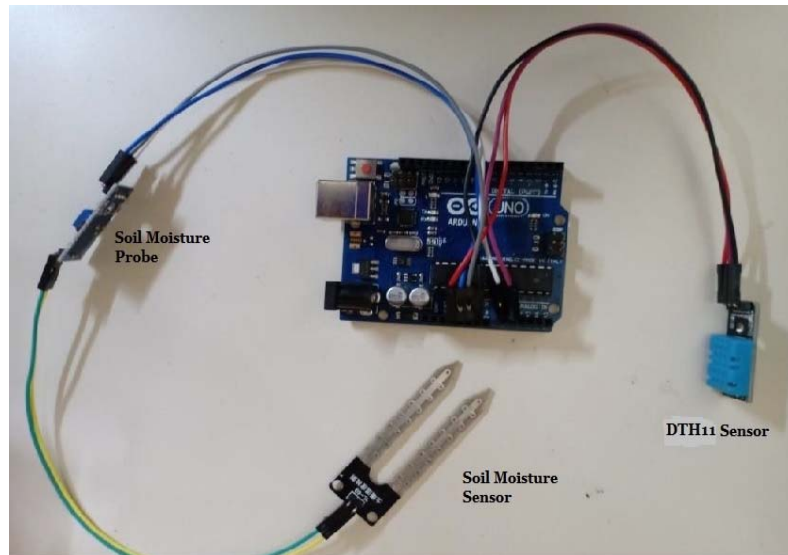

Fig. 2. IoT prototype of smart agriculture sensor network.

3.2. Intelligent Algorithmic Design

3.2.1 Overview of ANN Algorithms

The most common choice of algorithms adapted for effective decision making associated with this problem domain are as follows:

- **Naïve-Bayes:**
  Naïve-Bayes is a type of supervised learning mechanism, easy to use and implement. It uses the bayes theorem provided in Equation 4, to make a decision about class of the data. It is faster and works for multi-class prediction problems too. In order to handle categorical data well effectively, requires smoothing techniques in place.

$$P(c/x) = \frac{P(x/c)P(c)}{p(x)} \quad (4)$$

- **Support Vector Machine (SVM):**
  SVM falls under the category of supervised learning algorithm, used in solving classification and regression problems. For classification, plots the data in a graph, computes the hyper planar space using the formula as given Equation 5. It works well for high dimensional data whereas handling large dataset with noisiness slows down its time efficiency.

$$f(x) = w^T x + b \quad (5)$$

- **K-nearest neighbor (KNN):**
  KNN is one of the supervised algorithm, classifies the available data through deriving the similarity exists between the data by the calculating the Euclidean distance given in Equation 6. It is very easy to understand and implement, but it exhibits slow performance for larger datasets [Balducci et al. (2018)].

$$D = \sqrt{\sum_{i=1}^{k}(x_i - y_i)^2} \quad (6)$$

- **Decision Tree:**
  Decision tree is also an unsupervised learning technique, able to address classification and regression problems well. By mimicking the human thinking, to solve classification, it draws a tree based structure through branching the decision node with simple yes or no questions to obtain an output in leaf node. The formula's used with decision is projected in Equations 7 and 8. The randomness in data calculated as entropy (E) and the effective change is captured in information gain (IG) [Balducci et al. (2018)].

$$E = \sum_{x \varepsilon X} p(x) \log_2 \frac{1}{p(x)} \tag{7}$$

$$IG = E - \sum_{i=1}^{n} p(x_i) * E_i \tag{8}$$

- **Random Forest:**
  Random forest is a supervised learning mechanism, handles classification and regression problems well. It works under the concept of ensemble learning which uses multiple classifiers in order to improve accuracy. It generates number of decision trees based on features of data, the output picks the well effective choice of features that ensures the high accuracy [Jeong et al. (2016)].

3.2.2 Fine-tuned Random Forest with Linear Model (FRFLM): Proposed Model

The processing is powered by cloud platform in this design. The data collected from the various sensors and drones are imported to cloud server to enable data storage and analytics process. In this model, to predict desired condition accurately, a novel classification strategy is proposed by optimizing the random forest algorithm with linear. The proposed classification is hybridization of random forest with linear model. The linear model is exercised here to improve the feature set selection which in turn reduces the error rate of classification process. The skeleton of the proposed algorithm is provided as Table 1.

