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Genetic Algorithm based Internet of Precision Agricultural Things (IopaT) for Agriculture 4.0

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ABSTRACT

The development of IoT is increasing in our daily life. Its applications are now becoming famous in rural areas also, such as Agriculture 4.0. Cheap sensors, climate data, soil information, and drones are now used to solve many real-time problems. One of the most emerging topics in the IoT in the Agriculture field is IoT based precision agriculture. The range of IoT applications can range between water spraying from drone, soil recommendation for different crops, weather prediction and recommendation for water supply, etc. In this paper we propose a system that will recommend whether water is needed or not by predicting the rain fall using Genetic Algorithm. In this article, we proposed a unique decision making method to predict Rainfall using Genetic Algorithm (GA) to identify the necessity of manual water supply is needed or not. The sensor based system will be activated to check wheather the GA based system completes its prediction correctly or not by sensing moisture level from the soil. If the moisture level of the soil crosses the pre-defined threshold value then plant watering is performed by quadrotor UAV. A terrace gardening system is also implemented in this article, which uses a pump for water spraying. Various atmospheric parameters help to develop a rainfall prediction system to enhance efficiancy more than 80% in the proposed *IopaT* system to make the system more interoperable.

1. Introduction

The growth of a plant depends on the climate. Prediction of weather [8] is always a critical job as it is dynamic and messy in nature. It follows its own rules and generates intensive data. In today's digital world everything should be intelligent and automated, but weather prediction is quite challenging because of its nature. To predict the weather some parameters required but those are extremely difficult such that there is uncertainty in prediction even for a small time pass. Our frame works able to provide a completely independent solution and for the bestresult, we compare it also with the existing systems. An automated UAV system is also developed to improve spraying quality. The automated UAV system is designed to determine the wind speed and spray the water accurately. These belongings make weather estimating an intimidating task although it is important if want to monitor soil condition. This GA based system is able to identify automatically using multidimensional weather prediction data. For climate analysis, different weather benchmark parameters are considered. Sometimes rainfall prediction is essential for a good and healthy garden because of different plants, soil demand and different attention of water supply [27]. This automated water supply can implement using Internet and smart device

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Table 1
Weather parameters used or training process.

Notation	Description
D	Population considered
n	Size of population
R	Set of binary strings
P_{mi}	Probability of mutation
k	Capacity of coding
P_c	Probability of cross-over operator

or object, but to predict when and which section of garden needs water it will only handle by an intelligent system [23]. A genetic algorithm is used for rainfall prediction [19].

1.1. IoT in Agriculture 4.0

The Internet of Things (IoT) [11] has an ability to change the way of our living by transforming the ongoing systems [17]; smart cities [16], inter-connected cars, efficient agriculture, and industry are most popular IoT components. However, the deployment of IoT in agriculture can change the overview of conventional agriculture scenario. The population of India is set to touch 5 billion by 2050. To feed this huge population the agriculture industry must apply the IoT based system in agriculture fields. IoT based agriculture will decrease the wastage of water, pesticides and also increase the productivity of the seed [28]. The IoT based agriculture [12] can have a great impact inenvironment by providing efficiency in water spraying or optimization in inputs and treatments. The main features of Agriculture 4.0 are mentioned below:

i Big data or data analytics is used here as the analysis section is implemented in the weather data to calculate and predict whether water is required on that day or not.
ii Smart Agriculture system is used here as the whole system is automated. The sensor based system detects whether the land is wet or dry to apply water in the selected field.
iii The proposed system has fulfilled the basic features of the Internet of Things as the proposed system is connected to the internet to control the UAVs.
iv The whole system is interoperable as the proposed system has an accuracy level of more than 80%.
v A cyber physical system is used in this article to monitor all the sensor data to make the system more reliable.

1.2. Decision making in Agriculture using Genetic Algorithm

The assets of decision making using artificial intelligence [6] evaluate the data at first and then get the knowledge from it for imminent estimates which create a perfect solution for weather forecasting. To predict the climate some known algorithm from Artificial Intelligence (AI) is used but those algorithms face so many problems. Various researches are going on to attempt so many approaches from AI to solve these existing problems. Genetic Algorithm (GA) [5] is the evolutionary meta-heuristic approach for AI domain. It is an automated, computerized searching method. It is also an optimization algorithm, which mimics the attitude of natural genetic material also natural selection. To evaluate whether it provides improve results over another algorithm. In 1990 John Holland first proposed the basic idea of the genetic algorithm that is inspired by Darwinian principals (survival of the fittest) [2]. It has been applied to various problems including searching. In random searches, according to fitness criteria, the best result is found from a given set of choices. The best gen is selected using section procedure of GA and that gen is called the fittest one. Fitness is a character of excellence which is to be always optimum either maximized or in minimized form. In GA, parent selection is essential as the optimizations' results directly depend upon the fitness of the next generation (off-springs) [22]. In genetic algorithm, three major legacy operations are used they are selection, crossover, and mutation. As in real life the child may or may not get improved gen from their parent but in GA upcoming generation data always have developed in quality over previous one, because successive generation used appropriate survival criteria [3]. GA is parallel stochastic optimizing based (An optimization method that depends on the random variable) algorithms that are used widely. It is working for multiple populations of points instead of a single point. As mention earlier it's a population-based search algorithm along with a numerous number of optimal solutions is taken, which is reduce the effort. GA works with a sequence coding for the variable instead of a single variable. Therefore, a distinct function can be controlled at no additional cost.

1.2.1. The convergence of the Genetic Algorithm

The mathematical notations considered are presented in 1.

A continuous optimization problem is given as [21],

$$\left(\max_{x \in X} \; f(x) \right) \text{ where } f : X \longrightarrow R \text{ and } f(x) \geq 0$$

Two lemmas and one theorem are stated as follows [21]:

Lemma 1. *$P\{r^* \notin m(D)\}$ is the probability which the mutation does not give rise to r^* in population and $[k/2]$ is an integral part of the quotient $k/2$, where $p_{mi} \leq 0.5$ and $r^* \in R$ be a selected individual.*

Lemma 2. *$P\{r^* \notin m(D)\} \leq \left(1 - \frac{(1-p_{mi})^k}{C_k^{[k/2]}}\right)^n$, $P\{r^* \notin m(D)\}$ is the probability that the population D does not contain r^* after mutation and $[k/2]$ is the integral part of the quotient $k/2$, where $P_{mi} > 0.5$ and $r^* \in R$ be a selected individual.*

Theorem. if $p_{mi} \leq 0.5$ and $R = \left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)^n \left(2 - (1-p_c)^n\right) < 1$, then $Ef\left(D^j\right) \xrightarrow[j\to\infty]{} f^*$ where D^j is the population after the j^{th} iteration step of the genetic algorithm, $f\left(D^j\right) = \left(\begin{array}{c}\max\\ r \in D^j\end{array}\right) f(r)$ is the maximal fitness over the population, and $f^* = \left(\begin{array}{c}\max\\ r \in D^j\end{array}\right) f(r)$ is the required optimal value.

