IEEE Access
Multidisciplinary ⋮ Rapid Review ⋮ Open Access Journal

Received 28 February 2024, accepted 15 April 2024, date of publication 22 April 2024, date of current version 30 April 2024.

Digital Object Identifier 10.1109/ACCESS.2024.3391822

RESEARCH ARTICLE

Intelligent Control Shed Poultry Farm System Incorporating With Machine Learning

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This research was funded by Taif University, Taif, Saudi Arabia project number (TU-DSPP-2024-17).

ABSTRACT The traditional Control Shed Poultry Farm (CSPF) systems are operated manually or in a semi-automatic culture. The existing CSPF system is still not free from human intervention and needs 24/7 monitoring. The existing approach is laborious, prone to caretakers bias and human error, and repeatability is difficult. The Intelligent CSPF system is based on the Internet of Things (IoT) and Machine Learning (ML). The proposed approach comprises the learning and mastering phase. In the learning phase, the system will observe or learn from user behaviour patterns regarding poultry activity operations for a specific time duration. Upon completion of the learning phase, the mastering phase will eventually automate the system and control the poultry farm's environmental parameters, such as temperature, humidity, water level, light, and hazardous gases based on the historical data. The proposed system will replicate the operator's past business control behavior. For this learning task, we have used Supervised ML techniques to analyze the performance of ML algorithms such as Random Forest (RF), Decision Tree (DT), K-nearest Neighbors (k-NN), Support Vector Machine (SVM), and Naïve Bayes (NB). DT is the successful ML classifier with the highest accuracy performed in the Intelligent CSPF System; this leads to the development of a smart CSPF culture where successful business experiences, i.e. models, will be exchanged among the community to get a collective benefit in terms of revenue.

INDEX TERMS Smart poultry farming, machine learning, sensors network, Internet of Things.

I. INTRODUCTION

According to the current survey of [1], the growth rate of the population around the world is 1.05% per year. The current average increase in population is 81 Million per year. With this growing index of the population, it is very important to meet the food requirement of the ever-growing world's population. Globally, the consumption of meat is 315 million tons per year. Overall chicken meat consumption in the world is 72% of all kinds of meat [2]. The production of chicken makes a substantial contribution to the global food economy and is greatly influenced by the environmental circumstances in which it is reared [38]. It is necessary to produce healthy poultry to meet the overall consumption requirement. Poultry farms are the major source of getting cheap protein-enriched meat and eggs for the population consumptions. The above reports, among the many, have indicated serious challenges ahead to provide healthy chicken for the overall population consumptions in the world. The CSPF systems are playing their major roles in the production of healthy poultry meat and providing it in the global markets. A successful poultry farming needs substantial care in terms of chicken health and continuous monitoring. Isolated systems are not very efficient like networked systems they have capability to generate more smart and autonomous programs [3]. Internet of Things (IoT) is playing a major role to merge communication network and sensor network. The Internet of Things (IoT) may play a significant role in this effort and be used to a number of

The associate editor coordinating the review of this manuscript and approving it for publication was Bin Xu.

agricultural industries, including farm monitoring, irrigation, insect monitoring, animal monitoring, smart greenhouses, and smart poultry farms [37]. It enables effective data management and processing, which are accomplished through various procedures [6]. Electronic tools that may be used to gather data from the environment around them are known as sensors [7]. A sensor network is made up of sensor nodes that are placed inside or extremely near to the phenomena. It is not necessary to engineer or plan ahead for the deployment of sensor nodes. Sensor nodes may be randomly deployed in inhospitable terrain or during disaster relief efforts [8]. A wireless sensor network (WSN) is used to connect several sensors so they may communicate with one another and wirelessly share data that has been collected [9]. Small, networked nodes with wireless communication, processing, and sensing capabilities make up a WSN. These sensors have the ability to communicate directly with a washbasin (also known as an external base station) or with each other [10]. The term "Internet of Things" (IoT) describes the direct or indirect connectivity of a communication network and a sensor network, with data management and processing carried out by intelligently watching these actions [11], [12]. In the Internet of Things, sensors and actuators are essential for connecting us to the actual world. It is composed of the phrases physical, smart, and connectivity, which define the wireless or cable connections that smart sensors, microcontrollers, microprocessors, and physically-based devices like actuators use to communicate with other electronic devices [13], [14]. IoT enables individuals to effectively manage their lives and businesses, as well as bring about fundamental changes in the world that have the potential to totally reshape business and industry [15]. The Internet of Things' capabilities enable the development of a wide range of applications in the aerospace and aviation, automotive, telecommunications, medical, healthcare, independent living, pharmaceutical, transportation, manufacturing, retail, logistics, and supply chain management industries. The most crucial goal of IoT is to remotely monitor individual things and the surroundings [16]. ML is the statistical part of Artificial Intelligence (AI). It is focused on the production of algorithms that make predictions based on data. A ML process consists of three main components i.e. input, machine learning model, and output. For instance, With the use of inputs like temperature, humidity, and precipitation, we hope to complete our assignment and forecast whether it will be sunny or wet. A machine learning (ML) model, which is at the heart of this prediction process, demonstrates how we may identify a suitable model to precisely map every possible combination of precipitation, humidity, and temperature to the actual weather. Neural networks, logistic regression, support vector machines, and deep learning are only a handful of the options available in current machine learning approaches [17]. The conventional CSPF systems are run manually or with some level of semi-automation. An IoT and GSM based framework introduced by [18] that limits the impacts of environmental uncertainties in the poultry farms. The system controls the physiological parameters like temperature, humidity, light on the farm with the least human interaction. The safety measures such as fire protection, anti-thief features which ensure overall surveillance of the farm has been incorporated. Data collected by the sensors transmit to the cloud based website ThingSpeak where all the parameters were being analyzed and controlled eventually. Along with these examinations, the framework can allow farmers that they can control the poultry farm remotely by their handheld cell phones. Another autonomous poultry environment observing framework proposed by [19] reliant on WSN. Real time monitoring of temperature, humidity, CO2, and NH3 gasses were figured out in the research. Sensors were deployed to collect the data. Furthermore, poultry farm's environment data is sent to the Web and enabling clients can remotely monitor and control the environment of the poultry farm. The existing CSPF systems were not free from human intervention and needs a 24/7 monitoring. These approaches are laborious, prone to caretakers biased and human error, repeatability is difficult. Further, the operation of the poultry farm is not transparent to the stake holder and the instant decision is not feasible. Traditional system also lacks communication and limited in the capacity to timely respond all the time against any changes on one or more than one poultry environmental parameters.