Algorithm: Fine-tuned Random Forest with Linear Model (FRFLM)
Input: Dataset (Weather and Soil Characteristics)
Output: Predicted Soil healthiness (can be used to arrive the decision about best time to propose irrigation, cultivation and pest control)
1: Obtain a dataset
2: Apply pre-processing to find missing and redundant information
3: Partition the dataset employing decision tree
  3.1: for $\forall a$ (attributes) in dataset do
  3.2: for each value x do
  3.3: Apply decision tree to yield output decision trees namely dt1,dt2,…dtn
4: Classify the resultant decision trees based on its error rate calculation
5: Fine tune the decision tree by filtering attributes having high scope for classification accuracy using the linear model formula given in:

$$\sum_{0}^{n} g(n) = dt + n_1 x_1 + n_2 x_2 + \ldots + n_n x_n \tag{9}$$

$$\sum_{0}^{n} g(0) = gain + \sum_{0}^{n} w_i x_i \tag{10}$$

TABLE 1 Skeleton of the proposed classification- FRFLM.

4. Results and Discussions

The generic workflow of the proposed system is illustrated in Figure 3. In the dataset, the presence for missing and redundant values is analyzed in the name of pre-processing. Now the data is ready for classification. The proposed FRFLM is exercised to obtain the predictions about soil health. This section reveals the details about the dataset used as an input, the implementation environment through which the proposed model is exercised and also the performance metrics evaluated to determine the efficiency of the work.
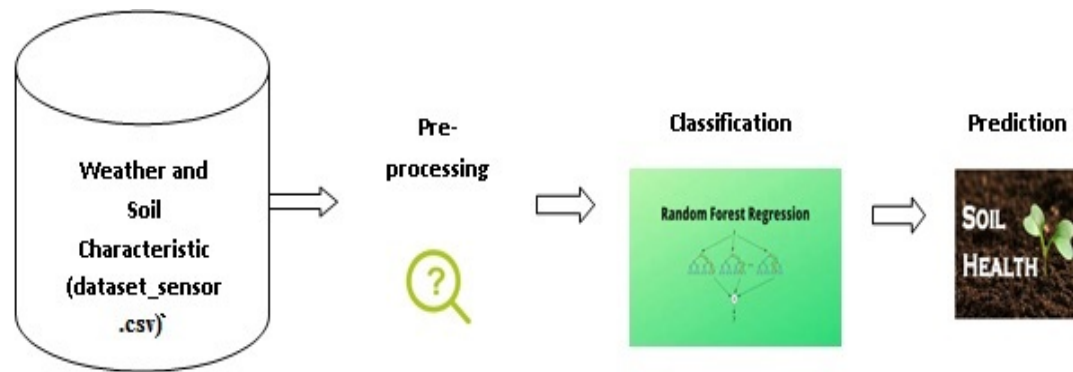
Fig. 3. Generic workflow of the proposed system.

4.1. Description of Dataset

The proposed algorithm is experimented over the publicly available dataset under Kaggle grouped into weather and agriculture dataset and entitled as dataset_sensor.csv. It captured the soil characteristics like soil moisture and temperature, solar radiation and weather pattern like atmospheric moisture and temperature. By ascertaining the list of features in the dataset, soil health is assessed with the help of the proposed algorithm. Few of the data readings from the input dataset are provided as a sample in Table 2.

weather_temperature	weather_humidity	solar_radiation	soil_moisture	soil_temperature
23.7	57.7	35	59.66	23.38
23.4	57.2	33	56.85	23.19
23.4	56.9	32	54.82	23.19
23.5	56.8	33	53.24	23.19
23.7	58	32	52.16	23.5
23.7	58.1	32	50.99	23.5
23.7	58.1	32	50.79	23.44
23.7	58.1	32	50.7	23.5
23.7	58.1	32	50.48	23.5

TABLE 2 Sample readings from the input dataset.

4.2 Execution Environment

The TensorFlow 2.0 which is developed by Google team chosen as the execution environment to assess the performance of proposed model. It became one of the most popular choices of platform to experiment the different machine learning algorithms, as it is available as open source and easily accessible by anyone. The system requirements for running exercises in TensorFlow environment is summarized in Table 3.