Let us assume $f\left(D^j\right) = \left(\begin{array}{c}\max\\ r \in D^j\end{array}\right) f(r)$ As there are elite selection methods,

$$f^* \geq f(D^j) \geq f(D^{j-1}) \geq .. \geq f(D^0) \tag{1}$$

If $p_{f^*}^j$ is the probability that $f\left(D^j\right) = f$ after j^{th} iteration, and $Ef\left(D^j\right) = \sum f p_f^j$. To prove that the sequence converges, we consider the following [21]:

- Consider an event $A^1 = A$ where no solution is found after the first iteration: The probability that the population has not solution is given as
  $P\{A|H\} = P\{r_1^*, \ldots, r_t^* \notin mut(cr(D^0))\} \leq \left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)^{nt} \leq \left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)^n$ where $P\{A|H\}$ is the probability that the population does not contain a solution after a mutation, provided it had solutions after a crossover.
  $P\{A|\overline{H}\} = P\{r_1^*, \ldots r_t^* \notin mut(cr(D^0))\} \leq \left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)^{nt} \leq \left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)^n$, where $P\{A|H\}$ is the probability that the population does not contain a solution after a mutation, provided it did not have solutions after a crossover.
- B is the event that at least one good pair will be selected for crossover: The probability that a good pair (r1,r2) provides a solution is given as, $P\{r_1 \times r_2 = r^*\} = \frac{u}{k-1} p_c \leq p_c$ that $u \leq k-1$ and $P\{r_1 \times r_2 \neq r^*\} \geq 1 - p_c$ where $\times$ denotes a crossover.
- C is the event that all pairs selected for crossover are good: The probability that a solution does not arise after a crossover given that all pairs are good is calculated as,
  $P\{\overline{H}|C\} = \prod_{r_1,r_2 \in cr(D)} P\{r_1 \times r_2 \neq r_1^*, \ldots, r_t^*\} \geq \prod(1-p_c) \geq (1-p_c)^n$.
  Then, $P\{H\} = P\{H|C\} = 1 - P\{\overline{H}|C\} \leq 1 - (1-p_c)^n$.
  Hence, it is observed,

$$P\{A\} = P\{A|H\}P\{H\} + P\{A|\overline{H}\}P\{\overline{H}\} \leq \left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)^n (1-(1-p_c)^n) + \left(1 - \frac{p_{mi}^n}{C_k^{[k/2]}}\right)^n$$
$$\times 1 = \left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)^n (2-(1-p_c)^n) = R \tag{2}$$

Now the basis of induction is proved. Now suppose $P\{A^{j-1}\} \leq R^{j-1}$.Let assume that after j^{th} iteration no solution arises. Then
$P\{A^j\} = P\{A^j|A^{j-1}\}P\{A^j|A^{j-1}\}P\{A^{j-1}\} \leq RR^{k-1} = R^k$, where $P\{A^j|A^{j-1}\}$ is the probability that no solution arises after j^{th} iteration and thus this is similar to $P(A^1)$ which proves the step of induction.
As $\left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)^n < 1$ and $(2-(1-p_c)^n)$ it can be less than 1 at least based on a chosen value of p_c.
To understand the convergence characteristics, consider the extrema of the function $R(n)$, where
$R(n) = \left(1 - \frac{p^k mi}{C_k^{[k/2]}}\right)^n (2-(1-p_c)^n)$ and $R'(n) = \left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)^n \left((2-(1-p_c)^n \ln\left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right) - (1-p_c)^n \ln(1-p_c)\right)$ Now if $R'(n) = 0$ for n, then $n = \log_{1-p_c} \frac{2\ln\left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)}{\ln\left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)(1-p_c)}$. If n is real, S will be maximum. As n increases,S will first increase, then it will decrease to 0.

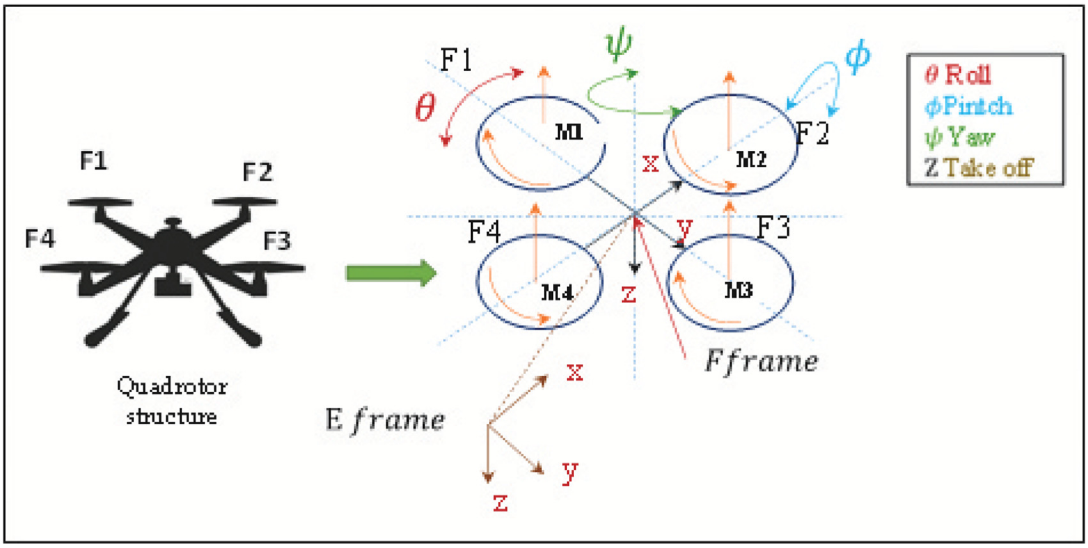

Fig. 1. Quadrotor- free body diagram.

To accelerate the convergence,p_c and k will be reduced,P_{mi} and n will be increased.

if $P_c = 0$, then $R = \left(1 - \frac{p_{mi}^k}{C_k^{[k/2]}}\right)^n$ Now $R < 1$ for any values of k, n and p_{mi}.Thus the convergence statement of Genetic Algorithm is formulated as [15]: If a Genetic Algorithm without a crossover is considered and $p_m i \le 0.5$, then $Ef(D^j) \xrightarrow[j\to\infty]{} f^*$, where D^j is the population after j^{th} iteration of the algorithm, $f(D^j) = max_{s\in D^j} f(s)$ is the maximal fitness over the population, and $f^* = max_{s\in S} f(s)$ is the required optimal value.

1.3. Quadrotor description

The outline structure of a quadrotor UAV is described in Fig 1 It has four number of rotors to generate parallel forces denoted as, $F_i = 1, 2, 3, 4$ along with this, rotors are classified into two classes; class 1: front, back, and class 2: left, right.

The rotation of two classes is exactly opposite to each other for sustaining the balances. In this quadrotor UAV system, various forces and motion are needed to be counted. They are torques and yaw motion. Yaw motion is generated using the different torque of the propeller pair. If four rotors are moving in the same direction then no motion is created. The up-down rotor is responsible for increasing speed and the forward-backward rotor is responsible for pitch and angle. For rolling sideways motion is needed. Fig 2 Shown this above mentioned scenario. Here we used UAV for water supplying in agriculture field [7].

1.3.1. Quadrotor Kinematic Model

Let, frame for earth fixed $E_{frame} = \{x_{e_{frame}}, y_{e_{frame}}, z_{e_{frame}}\}$ and frame for body-fixed $B_{fixed} = \{x_{b_{frame}}, y_{b_{frame}}, z_{b_{frame}}\}$ as expressions in fig 2. $Q = \{x, y, z, \phi, \theta, \Psi\} \in \Re^6$ is the general coordinates for our quadrotor, where $\{x, y, z\}$ to signify the absolute location of UAV and are $\{\phi, \theta, \Psi\}$ the attitude angles namely roll, pitch and yaw respectively this angle are responsible to describe the vehicle orientation. From the definedmodel, we form two equations for translational $\zeta = \{x, y, z\} \in \Re^3$ and rotational $\Upsilon = \{\phi, \theta, \Psi\} \in \Re^3$ subsystem respectively. These two equations form rotation $\Re$ and matrices respectively.

$$R = \begin{pmatrix} \cos\theta\cos\psi & \sin\phi\sin\theta\cos\psi - \cos\phi\sin\psi & \cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi \\ \cos\theta\sin\psi & \sin\phi\sin\theta\sin\psi + \cos\theta\cos\psi & \cos\phi\sin\theta\sin\psi - \sin\phi\cos\psi \\ -\sin\theta & \sin\phi\cos\theta & \cos\phi\cos\theta \end{pmatrix} \tag{3}$$

$$T = \begin{pmatrix} 1 & \sin\phi t\theta & \cos\phi\cos\theta \\ 0 & \cos\phi & -\sin\phi \\ 0 & \sin\phi/\cos\theta & \cos\phi/\cos\theta \end{pmatrix} \tag{4}$$