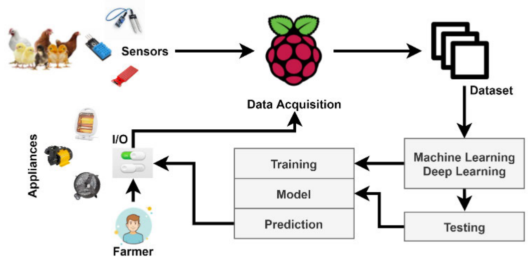

FIGURE 1. Intelligent control shed poultry farm system incorporating with ML framework.

The proposed Intelligent Control Shed Poultry Farm System is composed of IoT and ML. It will positively enable to address traditional or semi-automatic CSPF system and solution of aforementioned challenges. The proposed approach of this research comprises of learning and mastering phases. During the learning phase, the system will analyze and learn from user behavior patterns related to poultry activity operations over a specific period, which could span a week or even a month. IoT sensors are utilized to monitor and assess the environmental conditions of the poultry farm. Upon completion of learning phase the mastering phase will take place and start monitoring and controlling the environment parameters (temperature, humidity, water level, light and hazardous gases) using actuators are based on the historical data or in other words the system will replicate the operators past business control behavior. The system actions will be overruled by the user. The new action will be adopted by the system if the current behavior carried out persistently by the user. The organization of the paper is as follows: Section II enlightens the previous work proposed by the researchers. Material and Methods discusses in section III that presents the developments phases and equipment details used in the proposed CSPF system. In addition, Results and Discussions of the experimental testbed are provided in section IV, and conclusions are provided in section V.

II. LITERATURE REVIEW

An IoT based poultry protection and monitoring system was introduced by [20] the system can monitor various environmental parameters such as air temperature, air humidity, O2, CO2 concentration levels, and NH3 concentration. Sensors collect data effectively and wirelessly transmit it to a Raspberry Pi (RPi) acting as a gateway. The RPi is then connected to the internet via an Ethernet cable or USB Wi-Fi adapter. The system is accessible from anywhere through SSH remote login or by putty software by just putting RPi address in it. The system will notify the end user with a summary of certain parameters for a specific duration of time via SMS. Sim900 GSM module is used for notification. An IoT based system sheds' environmental control system [21] introduced that use to monitors both temperature and humidity levels in the poultry farm. It tends to monitor the poultry environment 24/7 to avoid incidents that caused the temperature to rise too high. RPi controls three programs that include a light sensor, temperature sensor and switches simultaneously controlled by the timer. The Birds Vital Monitoring System (BVMS) using RFID/NFC sensor was introduced by [22], motion sensor, temperature and weight measuring sensor. Monitor the weight of the birds using weighing machine equipped with RFID scanner. This is a unique addition into the system, based on the weight of the classification is carried out between healthy and non-healthy chicken manually. A WSN based approach to detect and report anomalies in the environment of the poultry farms was introduced by [23]. The chicken farm is primarily separated into four zones: the hatchery, the feeding area, the egg production area, and the multiplier breeder flocks zone, which produces broiler hatching eggs. Each zone has a unique local climate based on the zonal distribution and number of chickens. Three motes were placed in the feeding area as part of the monitoring setup to gather data on the variations in various climatic factors. Every particle throughout the three-hour timeframe took measurements of the temperature and relative humidity once every ten minutes. Collected data is sent to the Web-based application where users can access, monitor and take actions to control the environment of the poultry farm. An infected hen detection system [24], was deployed to analyze and identify the infected poultry using WSN and ML. The proposed work consists of audio and video analysis methods and comparing the results using MATLAB. The results show that MFCC sound feature extraction alongside the KNN medium has a better prediction for recognizing the sick poultry. The temperature control framework [25], in the egg hatchery for the Pelvic Inflammatory Disease (PID) was introduced to monitor chicken health using Pulse Width Modulation (PWM) method. The main objective of this system is to develop an automated system for hatching chickens that can use PID controllers to fix an incubator's temperature response so that it remains stable and in accordance with the set-point temperature value. Introduced by [26] the system uses GPRS and WSN connectivity to autonomously regulate and track environmental factors in the poultry farm. The internal environmental data of the poultry farm is available to farmers through text message on their registered cellphone number. The system takes action to control the environmental parameters if it detects there a sudden change in the environment. Reference [27], proposed a WSN based monitoring and controlling system that can examine the condition of temperature and humidity in the poultry farm. The system consisting of 3 sensor nodes and coordinator node. All sensor nodes communicate wirelessly with the coordinator node and make their connection as like star network topology. This network has 4 components consist of sensor node, coordinator node, actuator, and sensor deployment field. Xbee is used for the communication between the sensor node and coordinator node. The Xbee transmitter on the sensor node transmits data wirelessly to the Xbee receiver of the coordinator node. After that the data will be processed by the local server and make it visible on the website. VPN is used in this system for the connection between networks with other network to maintain privacy of the whole network. Examinations shows that DHT11 temperature and humidity sensor have an error rate of 1.51%. The power consumption required by each node is 3.15 mW and the life time for 4 hours 42 minutes. Range of Xbee in indoor Line of Sight conditions is 79 m and at the outdoor Line of Sight is 94 m. The range in urban area indoor is 46 m, and for outdoor is 83 m. After the successful deployment of the system shows that the heat index in the poultry farm can be maintained in 25 degree centigrade. A semi-automatic solution for smart poultry farming was introduced by [28]. It is composed of automated food distribution, clean feed water supply, automatic egg collection, temperature and humidity control, automated litter cleaning, automatic lighting, and intensity control. To supply a clean feed water supply, the water level sensor is used to detect the maximum and minimum level of water. The automated egg collection system used a conveyor belt where eggs will be collected by rotating it once every day. For the automatic control of temperature and humidity, the system used temperature and humidity (DHT-11) sensors that can measure the temperature along with the relative humidity. LDR sensor is used to measure the intensity and control light in the poultry farm. To clean the litter automatically, the cleaning pump will turn on automatically after every 6 hours in order to clean up the surface. A real time monitoring system [29] for the poultry farms based on ZigBee technology. TGS4161 (CO2 detection sensor) and SHT75 (Temperature and Humidity Sensor) are used to get the current environmental situation in the poultry farm. CC2430 is a data processing chip, which is used as a master control node where the detected parameter is processed and monitored. Results shows that ZigBee technology is 30% better and secure than the other transmission medium for data transmission from on node to another. Three fuzzy logic controllers were developed and tested to maintain indoor parameters (temperature, humidity, CO2 and NH3) at desired values using LabVIEW software [30]. The results showed that the fuzzy controller provides better response for temperature and humidity. For fuzzy controller, the percent of working time in which temperature and relative humidity were maintained in less than 1 °C and 5% from the set points were found to be 78.76% and 96.83%, respectively. These percentages for on/off controller were calculated as 31.36% and 68.35%. Results showed that the mean value of CO2 concentration with on/off controller (1124.64 ppm) was lower than that of fuzzy controller (2582 ppm). Both hardware and open source software are used in the poultry management system. Temperature, humidity, light intensity, and air quality are also included. Open source software, inexpensive hardware, and system focus are provided. System recognises the issues facing the poultry business [39]. Reference [40] proposes a system that, in an effort to improve identification accuracy, extracts characteristics from chicken photos using a (LSTM-RF) combination. Numerous data enhancement techniques were created in order to verify the effectiveness of the recommended LSTM-RF despite the unbalanced dataset. The final testing results demonstrate that the proposed model improves accuracy to 95% when used to chicken age detection. This study also shows the creation of a full image-acquisition system for aviaries in addition to the aforementioned mobile-ready detection software. The suggested method minimises the impacts of environmental variability while offering total operational protection. Maintain the health of the flock, keep an eye on physiological factors such the farm's temperature and humidity, and just lightly watch the flock [41]. An automated chicken farm based on IoT, where the entire farm will be covered with several sensors, including ones for water level, humidity, temperature, and day/night. The microcontroller will also be used to manage the system. This idea's primary goal is to automate the operation of chicken farms, including automatic lighting control, water bowl level detection, and pabulum supply monitoring [42]. The framework proposed by [44] uses an ESP32 Wi-Fi Module to transmit data to the cloud and an Arduino Nano to communicate with different IoT sensors in order to identify the upsides of defined boundaries. The poultry executive framework detects a number of environmental factors, including temperature, the amount of smelling salts in the air, and light power. The framework not only monitors these limits but also actively maintains them through various automated techniques. By using IoT and their mobile phones, people could easily access and operate the poultry farm remotely, reducing the need for manual inspection and increasing the farm's production. Wearable IoT sensor devices allow for the careful study of individual poultry by tracking and monitoring them over a predetermined amount of time. The cost of these devices has decreased due to rapid advancements in sensing technology, making sensor-driven data analysis a more attractive alternative. Using wearable sensing devices, more recent research has also improved data collecting methods for raising cattle and poultry. Reference [43] suggests a 98% accurate smart poultry monitoring system for classifying activities that impact the health of chickens.