Software Requirements	Hardware Requirements
Microsoft Visual C++ Redistributable pip 19.0 Python 3.5 Raspbian 19.0 Windows 10	Central Processing Unit (CPU) : Intel Core i7- 2.9Ghz Graphics Processing Unit (GPU) : NVIDIA GTX 1050 Ti with 4 GB RAM

TABLE 3 System requirements for enabling execution set-up.

4.3 Evaluation Metrics and Results

The metrics used to evaluate the performance of the proposed model are listed below with respective formulas addressed in equations 11 to 16.

- Accuracy(A_c): The term accuracy denotes the correctness
- Precision(P_c): Precision is the ratio of correct positively predicted value to the sum of positives
- Recall(R_c): The sensitivity or recall is the ratio denoting number of true positive predictions by the sum of true positive and false negative value
- Specificity(S_P): The term is the ratio denoting number of true negative predictions on total number of negatives
- F-measure(F_M): It refers the harmonic mean value of the precision and the recall
- Error Rate: It gives us the measure of how far the predictions were from the actual output

$$A_C = \frac{T_P + T_N}{T_P + F_N + F_P + T_N} \tag{11}$$

$$P_C = \frac{T_P}{T_P + F_P} \tag{12}$$

$$R_C = \frac{T_P}{T_P + F_N} \tag{13}$$

$$S_P = \frac{T_N}{T_N + F_N} \tag{14}$$

$$F_M = 2 \times \frac{P_C \times R_C}{P_C + R_C} \tag{15}$$

$$Error\ Rate = \frac{F_P + F_N}{T_P + F_N + F_P + T_N} \tag{16}$$

The experiment result of the proposed technique is evaluated against the other classifiers like naive bayes, KNN, SVM, decision tree and random forest and it is summarized as Table 4.

Classification Models	Evaluation Metrics					
	Accuracy	Precision	Recall	Specificity	F-Measure	Error Rate
Naïve-Bayes	75.8	90.5	79.8	60.0	84.5	24.2
SVM	86.1	86.0	100	0.0	92.5	13.9
KNN	82.9	89.6	90.2	25.0	90.2	17.1
Decision Tree	85.0	86.0	98.8	0.0	91.8	15.0
Random Forest	87.2	87.1	98.8	10.0	92.4	13.9
Proposed FRFLM	88.4	90.1	92.8	82.6	90.0	11.6

TABLE 4 Performance result of proposed method with other classifiers.

In comparing with other classifiers, the proposed FRFLM algorithm facilitates its overall accuracy as 88.6% as in Figure 4. It is observed that the proposed FRFLM is 1.4% accurate than random forest and 16.7% accurate than naive bayes. It is clearly envisioned that the proposed model exhibited very less error rate as 11.6% as comparing with other classification techniques and it is mapped in Figure 5.
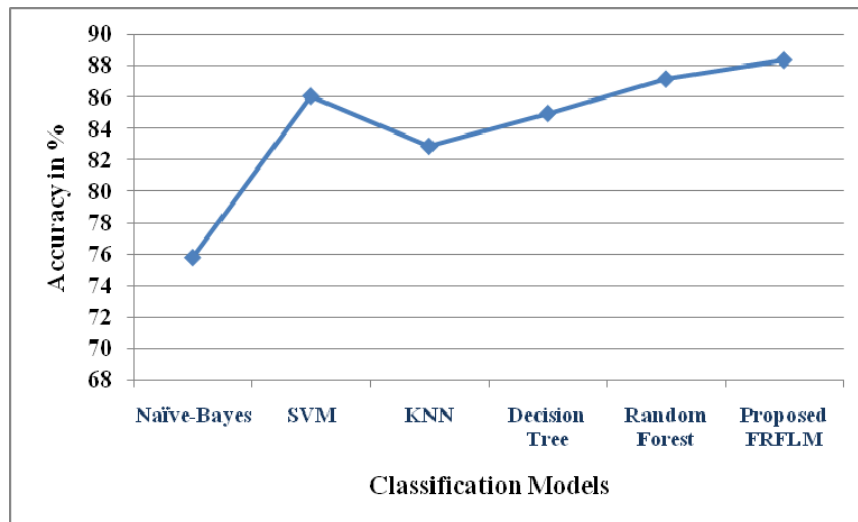
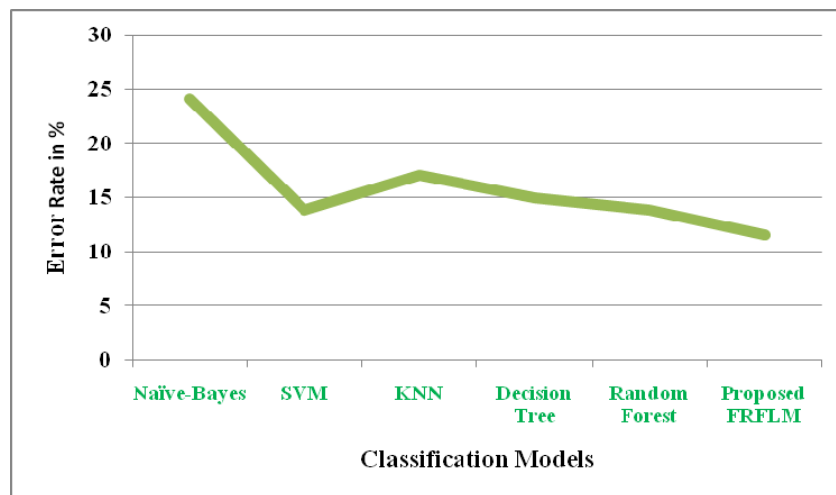Fig. 4. Accuracy map of proposed model with other methods.