Thus kinematic for translational is written as:

$$\dot{\zeta} = \Re\vartheta \tag{5}$$

Where $\dot{\zeta}$ and ϑ are represent the linear velocity for the earth-fixed frame $E_{frame} = \{x_{e_{frame}}, y_{e_{frame}}, z_{e_{frame}}\}$ and body-fixed frame $B_{frame} = \{x_{b_{frame}}, y_{b_{frame}}, z_{b_{frame}}\}$ respectively. Thus kinematic for rotational express as:

$$\dot{\gamma} = \Re w \tag{6}$$

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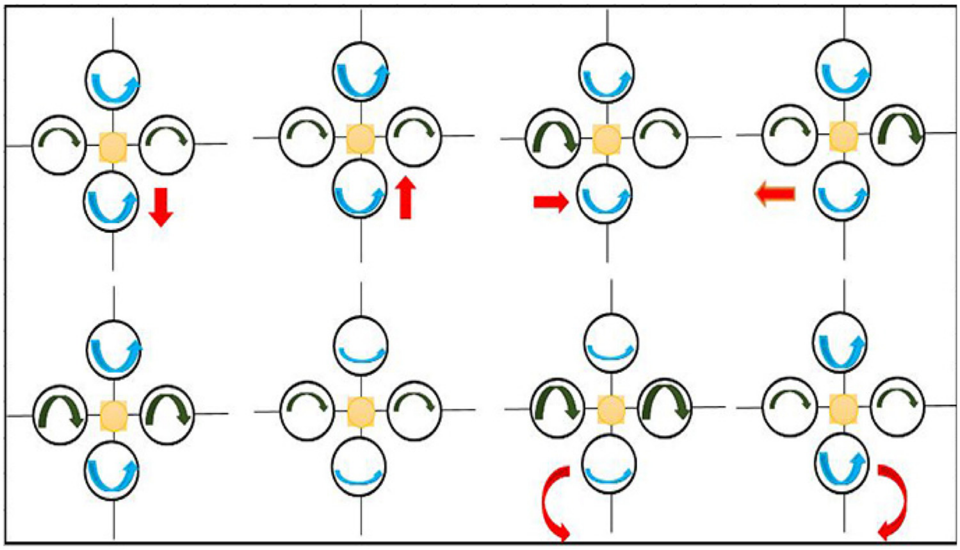

Fig. 2. Movement of a Quadrotor: the arrow width is equivalent to rotor speed.

where, $\dot{\gamma}, w$ are represent the angular velocity for the earth-fixed frame $E_{frame} = \{x_{e_{frame}}, y_{e_{frame}}, z_{e_{frame}}\}$ and body-fixed frame $B_{frame} = \{x_{b_{frame}}, y_{b_{frame}}, z_{b_{frame}}\}$ respectively.

1.3.2. Quadrotor Dynamic Model

Newton-Euler equation is used to describe a dynamic model of the quadrotor. To define the translational and rotational dynamic equations the earth-fixedframe is defined as, $E_{frame} = \{x_{e_{frame}}, y_{e_{frame}}, z_{e_{frame}}\}$ and the body-fixed frame is defined as, $B_{frame} = \{x_{e_{frame}}, y_{e_{frame}}, z_{e_{frame}}\}$ Thus, the dynamic equations for translational of the quadrotor are express as:

$$M\dot{\gamma} = -Mge_x + \vartheta_{Thrust} Re^z \tag{7}$$

Where, M signifies mass, g is the gravity, $e_z = (0, 0, 1)^T$ is the unit vector expressed in the earth-fixed frame $E_{frame} = \{x_{e_{frame}}, y_{e_{frame}}, z_{e_{frame}}\}$ lastly ϑ_{Thrust} defined as the overall thrust formed by the four rotors:

$$\vartheta_{Thrust} = \sum_{j=1}^{4} F_j = c \sum_{j=1}^{4} \phi_j^2 \tag{8}$$

Where, ϕ_j and F_j signify, the speed and thrust force of the rotor j and c the thrust feature. So, the dynamic equations for rotation of quadrotor are express by:

$$I_m \dot{\omega} = -\omega \times I_m \dot{\omega} - G_e + \tau \tag{9}$$

Where, I_m is a matrix of inertia, G_e and τ are the gyroscopic outcome for rigid body spin, propeller Direction change, and control torque respectively. The control torque is found because of rotor speed which variesfor every moment. So, G_e and τ can be written as:

$$G_e = \sum I_r (\omega \times e_z)(-1)^{i+1} \phi_i \tag{10}$$

$$\tau = \begin{pmatrix} \tau_\phi \\ \tau_\theta \\ \tau_\psi \end{pmatrix} \begin{pmatrix} \imath c(\psi_4^2) - (\psi_2^2) \\ \imath c(\psi_3^2) - (\psi_1^2) \\ \partial(\psi_2^2) + (\psi_4^2) + (\psi_1^2) + (\psi_3^2) \end{pmatrix} \tag{11}$$

Where,I_r is rotor inertia, $\imath$ signifies the distance between rotors and center of mass, ∂ is the drag feature. Then, by recalling equations 5 and 7, the dynamic model of quadrotor for the position (x, y, z) and rotation (ϕ, θ, ψ)are express as:

$$\begin{pmatrix} \ddot{x} \\ \ddot{y} \end{pmatrix} = \frac{1}{M} \begin{pmatrix} \cos\phi \sin\theta + \sin\phi \sin\psi \\ \cos\phi \sin\theta \cos\psi - \sin\phi \sin\psi \\ \cos\phi \cos\theta \end{pmatrix} \vartheta_{Thrust} \tag{12}$$

$$\begin{pmatrix} \ddot{\phi} \\ \ddot{\theta} \\ \ddot{\psi} \end{pmatrix} = \begin{pmatrix} \phi\dot{\theta}(\frac{I_{yy}-I_{zz}}{Ixx}) \\ \phi\dot{\psi}(\frac{I_{zz}-I_{xx}}{Iyy}) \\ \theta\dot{\phi}(\frac{I_{xx}-I_{yy}}{Izz}) \end{pmatrix} - \begin{pmatrix} \frac{I_r}{I_{xx}} \dot{\theta} \Phi_\partial \\ -\frac{I_r}{I_{yy}} \dot{\phi} \Phi_\partial \\ 0 \end{pmatrix} + \begin{pmatrix} \frac{1}{I_x x} \tau_\phi \\ \frac{1}{I_y y} \tau_\theta \\ \frac{1}{I_z z} \tau_\psi \end{pmatrix} \tag{13}$$

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Table 2
Comparison of contributions for proposed and existing systems

Features	Eliminating the interference of soil moisture using a NIRS-based portable detector[12]	Future weather prediction using genetic algorithm and FFT for smart farming	UAV-assisted data gathering in wireless sensor networks	IoPaT- Internet of Precision Agricultural Things
GA based water prediction system	×	×	×	✓
Power efficient	×	✓	✓	✓
IoT based Agricultural system	×	×	×	✓
Developed App	×	×	×	✓
Considered both indoor and outdoor environment	×	×	×	✓
Efficient plant watering system	×	✓	×	✓

Thus, the quadrotor is an under an actuated system with six outputs and four control inputs. Finally, the quadrotor dynamic model is written as follows

$$\ddot{x} = (\cos\phi \sin\theta \cos\psi + \sin\phi \sin\psi)\tfrac{1}{M}\vartheta_1$$
$$\ddot{y} = (\cos\phi \sin\theta \cos\psi \sin\phi \sin\psi)\tfrac{1}{M}\vartheta_1$$
$$\ddot{z} = -g + (\cos\phi \cos\psi)\tfrac{1}{M}\vartheta_1$$
$$\ddot{\phi} = \dot{\theta}\dot{\psi} = \left(\tfrac{I_{yy}-I_{zz}}{I_{xx}}\right) - \tfrac{I_r}{I_x x}\dot{\theta}\Phi_{\partial} + \tfrac{\imath}{I_{xx}}\vartheta_2$$
$$\ddot{\theta} = \dot{\phi}\dot{\psi} = \left(\tfrac{I_{zz}-I_{xx}}{I_{yy}}\right) - \tfrac{I_r}{I_y y}\dot{\theta}\Phi_{\partial} + \tfrac{\imath}{I_{yy}}\vartheta_3$$
$$\ddot{\psi} = \dot{\theta}\dot{\phi} = \left(\tfrac{I_{xx}-I_{yy}}{I_{zz}}\right) + \frac{1}{I_{zz}}\vartheta_4 \tag{14}$$