The parameters monitored and tuned in these investigations as a stick yard for poultry specific environment includes temperature, humidity, hazardous gases, air-composition and light intensity. These proposed systems lack the complete automation, a system that should observe the environment, learn from it and take decisions by its own without manpower management. These proposed CSPF systems are working in semi-automatic behavior system. They are not much intelligent that makes its own decisions by learning the environment of the poultry farm.

III. MATERIALS AND METHODS

For the development of an Intelligent CSPF system, IoT infrastructure will be designed and divided into three stages. In the first stage, sensors and actuators structure will takes place known as edge layer or sensor layer. Sensors are responsible for sensing and collection of data while actuators act in response to that sensed data. In stage 2, the sensors collected data will be then routed to the centralized control center Raspberry Pi (RPi), where a contemporary data will be stored and analyzed. RPi will run the ML model designed in it. This model is basically a trained machine learning model. RPi this way act as a local decision-making agent to control and issue command back to the actuators. Further the RPi will hold a trained model, we call it policy that will control the deployed actuators. At last stage 3, Machine Learning will take place to extract activity pattern. The model will be trained on the recent range of data and that model will be then sent to the respective gateway to automate the system in user-centric fashion. Fig. 2. Describes the whole architecture of the Intelligent CSPF System. to the Raspberry Pi (RPi). Sensor nodes in a network are typically distributed across a sensor field, enabling each node to gather and relay data to the gateway. This gateway can then communicate with a task manager node over the internet. The overall strategy of the sensor network is shaped by a variety of factors, including fault tolerance, scalability, production costs, operating environment, sensor network topology, hardware constraints, transmission media, and power consumption [30]. Within this CSPF system, sensors such as DHT11, LDR, MQ135, and water level are connected to an RPi using jumper wires. These connected sensors are transferring data to the RPi after every single minute. The data received in the RPi is being registered in a CSV file.