Fig. 5. Error-Rate analysis of proposed model with other approaches.

The evaluation result of proposed classifier model with the other selected classification strategies including all the performance metrics is visualized as in Figure 6.
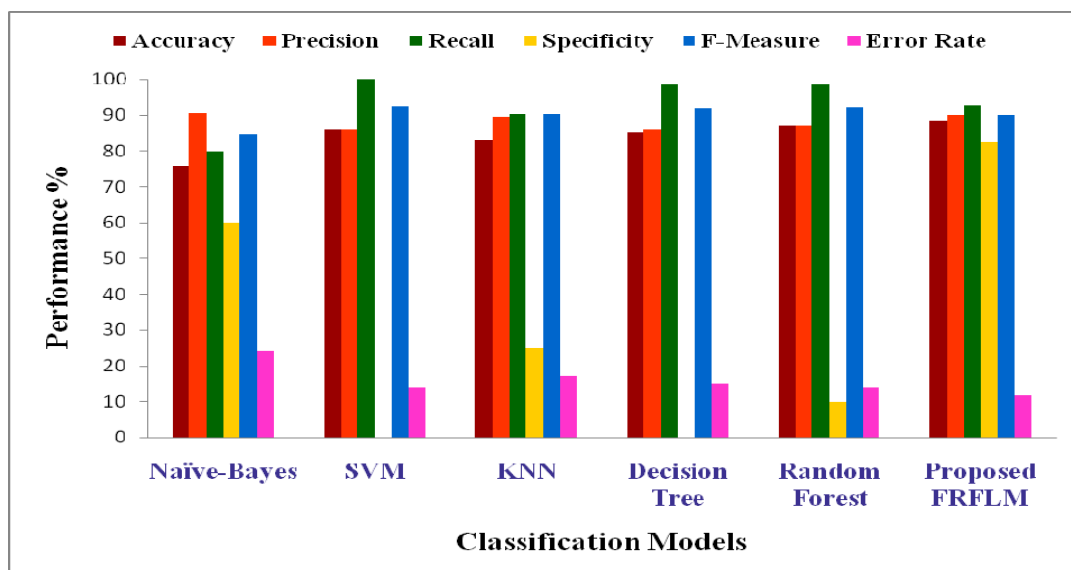

Fig. 6. Performance analysis of proposed model with other approaches.

5. Conclusion

The proposed work highlighted the usage of multimodal system (IoT sensors, drones and weather stations) for precision agriculture. The effective design of agriculture drone with improved rotors is discussed. In improving the predictive accuracy, a novel version of random forest algorithm adjoined with linear model (FRFLM) is implemented. The experimental results of proposed model showcased the high accuracy as 88.4% with less error rate as 11.6%, while comparing with other machine learning candidates of choice. Here the system is interested to evaluate the health of soil. In future, the same method can be tested in making decisions about irrigation, soil quality analysis and crop damage control.

Acknowledgments

Conflicts of interest

The authors have no conflicts of interest to declare.

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