With a renaming of the control inputs as:

$$\begin{aligned} \vartheta_1 &= c(\Phi_1^2 + \Phi_2^2 + \Phi_3^2 + \Phi_4^2) \\ \vartheta_2 &= c(\Phi_4^2 - \Phi_2^2) \\ \vartheta_3 &= c(\Phi_3^2 - \Phi_1^2) \\ \vartheta_4 &= c(\Phi_2^2 + \Phi_4^2 - \Phi_3^2 - \Phi_1^2) \end{aligned} \tag{15}$$

The definition of disturbance:

$$\Phi_d = c(\Phi_2 + \Phi_4 - \Phi_3 - \Phi_1) \tag{16}$$

2. Related Work

Internet of Things (IoT) is mainly used for the devices to intercommunicate. It is a concept where everyday objects like vehicles, home appliances and any type of smart materials are controlled and monitored by the internet. Innovative use of different technologies like NFC, Bluetooth, Zigbee, etc. is heavily used to implement IoT services [4]. Reputed companies like Walmart have implemented RFID tags to maintain their inventory in the year 2005. IoT is advance technology which is a combination of intelligence, sensing, and identification. Our modern life is also regarded as a part of IoT. It is used in measurement as a part of pattern recognition and it is also used in communication computing, like sensing, information collection, processing in cloud, etc.[9,14,20,25]. Cloud computing changes the definition of IoT. IoT is a combination of wireless sensing networks and cloud computing. Cloud computing management, which is also the brain of cloud computing customize the user application of IoT. As an Agriculture dependant country, India has 2nd largest economic growth in the agriculture field among 195 countries. The biggest barrier to traditional agriculture in India is climate change. The effects of climate change result in draught in some areas and crop loss due to rain in some areas. We have discussed the limitations of some related articles and tried to make the proposed system beyond those limitations. This system can also control the water spraying using an Android app which makes this system fully automatic and different from others. In table 2 we have discussed the advantages of the proposed system over the previous systems.

3. Motivation and Contributions of proposed work

With this gradually increment in livelihood, IoT based Agriculture system is an emerging research field. So, the motivation of this article is to integrate IoT with GA to get intelligence for the smart garden [18]. The system is able to provide accurate weather predictionwith a smart and efficient manner. Secondly, to save power supply and save energy. The automated plant watering system allows the user to build and maintain an agricultural field that is smart enough to keep moisture level balanced while providing more automated applications.[10,13,15,24,26] The contributions of the paper are:

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Table 3
Contributions

Eliminating the interference of soil moisture using a NIRS-based portable detector[12]	Wetting front detector scheme is used for the smart agricultural system. Frequency Domain Reflectrometry sensor (FDR) and Resistor-based sensor (RB) are used here.
Future weather prediction using genetic algorithm and FFT for smart farming	Wireless mobile robot based on IoT is used and applied for performing various operations on the farming field. Raspberry Pi 2 model B is used for the experimental purpose.
UAV-assisted data gathering in wireless sensor networks	Proposed an algorithm for data gathering in wireless sensor networks by employing two technologies: mobile agents and a UAV.
IoPaT- Internet of Precision Agricultural Things	The Soil sensor senses the soil moisture and if it is below the threshold it sends a signal to Arduino UNO. It sends a signal to the Relay and UAV to activate the water supply.

i A genetic algorithm based watering system will predict the rainfall using its training procedure. The training has made using real weather data set.
ii The system will predict for a specific time, if it does not get the prediction of rainfall till that time then the sensor-based watering system will be activated.
iii In this article, a soil moisture sensor is used with a relay module.
iv A fixed value is given externally as a threshold, once the sensor senses the moisture of the soil and if it is below the threshold it sends a signal to Arduino UNO. Once the Arduino receives a signal from the soil moisture sensor it sends a signal to the relay module. The relay module triggers the water supply pump and the pump is being activated until again the soil moisture sensor senses that the soil moisture reached the threshold value.

4. Proposed IopaT architecture using edge-cloud computing

4.1. Smart architecture for the terrace gardening

In the proposed system, the voluminous weather and soil moisture data are stored inside the cloud servers. Based on the GA the data is analysed and water spraying is performed. Through a mobile Application, the soil moisture monitoring is performed as well as the UAV is controlled at the outdoor region. The mobile device works as edge device in this system. The weather and soil moisture data are of large amount and data processing is also extensive. Hence, cloud servers are used for storing and processing these large volumes of data. For the terace gardening section, we have used the soil moisture sensor to sense the humidity level of the soil. A fixed value is given externally as a threshold, once the sensor senses the moisture level of soil and if it is below the threshold it sends a signal to Arduino UNO. Once the Arduino receives a signal from the soil moisture sensor it sends a signal to the relay module and also to a GSM module. The Relay module triggers the Water supply pump and the pump is activated until again the soil moisture sensor module senses that the soil moisture reached the threshold value. GSM module sends a notification to the mobile devices connected with it via the internet. Once the Soil moisture sensor senses the threshold level it again sends the signal to Arduino UNO. The Arduino sends the signal to the relay module, the Relay module is triggered, and the watering pump is turned off. Again a notification is sent to the connected mobile devices about the status of the water supply.

4.2. Smart architecture for the outdoor region

For the outdoor region, soil moisture sensor to sense the humidity level of the soil. A fixed value is given externally as a threshold, once the sensor senses the moisture level of soil and if it is below the threshold it sends a signal to Arduino UNO. Once the Arduino receives a signal from the soil moisture sensor it sends a signal to the ESP8266 wifi module. The wifi module sends notifications to mobile devices. The mobile device directs UAV to spray the water in the required region. In Fig. 13 we have analyzed the simulation result of the mobile device directs UAVs to spray water at the required region of the outdoor garden and illustrates the performance analysis of the UAVs connected to the mobile devices. The Algorithm 1shows the proposed smart garden system for efficient plant watering.

The whole method is divided into two different parts. One is the terrace gardening system and another is the outdoor gardening system. Both the system has two different methods. The first method is where the Genetic algorithm based system is applied and if the GA based system failed then in the second method a sensor based water spraying method will be applied. Arduino Uno with relay module and the pump is used for terrace gardening system and unmanned aerial vehicle or UAV is used for the outdoor gardening section. This is the section of a proposed framework based on Genetic Algorithm to predict weather conditions. The process is divided into three parts pre-processing, processing and simulation. For pre-processing it starts via a collection of weather associated data, choosing the weather parameters to be estimated then construct data set for training and testing data or normalized data. Lastly, processing and simulation are delivered.

4.3. Data Pre-processing

The data pre-processing considers the weather parameter, data collection and normalized data, described as follows.

4.3.1. Weather Parameter

The daily weather parameters are collected from Accuweather [1] shown in Table 1 along with their units of measurement. Temperature (°C), date (dd/mm/yy), season and daily rainfall (mm) this parameter is elected for estimate rainfall for a particular day.

These above parameters are selected to match the predefined probability of rainfall. The selected parameter is prepared to just forecast the weather.

4.3.2. Data Collection

For this experiment, we have used real-life data with more especially we have used weather data of Kolkata, West Bengal. The data is in normalized form. This data is collected from an online weather site namely Accuweather.com. First one-year data are used for training and the next fifty days data are used for testing purposes.

4.3.3. Normalized Data

After selecting weather parameters and data collecting is done then the next phase has come for processing, namely, normalization of data. For training and testing random data in GA data most be in normalized form. The use of actual data to train the GA may cause conjunction difficult. Every whether data is fixed and transformed into either 0 or 1.

4.4. Data Processing

In the processing step entire methodology is explained as step by step. The method hasthemaintwo-phaseintelligence system developed using a genetic algorithm (GA) and Sensor-based system for IoT platform. The method is a sub-part of processing so it is explained below.