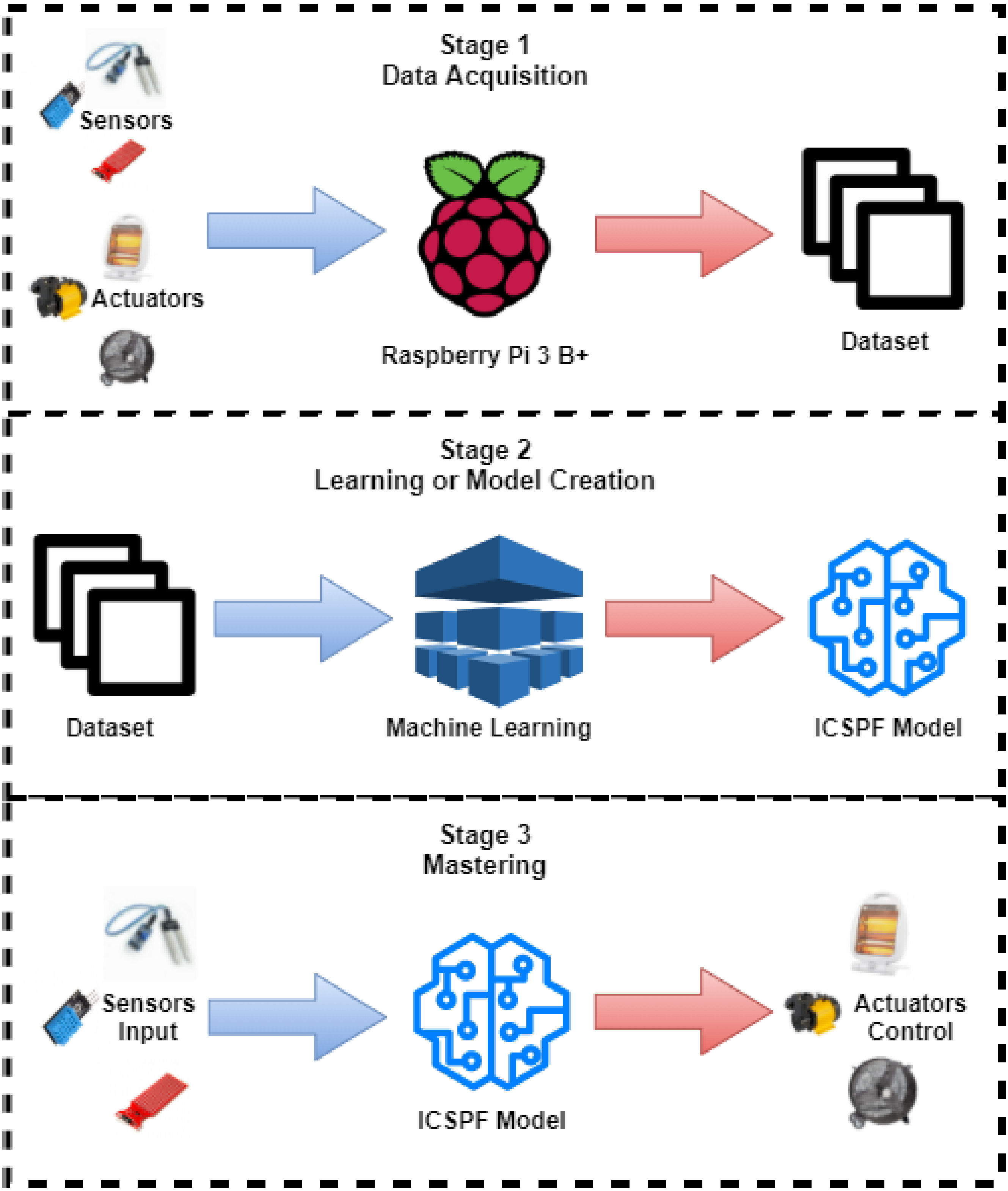

FIGURE 2. Intelligent control shed poultry farm system incorporating with ML architecture.

A. IoT SENSORS

In this research, we have used some sensors to monitor and control the CSPF environment. These sensors are described in detail below:

1) DHT11: TEMPERATURE AND HUMIDITY SENSOR

The Intelligent CSPF system used DHT11 sensor to calculate the temperature and humidity percentage present the poultry farm. The DHT11 is a temperature and humidity sensor with

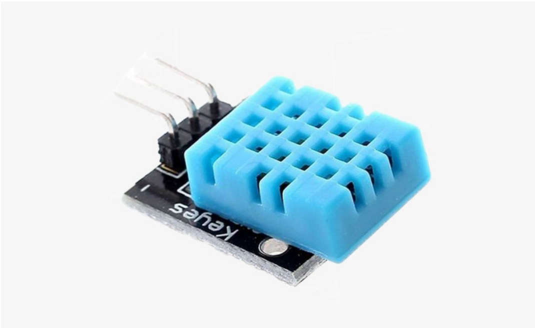

FIGURE 3. DHT-11 temperature and humidity sensor.

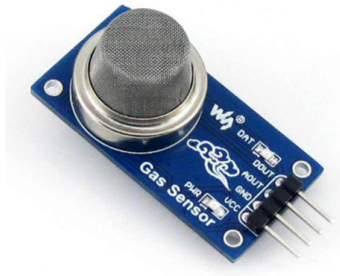

FIGURE 4. MQ-135: Gas detection sensor.

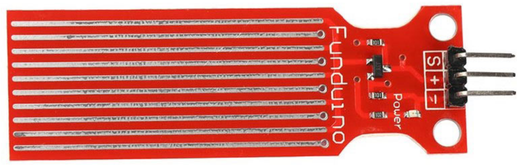

FIGURE 5. Arduino water level sensor.

digital signal output. It uses digital acquisition technology to read the current temperature and humidity levels. DHT11 uses resistive humidity measure component and NTC (negative temperature coefficient) temperature sensor component. It gives excellent readings or results when it is connected with an 8-bit high-quality single-chip microcontroller. DHT11 allows connecting with a microcontroller with an I/O port. It sends 40 bits of humidity and temperature data to the microcontroller all the time when it starts working. Because of this accuracy of the temperature and humidity data is guaranteed. The power consumption of DHT11 is very less. It requires 5 V power supply voltage and the maximum average current is about 0.5 mA [31]. The typical connection circuit diagram of DHT11 with RPi is shown in Fig. 3.

The single bus data format is used by the DHT11, it means that a single data port completes two-way transmission (input/output). The size of data containing a single packet is 5 Byte (40 Bit). It takes less than 3 milliseconds to communicate with a microcontroller. Data format contains 8-bit of humidity integer data, 8-bit humidity decimal data 8-bit temperature integer data, 8-bit temperature decimal data, and 8-bit of calibration. The sum of the first four bytes is called calibration.

2) MQ-135: GAS DETECTION SENSOR

To detect the smoke and hazardous gases in the CSPF environment, the CSPF system have used MQ-135 gas/smoke detection sensor, shown in Fig. 4. These gases include, NH3, NOx, alcohol, benzene, smoke and CO2. MQ-135 gas sensor has high detective sensitivity to Ammonia. It is also very efficient in detecting Sulfide and Benzes steam. MQ-135 is also very sensitive to smoke and other harmful gases that is why it is mostly used as smoke sensor [32].

Micro ceramic tubes make up the MQ-135 sensor. The heater, measuring electrode, and tin dioxide sensitive layer are all attached inside a plastic and stainless steel net crust. There are 6 pins in the MQ-135 gas sensor. The signal is fetched using the 4 pins. The other two of them are employed to supply heating current. In the presence of flammable gas, the MQ-135 sensor's conductivity increases from low to high. This semiconductor gas sensor's detection range is between 10-300 ppm, according to [33].

3) ARDUINO WATER LEVEL SENSOR

In the intelligent CSPF system, water level sensor is used to detect the level of the water present in the water bowl. Water level sensor is connected and sending detected data values to the RPi. Its range of detection is between 0-1023. Water level sensor has a series of ten exposed copper traces. Five traces are used as power traces and five are sense traces. Traces are interlaced so that there is one sense trace between every two power traces. These traces are not connected with each other but bridged by liquid when submerged. Water level sensor is an easy-to-use and cost-effective sensor. It takes analog value as input and coverts it into digital value as output. As shown in Fig. 5. Water level sensor has 3 pins, i.e. VCC, Ground, and Data. It requires current less than 20 mA and DC 3-5V voltage to work efficiently. Its detection area is between 40 mm× 16 mm. Water level sensor give its best results in temperature between 10 to 30 degree centigrade and humidity level of 10% to 90% without condensation. In this system, water level sensor is placed in the water bowl. If it detects the water in the bowl is below the required level the water motor will automatically turned on by the system and when it is filled up to the required level the motor will automatically turned off by the system.

4) LDR SENSOR

In CSPF system, Light Dependent Resistors (LDR) are used to calculate light intensity levels. LDR sensor is very inexpensive and common everywhere. The LDR carries out an analog voltage when connected to VCC (5V). It varies in magnitude in direct proportion to the input light intensity on it. The higher intensity of light will give the higher the corresponding voltage from the LDR. Microcontroller converts its analogs values into digital values. Digital values range is between 0 1023. The Dark resistance is up to 1Mohm, when the light falls on LDR the resistance drops to an ohm. LDR sensitivity varies with the wavelength, response is maximum around 600 nm wavelength.

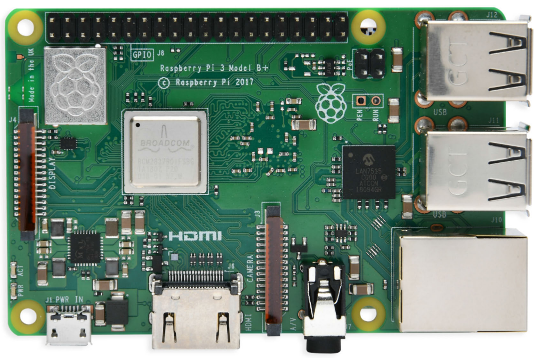

FIGURE 6. Raspberry Pi B 3+.

B. RASPBERRY Pi B 3+

In this research, we have used the Raspberry Pi 3 model B+ as a hardware platform shown in Fig. 6. Raspberry Pi 3 B+ is a small computer with the dimensions; 85.60 mm53.98 mm 17 mm. Its weight is only 45 grams and it is affordable as well [34]. Raspberry Pi 3 B+ is a microcomputer with 64 bit ARM Cortex A53 architecture. It has four core CPU. CPU's main frequency is 1.2GHz [35]. Debian GNU/Linux is the GUI based operating system for the Raspberry Pi used in this research. In Intelligent CSPF system, RPI is used to get values from the sensors, apply ML and control the poultry farm's environment with actuators by getting predictions from the ML model.

C. ACTUATORS

An actuator is an electronic or electrical component that turns the control signal into action. A sensor can collect the values from the environment and actuator is in charge to control the environment at the specific point on the basis of collected data by the sensor. In this proposed smart CSPF system, there are some actuators installed to control the environment for the better production of the chickens. The detail of these actuators is given below:

1) FAN

Fan is an electrical device which is used to control the temperature of a specific place like a room, hall, building, and etc. In this proposed smart CSPF system, fan act as an actuator which can control the temperature of the farm when the temperature rises up from the suitable point for the poultry production.

2) HEATER

Heater is also an electrical device which is used to control the temperature in a cold environment. In this proposed smart CSPF system, heater is used to control the temperature when it is lower than the required temperature for the development of chickens.

3) WATER MOTOR

Water motor is used to fill up the water bowls in the farm when they get empty. Water level sensor can detect whether the bowl is empty or not. If it detects the bowl is empty then the system send ON signal to the water motor and if it detect it is filled at the required level, the system send OFF signal to the water motor.

4) LIGHTS

Light is another important feature for the production of healthy chickens. Electrical lights are used to control the presence of required intensity of light in the farm.

5) EXHAUST FAN

It is an electrical device, which is used to exhaust out the smoke and other harmful gases like NH3, CO2 from the farm if any of these can be detected by the gas sensor.

D. CSPF ENVIRONMENTAL CONTROL PARAMETERS

1) TEMPERATURE

For the healthy poultry production temperature is an important factor to be controlled. Chickens body temperature is maintained between 41°C and 42.2°C. The upper level of temperature in the comfort zone is known as HCT (highest critical temperature) and the lower level is known as LCT (lowest critical temperature). It is necessary to maintain temperature in between these both levels for the healthier poultry production. Any change below and above these levels may harm chickens and their eggs production. The suitable temperature for the chickens in the production of their healthy eggs is between 20°C to 24°C. If the temperature rise above 24°C it affects the quality of eggs and their weight as well [21]. In this research we have used DHT11 (temperature and humidity sensor) to calculate the relative temperature of the CSPF system and fan as actuator to control it.

2) HUMIDITY

Humidity is the major cause of respiratory diseases in the chickens [36]. High humidity levels causes the microorganisms to grow in the poultry farm and effect the health of the chickens. To measure the humidity level of the air in the poultry farm, following concepts are given below: Absolute humidity = grams of moisture present in 1 cubic meter of air. Maximum humidity = maximum grams of moisture that can be present in 1 cubic meter of air at a given temperature. Relative humidity = the relationship between the moisture content of the air and the maximum moisture content at the current air temperature expressed in percentages. To measure the percentage of relative humidity in the air, take the reading of the current moisture present in an environment. It is then divided by the maximum amount of moisture and the result is multiplied by the 100. For example, if the moisture is 6.4 and maximum moisture present in the air is 9.5 then 6.4/9.5*100 = 67% humidity. Humidity decreases when the temperature increases whereas humidity increases when the temperature decreases [35]. In this research work, we have used DHT11 (temperature and humidity sensor) to calculate the relative humidity of the CSPF system and fan and heater are used as the actuators to control it.

3) SMOKE AND OTHER HARMFUL GASES

Chickens inhale Oxygen and exhale Carbon Dioxide. Presence of smoke and other harmful gases in the poultry farm is very harmful for the chicken's health. Gases like Ammonia (NH3), Carbon Dioxide (CO2), Hydrogen Sulphide (H2S) and Carbon Monoxide (CO) are also very harmful for the chickens and their presence also effect the overall production of the chickens. To overcome this problem, in this research, we have used MQ-135 and MQ-2 smoke sensors to detect smoke and other harmful gases. Exhaust fan is used to remove these gases out from the poultry environment.