4.4.1. Proposed Method

As mention earlier, it has two major part, so it starts with an intelligence system which application of the genetic algorithm. First a request made by the user that water supply starts working according to weather condition, so first enter to accuracy checking. Accuracy checking is done according to algorithm then GA is applied for selection, crossover and mutation Here the selection is done Rowlett wheel method then crossover and lastly mutation is done.

This complete intelligences system is working according to predefine and explained the algorithm. After that stopping criterion is met for the check is this system output. As it is an application of Meta-heuristic so it may fail to predict rain. So here we set a threshold time for rain occurrence to check is this system able to meet user requirement if yes then ok if not then follow the Secord part of our proposed framework.

4.4.2. Proposed IopaT Algorithm

As per the proposed algorithm, the entire intelligence system is working to make the system more accurate than ever. Initially different months define as in numerical as 1 to 5. The first check in the actual dataset $ifRain = 0$ then delete the row from the dataset and get a matrix of 112 × 4 then to calculate the probability for each season. After that generate a random matrix $M_{mat}(m \times n)$. The value of the random matrix is 10 × 10, where each row represents a single candidate solution. For example Fig 6 where a candidate solution is 7,3,5,2 respectively and here the original dataset depicted in table color in blue, then a matrix is generated having 10 rows and 4 columns.

A candidate solution has some particular dates as a parameter. Now it moves to calculate accuracy for each row exist of that matrix having 10 rows and 4 columns. The table in green is just a small dataset generated according to the candidate solution. Accuracy count is done with this equation $Accuracy = \frac{C_{count} n}{\times} 100$, where C_{Count} is a number of rainy days which counted and n is a column. For C_{count} at first generates a random variable r, and its value lies between $0 \leq r \leq 1$ then check if the value of $r \leq$ every season and update the C_{count}. Suppose it generates$R_{random} V_{value} 0 \leq r \leq 1$ check condition $(r \leq Percentage_{Rain}[1])$ for $Season = 1$ where $Rain[1]$ is a blank array that store value for the probability of rain of season 1. If condition satisfies then $C_{count} = C_{count} + 1$ otherwise repeat the procedure for next season. To increase accuracy here genetic algorithm is applied on random matrix $M_{mat}(m \times n)$.According to Rowlett wheel Selection is done then crossover and lastly mutation.

This entire process is explained in the first part of our proposed system. Now weather prediction system is learning and its training procedure is complete. At this time if an unknown day is inserted by checking its prediction, the system will generate a result from its learning method. The proposed system will automatically move to the sensor based system if the GA based system failed until the fixed threshold time ends. $P_c = 0.8 and P_m = 0.05$

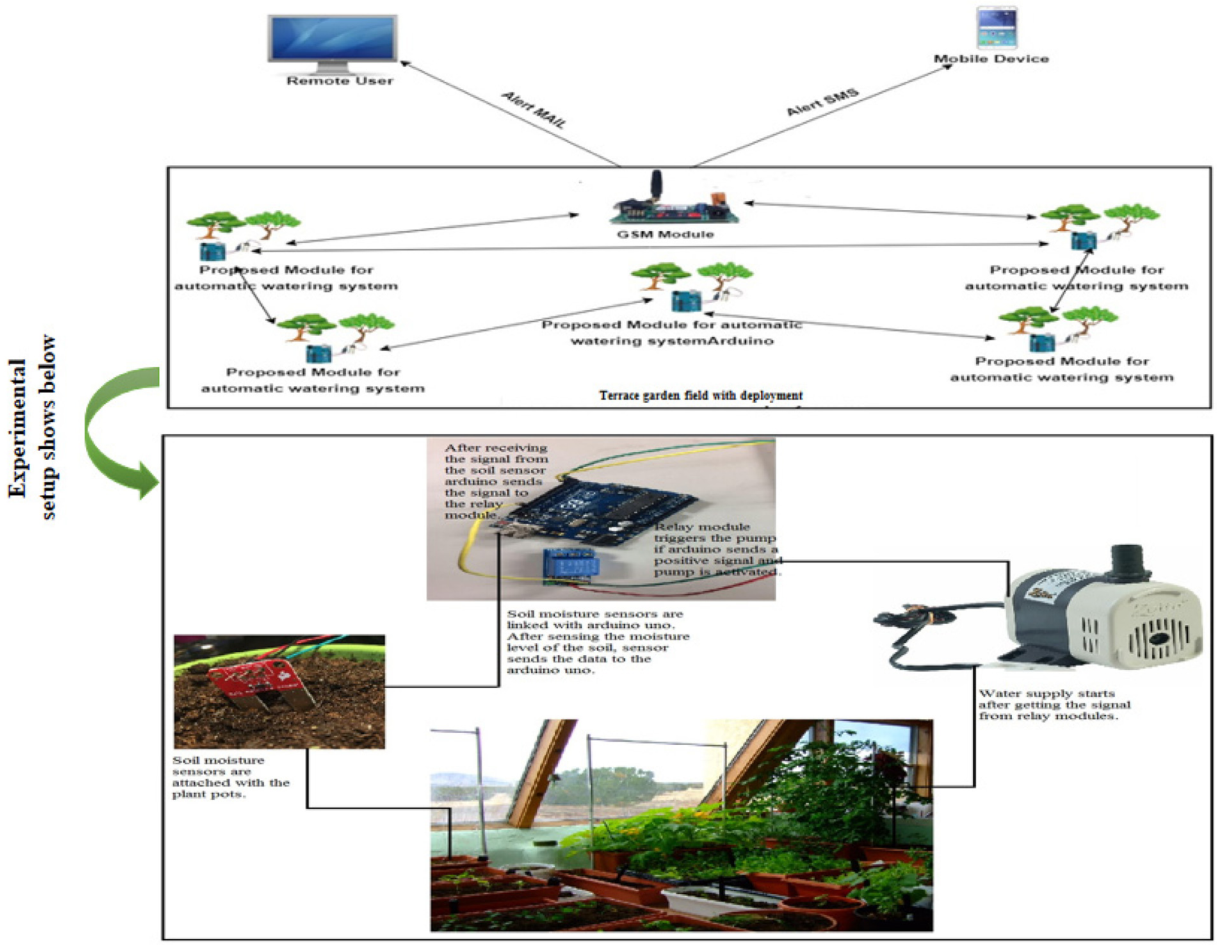

Fig. 3. Implemented Sensor based Architecture of Smart Agriculture system for the indoor garden region

4.5. Mathematical Model of Intelligence Based Weather Prediction and Smart Watering System For IoT Platform

We describe the significant physical and virtual components of IoT based smart gardening system as follows

Definition 1 (IoTD)**.** An IoT device is denoted by *I*, is defined as a four-tuple:

$I = (I_{id}, I_{st}, I_s, A_{IoT})$

Where, I_{id} is an integer that denotes the unique ID of the IoT device, I_{st} denotes the status of the device, I_s denotes the event type sensed by the device and A_{IoT} denotes the application. The set of ID is indicated by *I*.

Definition 2 (Status of IoTD)**.** The type of an IoTD, I_{st} defines whether the device's state is active or inactive. The state is denoted by a Boolean:$I_{st} = 0, 1,$where 1 and 0 respectively denote the active and inactive states.

Definition 3 (Type of IoTD)**.** The type of an IoTD(I_{st}) defines the event type sensed by a device. It is presented as an element of the set $i = i_1, i_2, ...i_p,$ where *i* contains the set of all events which are monitored by the IoTD and P denotes the total number of distinct event types.

Definition 4 (Applications of IoTD)**.** An application A_{IoT} is defined as a two-tuple:

$A_{IoT} = (AI_{id}, AI_{sp})$ where (AI_{id} is the ID of the application. AI_{sp} states the minimum system specifications which are essential to run the application including the primary memory, processor, secondary storage details and the version of the operating system.

Property 1Decision Variables for edge devices to operate UAVs. *Binary decision variables are stored by mobile devices with three parameters. Uxyz= 1 if* UAV_x *is allocated to excute a task z on target y, otherwise* $U_{xyz} = 0$*; where x is the integer number to denote UAV, y is the target location and z is the task.*

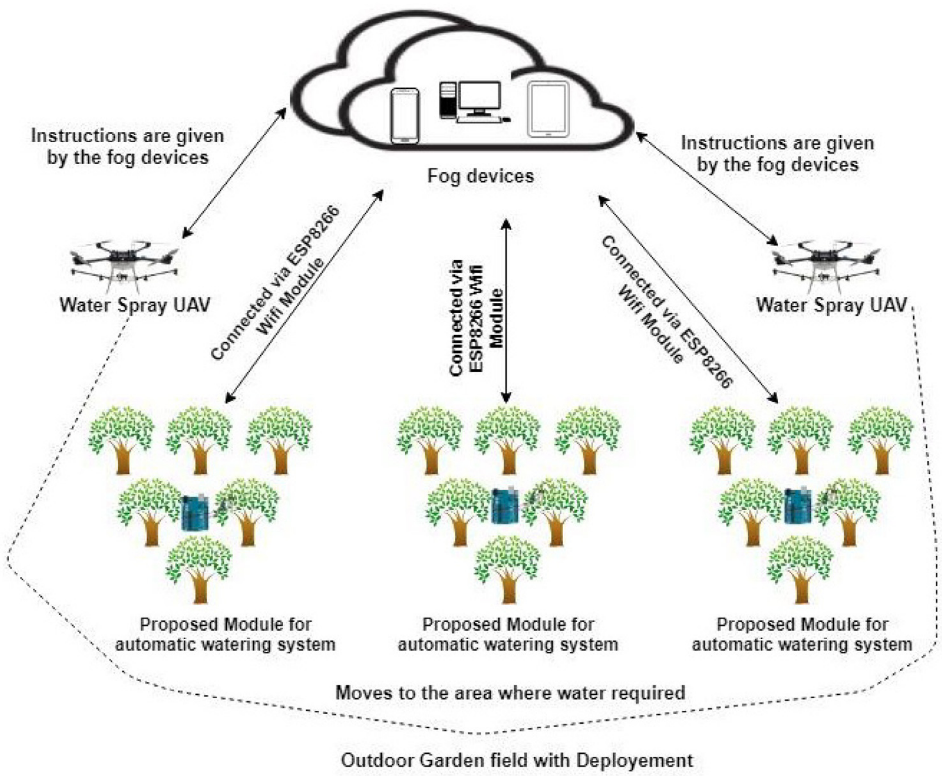

Fig. 4. Implemented Sensor based Architecture of Smart Agriculture system for the indoor garden region

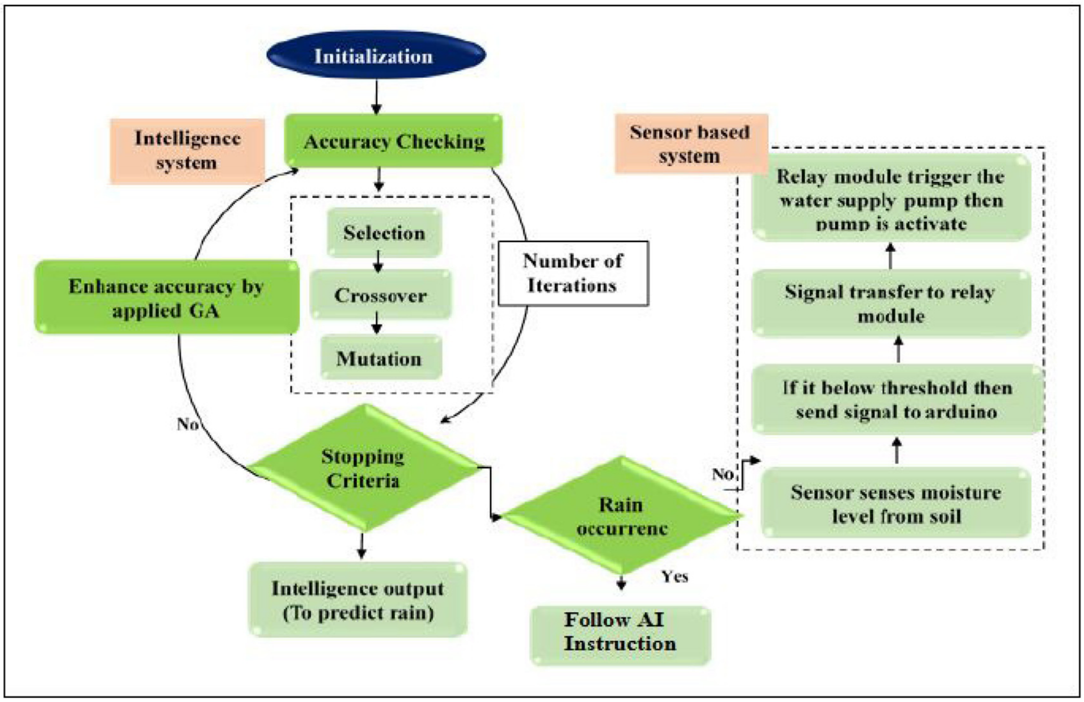

Fig. 5. Workflow diagram for IopaT system

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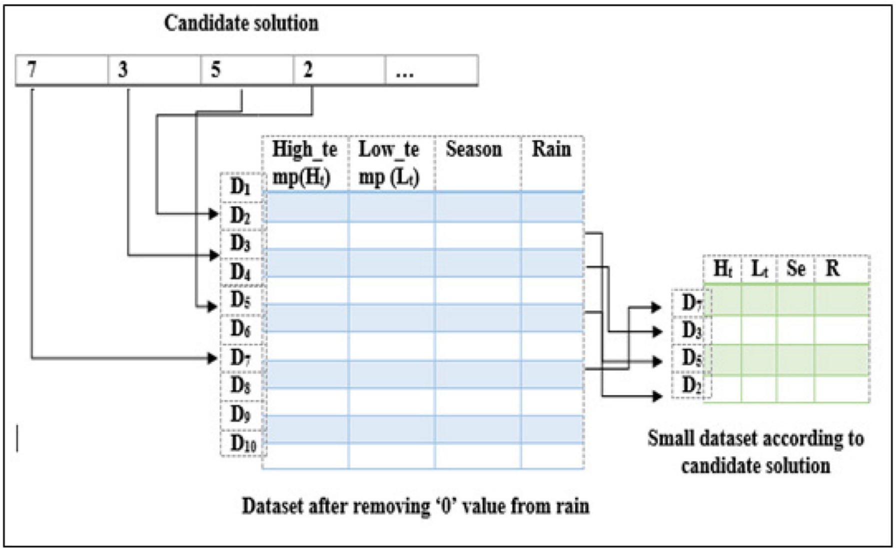

Fig. 6. First Candidate solution find procedure

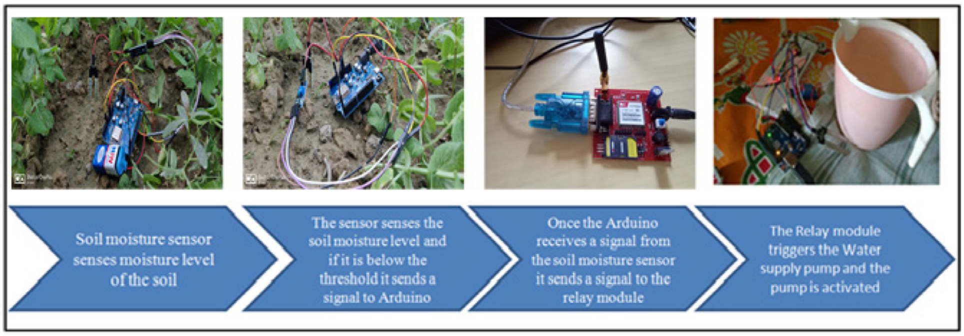

Fig. 7. Experimental setup for the proposed IoT based smart plant watering system in our lab