4) WATER LEVEL

Water is very necessary for the production of living organisms. In the poultry farms, there are water bowls for the chickens to drink water. These water bowls need to be refilled again and again. In this research, the main idea is to fully automate the poultry environment. Water Level sensor is used to detect the current water level in the bowls. If it is below the threshold level water motor will be automatically turned on, fill the bowl, and automatically turned off when it is reached at the expected point.

E. DATA COLLECTION

The dataset used in this research is based on the collection of the sensors and appliances control data in the poultry farm. In the system's test bed, sensors and actuators are connected with RPi. Sensors values and appliances control (on/off by the user) values are being registered every single minute in the .CSV file.

F. MACHINE LEARNING MODELS APPLICATION & SELECTION

The proposed methodology of the intelligent CSPF system is based on two major ML phases i.e. Learning and Mastering. In the learning phase, it is based on the collected dataset, the system will apply ML algorithms to learn how the user is dealing with the system. After the successful completion of the learning phase, the resultant ML model will be saved and applied to control over the system in the mastering phase. In this research work, we have tested and analyzed some supervised ML classifiers to implement in our CSPF system's Test bed. The classifier with the best accuracy is used to be implemented in the intelligent CSPF system. On the basis of collected dataset, the intelligent CSPF system will apply ML to learn how the user interact with the system. To determine the most suitable machine learning technique for a particular application, one can assess the essential components required for an effective supervised machine learning pipeline. Reference [36] The pipeline defines the creation of an effective classifier that generalizes well to new data instances. Figure 7 illustrates this pipeline, with the first two steps being crucial as they

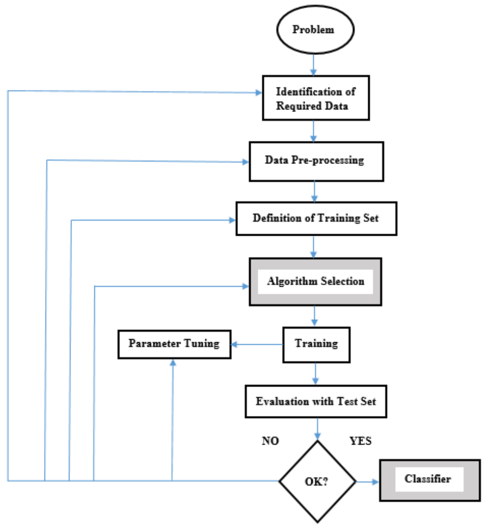

FIGURE 7. Machine learning models application & selection.

determine the classifier's performance. One of the key tasks in this process is identifying the necessary data, which involves selecting the most relevant features and reducing data dimensionality by excluding irrelevant or redundant features. Too much irrelevant or redundant information can hinder the learning algorithm from identifying patterns and may lead to inaccurate results. Preprocessing is employed to alleviate information redundancy, as well as to address noise or missing values. The output of the preprocessing step serves as the input for the training dataset.

G. MACHINE LEARNING MODELS COMPARISON

Five machine learning models used in Intelligent Control Shed Poultry Farm (CSPF) systems are reviewed in detail in this section. SVM, k-NN, DT, RF, and NB models on the previous usage of datasets have been tested. Both machine learning models were tested with the expectation of helping create best-performing models when generally applied to CSPF in the said real-world applications.

Factors considered in evaluating models in this experiment are the models' accuracy, precision, and recall. The testing program for the models considers a comprehensive list of data containing past performance data on CSPF. Table 1 shows the machine learning models' performance assesment using the standard measures of common machine learning accuracy, precision, recall, and F1 scores.

The Decision Tree (DT) performed better than other models in all metrics. The model's nature was a crystal ball; thus, it was the most realistic. Since interpretability is part of the CSPF process, this is how this model is met. Given the criteria, the DT, major for capturing the nonlinear interaction of poultry performance, is precise. DT's overall performance was the best interpretation it provided and weakness, which should assist it inform the choice of DT over other models in the work. Besides, the model was more accurate in performance than any other, and the decision tree model ensures that decision-making is done transparently. Therefore, CSPF can understand and trust automated systems.

H. SCALABILITY AND ADAPTABILITY OF THE INTELLIGENT CSPF SYSTEM

Firstly, the Intelligent Control Shed Poultry Farm system is a system that can be used in any poultry. This ability to use a system in other poultry's excluding the original poultry;s means the system is scalable and flexible. The system and design are meant for poultry farmers in small scale to large scale poultry farming.

The main contributors for scalability purposes are custom built and modular in architecture. Scalability is assured by the central processing unit, the Raspberry Pi 3 Model B+. So this one device the Raspberry Pi 3 Model B+ can be replicated by multiple animals within the farm or multiple organisms doing the computing activities. Hence, the system can accommodate several animals or multiple and reduce the number of replications used. Flexibility is based on farm size; it can be used by any poultry farmer irrespective of size because the system can be adjusted to any farm size.

On top of all these, the infrastructure of sensors and actuators is again scalable. The intelligent design of the system enables the incorporation of several sensors or actuators, making it possible to do an environmental observation that fit the requirements of the types of birds raised in the poultry. This kind of flexibility is required to address the requirements of different poultry breeds and farm system needs, and it ensures that intelligent CPFSs are successful.

The flexibility of an intelligent CSPF system for environmental performance is characteristically revolutionary. The sensors in the system are selected and adjusted to edge changes in temperature, humidity, and other external factors, ensuring reliable operation in different weather conditions. The decision module is also performed which is flexible, as it can be adapted taking into account certain breeds of poultry or farming methods.

The versatility of the system is further enhanced by its open architecture and interface with conventional networks. This facilitates the integration of new technologies, the continuous development of sensors, or upgrades to improve system performance. The smart CSPF system is dynamic and ready to change as technology and poultry techniques improve. It is not static.

IV. CSPF DATASET

As it is mentioned in the introduction section, this research is based on a user-centric mechanism. This means that this smart system will learn from the user behavior and after learning, it takes control of the system. The intelligent CSPF system is an automated poultry farm's environmental control system that has two main phases i.e. learning phase and the mastering phase. In the learning phase, the ML model requires a precise dataset to learn the decisions made by the users to control the environment of the control shed. CSPF

	Temperature	Humidity	GasSens	LightSens	WaterSens	Light	Fan	Heater	Motor	Exhaust	Catagory
0	17	88	0	97	1	1	0	1	1	0	22
1	17	88	0	98	1	1	0	1	1	0	22
2	17	88	0	117	1	0	0	1	1	0	6
3	16	88	0	86	1	1	0	1	1	0	22
4	27	68	0	85	1	1	1	0	1	0	26

FIGURE 8. CSPF dataset & selection.