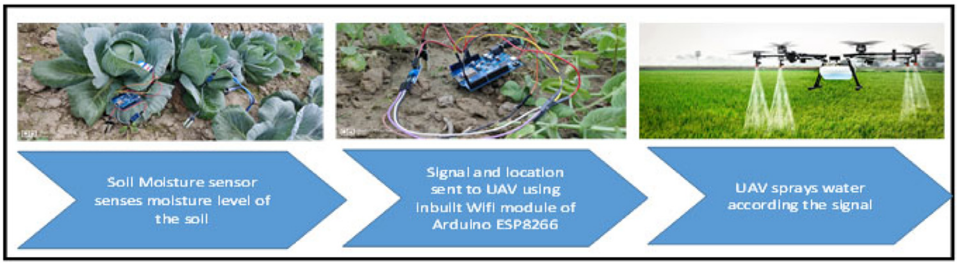

Fig. 8. Experimental setup for the proposed IoT based smart plant watering system in our university premises

5. Performance evaluation of IopaT

The experimental setup is mainly divided into two different sections. One is the terrace gardening system and another is the outdoor gardening system. The terrace gardening section is described in section 5.1 and in section 5.2, the outdoor system is described. For the experiment, we have used Arduino-Uno along with a soil moisture sensor based model used for moisture measurement. For monitoring system, a mobile App is used. The entire experimental setup along with output is described in figure 3. Figure 13 and figure 14 shows the predicted data graph of temperature and winds speed data. We assumed the temperature and wind speed according to the last few years result by applying genetic algorithm. The temperature is required to spray water accordingly so that the water is not wasted. The wind speed is required to control the UAV. The UAV may not spray the water in the exact space if the wind speed is high. This problems force us to predict

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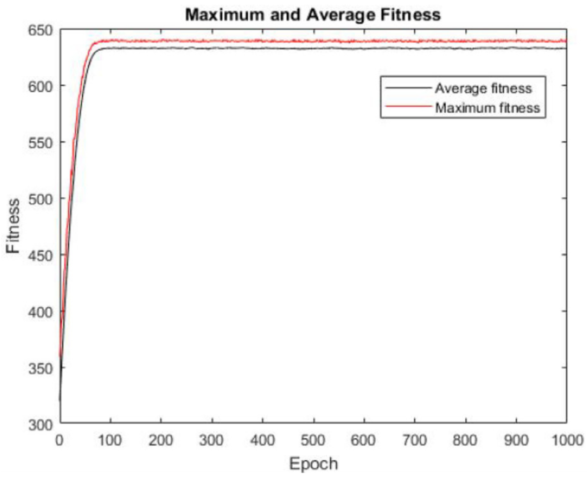

Fig. 9. Maximum and average solution of the IopaT system.

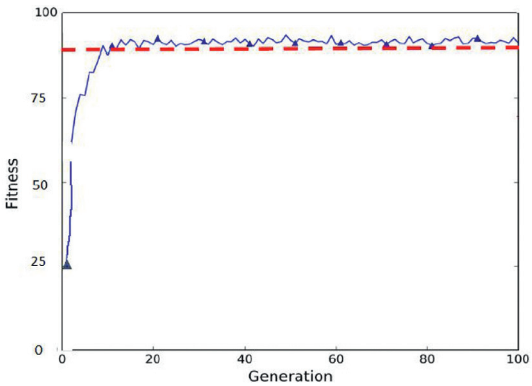

Fig. 10. More than 80% Accuracy achieved using proposed methodology.

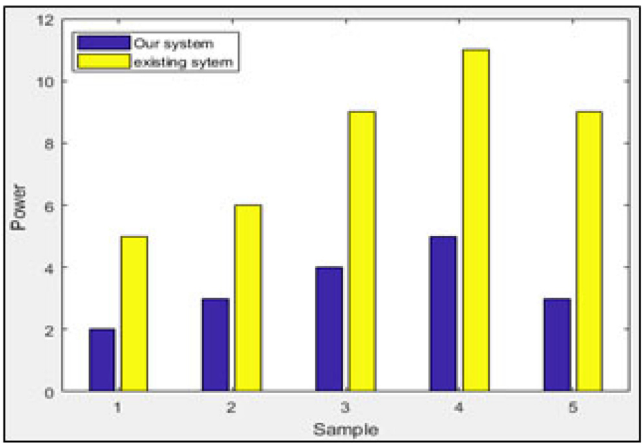

Fig. 11. Comparison of power consumption Between IopaT and existing system

the temperature and wind speed to make the whole system stable. In figure 13 and Figure 14 it shows the graph of that predicted temperature and wind speed data.

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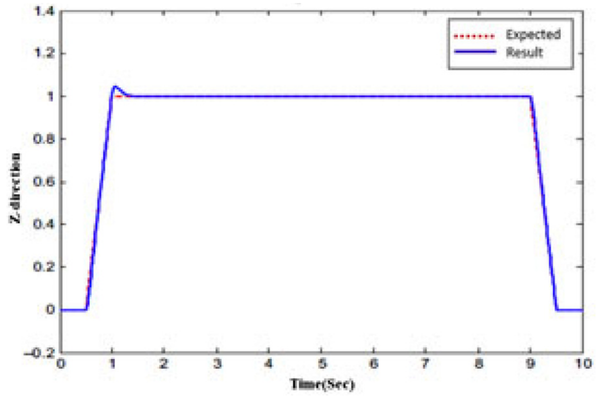

Fig. 12. Altitude chasing report for automatic take-off, landing mission using OBC

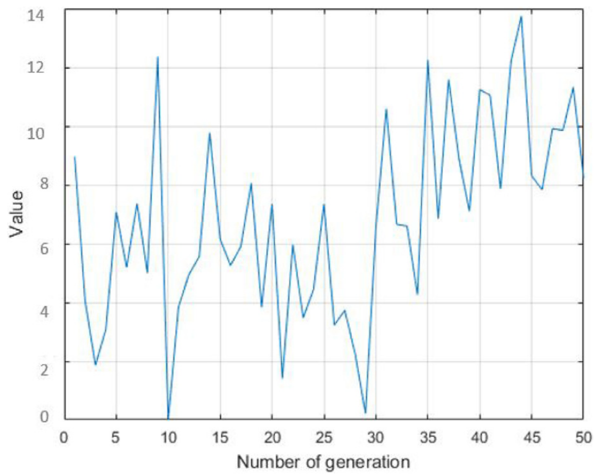

Fig. 13. Output predicted temperature data

5.1. Experimental setup for terrace plant watering system

The main work of the Soil Moisture Sensor is to measure the presence of water content in the soil. In this article, we have used it to sense the soil moisture. A fixed value is given externally as a threshold, once the sensor senses the moisture of the soil and if it is below the threshold it sends a signal to ArduinoUNO. Once the ArduinoUNO receives a signal from the Soil Moisture sensor it sends a signal to the relay module. The relay module triggers the water supply pump and the pump is activated until again the soil moisture sensor module senses that the soil moisture reached the threshold value. Once the soil moisture sensor senses the threshold level it again sends the signal to ArduinoUNO. The Arduino-UNO sends the signal to the relay module and the Relay module is triggered and the watering pump is turned off. Fig 3. provides the experimental setup scenario for the proposed smart terrace gardening system based on IoTin our experimental lab.

5.2. Experimental setup for Outdoor plant watering system

In this section two methods are used, the Genetic algorithm based water spraying system and sensor-based system. In this section, an Unmanned Aerial Vehicle or UAV is used for water spray purposes. The Genetic Algorithm based system is explained in the methodology section. In Fig 4 the architecture of the system is described where a sensor-based system collects the information of soil moisture and sends it to the UAV through Arduino ESP8266, which has an inbuilt Wi-Fi module.