Dataset as shown in Fig. 8 used in this research is based on the collection of real sensors and appliances control data. In the system's test-bed, sensors and actuators are connected with RPi. Sensors values and appliances control (on/off by the user) values are being registered every single minute in a .CSV file named as "CSPF dataset.csv". CSPF dataset consists of 11 attributes i.e. Temperature, Humidity, Gas Sensor, LDR Sensor, Water Level Sensor, Light, Fan, Heater, Water Motor, Exhaust and Category (Class). Temperature and Humidity attributes carry the current temperature and humidity values in the poultry farm, sent from the DHT11 (Temperature and Humidity Sensor) calculated in degree Centigrade and humidity percentage. Gas Sensor attribute collects the gas detection values sent by the MQ-135 sensor. LDR Sensor column carries the current light intensity values in the shed, sensed by the LDR sensor. Water Level sensor transfer the water level detection values and these values are registered under the Water Sensor attribute. The next five attributes consist of appliances installed in the test-bed i.e. Light, Fan, Heater, Water Motor, and Exhaust. Users have full privilege to control (on/off) the appliances on their desired levels. As shown in Fig. 9, every action (on and off the appliances) performed by the user is being registered in the dataset. For example, the user turned on the fan when the temperature is 27°C. Category is the class attribute on which the ML model is being trained. There are totally 13 classes in the CSPF dataset. Figure indicates the total classes and their number of instances present in the dataset.

A. PRE-PROCESSING

Pre-processing has been done by converting the actuators' input from binary to digital form to make categories, which are further being used for supervised ML model training, as mentioned in Figure 8. Further, the CSPF dataset already contains numerical values generated by the sensors. All features present in the dataset are selected for the training process. To conduct the experiments, 70% of this dataset is used for training and the remaining 30% is taken for the testing of the resultant model.

V. RESULTS

The performance of the CSPF framework, given in Fig. 1, depends on the following three key phases: 1. Data Collection: Data is collected by the sensors and actuators deployed in the test-bed. 2. Learning Phase: In the learning phase, the system will observe from user behavior patterns in terms of poultry activity operation for specific time duration using machine learning. 3. Mastering Phase: Upon completion

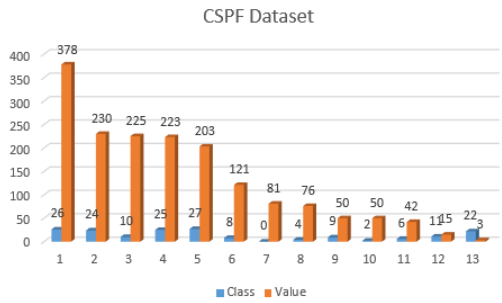

FIGURE 9. The classes' representation in CSPF dataset.

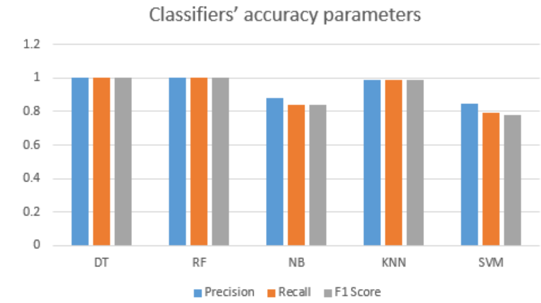

FIGURE 11. All evaluation parameters comparison.

TABLE 1. Accuracy obtained by the ML classifiers.

No.	Classifier	Accuracy	Precision	Recall	F1-Score
1	Decision Tree (DT)	99.97%	1.00%	1.00%	1.00%
2	Random Forest (RF)	99.97%	1.00%	1.00%	1.00%
3	Naive Bayes (NB)	82%	0.88%	0.84%	0.84%
4	K-Nearest Neighbours (KNN)	99%	0.99%	0.99%	0.99%
5	Support Vector Machine (SVM)	79%	0.84%	0.79%	0.78%

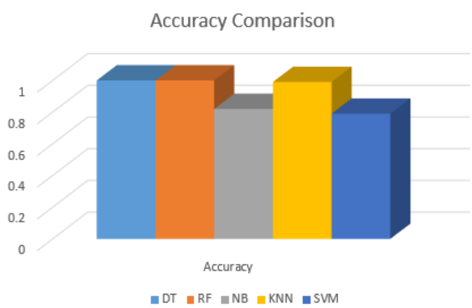

FIGURE 10. Accuracy comparison.

of training phase the mastering phase will take place and start monitoring and controlling the environment parameters (temperature, humidity, water level, light and hazardous gases) based on the historical data or in other words the system will replicate the operators past business control behavior. Using the CSPF dataset that were introduced in the previous section, the experiments that will be conducted focus on the last two phases. The following section will briefly discuss each experiment and their results are also given.

A. CLASSIFIER SELECTION

The machine learning algorithms implemented in the framework are Naive Bayes, Decision Tree, Random Forest, Support Vector Machine, and k-Nearest Neighbor. For the evaluation of each classifier the accuracy, precision (P), recall (R), and F1-score values are obtained using Python language. The best-selected classifier with the highest prediction accuracy is used to be implemented in the test bed. Results are given in Table 1. The comparison of the accuracy obtained by the classifiers is presented in Fig. 10.

B. DISCUSSION

For the development of an intelligent CSPF system, there is a need for an efficient classifier that predicts accurately. In the above mentioned experimentation and evaluation, DT and RF have given 99.97% accurate results. The KNN classifier have given 99% accuracy which is satisfactory but it is not better than DT and RF. The SVM and NB results 79% and 82% accuracy (Table 1). So, we have chosen DT classifier to implement in our CSPF Testbed (Fig. 12).

Our study's findings demonstrate the Intelligent Control Shed Poultry Farm (CSPF) system's remarkable efficacy in transforming poultry farming methods. Of particular note was the exceptional precision with which the Decision Tree model-driven automated decision-making process was able to forecast and regulate environmental conditions. This result has real-world ramifications for the chicken farming industry and suggests a possible transition to a more productive and efficient operating paradigm.

Optimized circumstances for chicken growth are directly influenced by the system's precise regulation of temperature, humidity, water levels, light, and dangerous gases. By minimizing human engagement, the automated control lessens the need for tiresome activities from carers and lowers the possibility of prejudice and mistakes. This more efficient method not only makes things go more smoothly but also gives chickens a more stable and healthy environment, which is good for their development.