5.3. Comparing Proposed system with the existing system

The existing system or the manual system was time taking and human controlled but the new proposed system decreases the time and effort of humans by applying AI and UAV. The AI based system automatically triggered the water system by predicting the weather and the UAV spray water according to that. The previous system needs a human to control the pump

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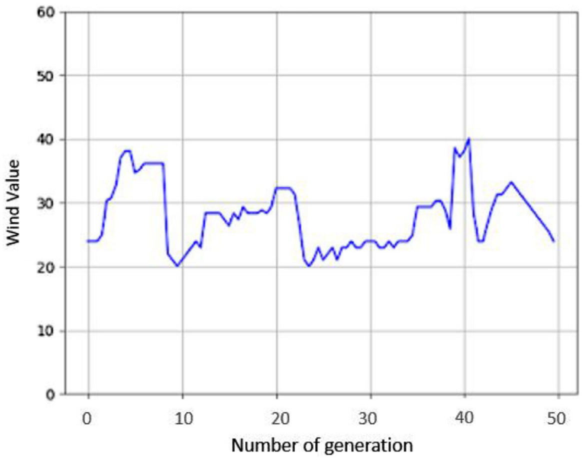

Fig. 14. Output predicted wind speed data

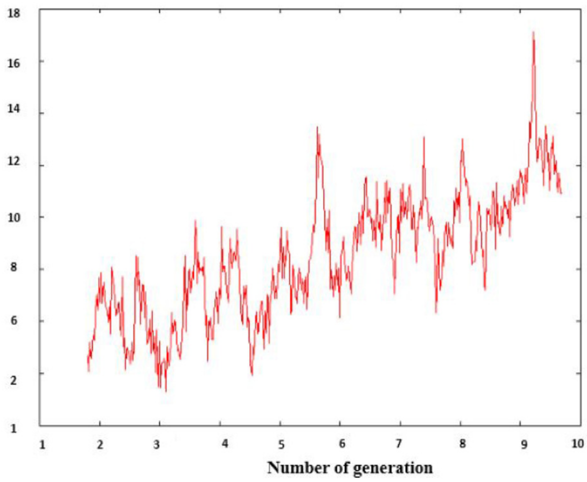

Fig. 15. Evolution of the number of chromosomes in each generation with temperature errors smaller than 2.1 degrees Celsius for our data set.

at the field but in the new system, the farmer can switch on or off his pump from his house by using the android application installed on his phone. In the proposed system we have also achieved more than 80% accuracy which also decreases the extra usage of water by predicting the water. We have also developed an application to control the UAV and monitor the field (Fig. 17). In this app, we can control the UAV accordingly the need for water in the field and as well as monitor the field in which water is required. The application has several zones where we can select the zone to spray water and we can also control the pump (for indoor gardening) with this application.

6. Accuracy, Fitness and Power consumption

For evaluating performances some specific rules are followed.GA is used for enchasing accuracy rate, as itspopulation-based algorithm and it has three operators that are used for the balanced purpose. First, we define average accuracy and maximum accuracy in Fig 9. For mathematical analysis, we have used MATLAB 2017A.

In the proposed system we have achieved more than 80% accuracy while applying the Genetic Algorithm in our weather dataset which is shown in Fig 10. In case the intelligence system is failed then the sensor based method start working. This option enhances efficiency and reduces unnecessary power costs. It shows in Fig 11. In Fig 12 Altitude chasing report for automatic take-off, landing mission using OBC. Fig 13 and 14 predicted output are shown for temperature and wind speed. In Fig 9 and 10 shows the Evolution of the number of chromosomes in each generation with an operated data set. In figure 9 the graph shows the maximum and average solution of the proposed IopaT system. It shows the the maximum and average solution after applying the fitness function after every epoch. The proposed system achieved almost the maximum solution by applying the fitness function.

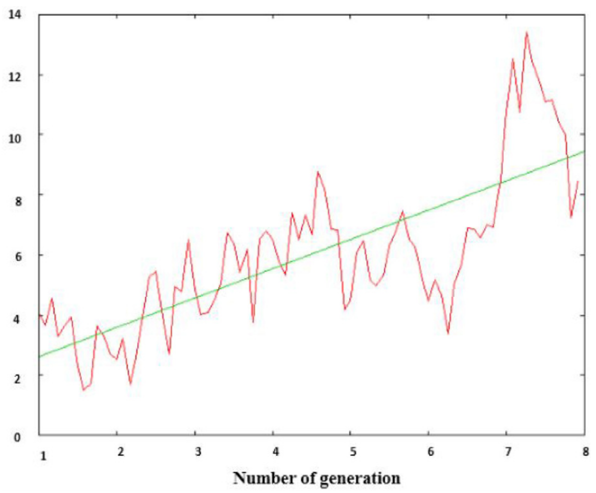

Fig. 16. Evolution of the number of chromosomes in each generation with relative humidity error smaller than 10 percent Celsius for operated dataset. Output predicted wind speed data

Fig. 17. Screen shots of the Android Application

Algorithm 1: Enhancing Accuracy of Proposed IopaT system

Input : $winter = 1, spring = 2, summer = 3, monsoon = 4, autumn = 5, Accuracy, Rain$), Deadline of receiving result (D_L)
Output: M_{at} = Final accuracy after applying GA
start;
if $Rain = 0$ **then**
  Delete row;
end
for `select season (P=1 to 5)` **do**
  $C_{ount} Rain \geq 0, Day$
  $P_{ercentage} Rain = \frac{C_{ount}}{D_{ay}} \times 100$
end
$M_{at}(m \times n) *$ generate random vector matrix $*$
for `Iteration (` ψ `=1 to x)` **do**
  for `(i=1 to m)` **do**
    `Fetch Element`
    $Checkcountas C_{ount} = 0$
    for `(I  1 to n)` **do**
      $M_{mat} m = \int m * getseason *$
      C_{ount}= Calculate number of rainy days
      Accuracy $\frac{C_{ount}}{n} \times 100$
    end
    List Accuracy[] LA
  end
  $* IncreaseAccuracy *$
  Set $P_c = 0.8$ and $P_m = 0.05$ Select m from $M_{at} Accuracy$ and store in $M_{atrix} M_{at} 2$
  $* RowlwettwheelSelection *$
  for `i = 1 to` $\frac{m}{2}$ **do**
    `Select two rows from` $M_{at}2 * Crossover *$
    if $r1 \leq P_c$ **then**
      crossover and copy to $M_{at}3$ **end**
      Copy to $M_{at}3$
    end
    $V_1 = P_m \times m$
    Find Position as $Position[] = findV_1$ number of random position from $M_{at}3$
    Repeat Position [] = with current value
    $V_2 \in [1$, no of rows in $\int$ m] Update matrix $M_{at}3$
  end

Algorithm 1. Enhancing Accuracy of Proposed IopaT system

7. Conclusions and future scope

A speculative process is proposed in this article that predicts the rainfall using GA that helps to optimize the usage of water. The present models use the monthly prediction of the weather. In this paper, a genetic algorithm based smart and intelligence system is developed to predict rainfall for the tropical region.This system will help the farmers in their water based activities in the field.A genetic algorithm based watering system will predict the rainfall using its training procedure. The training has made using real weather data set.The system will predict for a specific time, if it does not get the prediction of rainfall till that time then the sensor-based watering system will be activated. If it fails to detect then a soil moisture sensor is used.This manual system used a relay module, which works as wireless media.It is used to spray the water in the target area despite heavy wind.This is a useful system for the farmers to get the weather forecast. So this helps farmers to plan different activities of agriculture according to rain prediction. The proposed system also offers a smart power and resource optimized system.The proposed system will also help in different decision making like crop patterns and water management. The proposed terrace gardening water spraying system will help those who have their own terrace garden. The system will use the soil moisture sensor and a motor based water spraying techniques to make it an automatic watering system. A Gravitational Search Algorithm(GSA) based search technique to predict places, where water is required, can be developed for an agricultural system where GSA will be used to predict the right place where the water should be sprayed despite the wind. To overcome the deviation of the direction the back-stepping procedure can be applied to the UAV based water spraying system. It will help the farmers to optimize their available water to distribute among the drought-affected areas. With the use of the Gravitational Search Algorithm, a smart soil condition prediction system can be implemented.

Declaration of Competing Interest

All authors have participated in (a) conception and design, or analysis and interpretation of the data; (b) drafting the article or revising it critically for important intellectual content; and (c) approval of the final version.

This manuscript has not been submitted to, nor is under review at, another journal or other publishing venue.

The authors have no affiliation with any organization with a direct or indirect financial interest in the subject matter discussed in the manuscript

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