Adoption of the Intelligent CSPF System has intriguing socioeconomic ramifications beyond the short-term operational gains. The technology might potentially boost farm output by automating and optimising poultry farming procedures, which would raise farmers' income. Furthermore, the simplicity with which the farming community may replicate successful models encourages group learning and information exchange, so fostering a collaborative approach to improved chicken farming techniques.

The findings of our research indicate wider societal advantages in addition to the obvious practical implications for productivity and efficiency in chicken production. One game-changing piece of technology that has the potential to push the chicken farming sector towards sustainability and financial success is the Intelligent CSPF System.

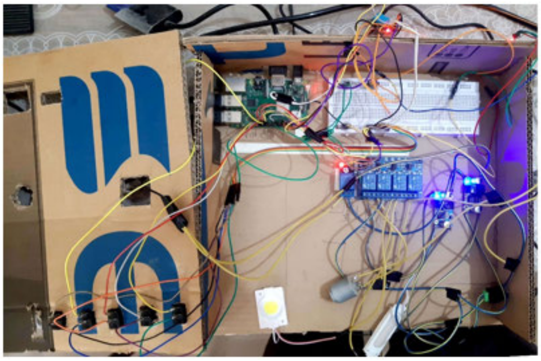

FIGURE 12. Development of CSPF testbed.

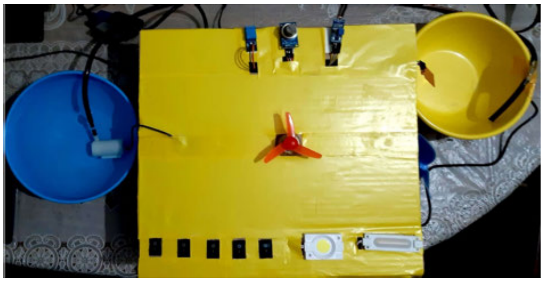

FIGURE 13. Intelligent CSPF testbed.

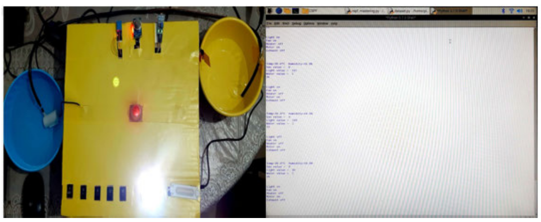

FIGURE 14. Intelligent CSPF system testbed.

VI. INTELLIGENT CSPF SYSTEM'S TESTBED

To develop the Intelligent CSPF System's Testbed, we have used RPi 3 model B+, a breadboard, jumper wires, five 12V Relays, 2 voltage converters, and 5 ON/OFF buttons (Fig. 12). As given in Fig. 12, four sensors (DHT11, MQ135, LDR, and Water Level) are connected with the RPI and five actuators (light, fan, heater, water motor, and exhaust) are connected with the system. Fig. 14, shows the working of the intelligent CSPF system incorporating with ML. As the temperature of the farm is 36°C ML model predicts that the fan should be ON, so the system turns on the fan. Light intensity in the farm is 92, so light is predicted to be ON. The water level is 1, so the water motor is ON. The heater is OFF because the model predicts that the temperature is too high already. No smoke or gas is detected by the sensor, so there is no need to ON the exhaust that's why the exhaust is predicted OFF.

VII. CONCLUSION AND FUTURE WORK

The existing CSPF system still not free from human intervention and needs 24/7 monitoring. To develop an intelligent CSPF system we have combined two major approaches i.e. Sensors Network and Machine Learning. The proposed approach of this research comprises of learning and mastering phases. In the learning phase, the system will observe/learn from user behavior patterns in terms of poultry activity operation for a specific time duration. Upon completion of the learning phase, the mastering phase will take place and start monitoring and controlling the environment parameters (temperature, humidity, water level, light, and hazardous gases) based on the historical data. In the system's Testbed, sensors (DHT11, MQ135, LDR, and Water Level) and actuators (light, fan, heater, water motor, and exhaust) are connected with RPi. Sensors' values and appliances control (on/off by the user) values are being registered every single minute in CSV file named as "CSPF data.csv". Decision Tree and Random Forest classifiers have given the highest accuracy. Decision Tree classifier is selected to apply in the intelligent CSPF system's Testbed. The Intelligent CSPF system can retrain itself after a month. After examinations, it is concluded that the Intelligent CSPF system incorporating with ML will play an important role by saving time and management expenses of the poultry farmers. The intelligent CSPF system will help to reduce the manpower required for the poultry farm's management by controlling the environmental parameters like temperature, humidity, water level, gases/smoke, and light automatically. By giving more autonomy to the users this system will become more productive, efficient, and reliable. This system will also help control shed owners in increasing the efficiency of their poultry farm, high-quality chicken production, and saves their time as well.

Many different adaptations, techniques, tests, and experiments have been left for the future due to lack of time (i.e. the wireless connection of the sensors to the gateway). Future work concerns the deeper analysis of the best wireless data transfer strategies, data security, and new proposals to try different methods. We now focus on the user experience (UX) and potential adoption problems related to the Intelligent Control Shed Poultry Farm (CSPF) system in an effort to further strengthen the practical aspect of our study. Pilot study insights offer insightful commentary on user satisfaction and system usability, illuminating how the farmer interacts with the automated controls. We describe training programs and support systems in recognition of the potential learning curve farmers may encounter while switching to automated chicken farming. We also explore possible adoption roadblocks, taking into account factors such as setup difficulty, prices, and cultural impacts. In order to ensure that the Intelligent CSPF System effortlessly satisfies the practical requirements of poultry farmers as well as technical functions, this enlarged part attempts to give a more comprehensive picture. The following are some considerations for future work in this study:

1. Analysis and implementation of the wireless data transfer technologies e.g. ZigBee, Wi-Fi module and Bluetooth.
2. Analysis and improvement in the security of the data.
3. Sensors error rate analysis and improvement.
4. Development of the smart CSPF application which allows users to monitor, analyze and control (over rule) the system whenever and wherever they want.

ACKNOWLEDGMENT

The author extend their appreciation to Taif University, Saudi Arabia, for supporting this work through project number (TU-DSPP-2024-17).

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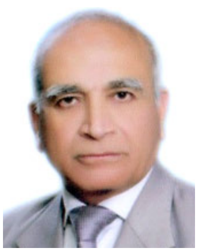

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