Applications of Neutrosophic Logic of Smart Agriculture via Internet of Things

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Abstract

This study presents a smart agriculture mechanism model equipped with neutrosophy theory for the first time. The model is created by meticulously bringing together the fields of decision making, IoT and cloud computing. We have demonstrated that smart agriculture can be used in integration with neutrosophic, integrated with IoT. This integration is a model created by making much more detailed calculations by taking into account and using the uncertainty situations in neutrosophic numbers and logic, by automating both the geometric analysis of the soil and surface control and the numerical data of the environment for smart agriculture.

Keywords: Smart Agriculture, Internet of Things, Cloud Computing, Neutrosophic Logic, Neutrosophic Geometry

1 Introduction

The term IoT (Internet of Things) was first used by Ashton, director of the Auto-ID Center. He defined that "Objects of The Internet (IoT) is a communication network in which physical objects are connected to each other or to larger systems. This network, from every moment of life it is full of technological devices that collect billions of data, turning it into meaningful information" [1]. IoT technology, electronics it has gained a new dimension thanks to miniaturization and advances in network connections. With these developments, IoT wireless is a network of advanced sensors that can communicate with each other over the internet and can be accessed through web technologies over the internet network it has become a technology in which it is used. IoT data collection, transmission, processing, business management, etc. currently and next-generation information it is a significant part of their technology and has opened a new way for people to collect and process information [2]. Within the fundamental IoT, natural environment includes temperature, position, weight, light intensity, pulse rate, blood pressure, hardness, carbon dioxide ratio, humidity, ph value, sound intensity, etc. all kinds like there is an environment where there are measurable physical magnitudes. These data are received through sensors are detected raw and analog or they are converted to digital signals. These data from nature are the RFID needed for IEEE 802.5.4, Bacnet, Bluetooth, GPRS and GSM, infrared, LPWAN, M-Bus, machine-machine communication, Man-Machine, ModBus, NFC, power line carriers, Zigbee, ethernet and it is transmitted to cloud computing systems for storage, such as for processing with wireless and wired communication infrastructure and communication protocols. The data store form big data in increasing stacks. This big amount of data to increase efficiency needs to be analyzed, and this is done using machine learning methods or the established rule base. IoT with the growth and spread of technology, traditional agriculture will be abandoned and switched to modern and more efficient agriculture. Also for industries, it will provide great business opportunities. These developments provide important groundwork for the development and innovation of Agriculture 4.0.

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Internet of Things (IoT) is a technology that has been growing in popularity in recent years. IoT is defined as the way objects communicate with each other through advanced communication technologies. In the future, thanks to developed projects such as LTE (Long-Term Evolution), M2M (machine-to-machine communication), today's most devices in use will be able to access an IP. The importance of IoT technology will bring many innovations increasing day by day via many similar developments. The industry 4.0 solutions, can achieve information about the place of IoT technology in smart agriculture is provided [3]. However, there is no specific consensus on the definition of IoT by the community of users around the world among academics, researchers, people from many different segments, including practitioners, developers, and legal entities. What all the definitions have in common is that the first version of the internet was created by people the idea is that it's about the data created, and the next version is about the data created by generations. The best definition for IoT "A clear and comprehensive smart objects capable of reacting and behaving in the face of changes in situations and the environment the network is stated as" [4]. IoT technology generally consists of detection, transmission and application layers. This technology has made measurable information about all kinds of objects that you can think of, remotely detected and monitored. Detection sensors are used to collect data at the layer. Sensors for fixed or mobile use as needed it can be designed. Electrical conductivity (EC), CO2 ratio, soil and, air humidity in the agricultural area discussed in this study today, temperature, light sensors are some of them. In recent years, passive, battery-free, non-contact, electrical resistance measurement sensors and studies are also being carried out on sensors that detect the physiological state of plants [5, 6]. Wireless devices with sensor networks (KSA) and RFID technologies and traditional wireless communication protocols such as WiFi, Bluetooth, GPRS in addition, the IEEE 802.15.4 standard and next-generation protocols such as Zigbee are used designed for this purpose at the transmission layer. The software layer is web-based mobile applications, especially microprocessor (MCU) software, server and cloud computing management software with it covers inter-machine communication protocol (M2M) software.

Agricultural system optimization is one of the significant factors for the recent economy to improve since countries are fully dependent on the factor that the today's resource management in agriculture is the most complicated, such as the water resource; the agriculture uses approximately 65 per cent of the fresh water; hence, water management is the most critical part in the agriculture to accomplish; hence, to achieve this, there are certain areas in agriculture where it is dependent such as the crop section for the soil, and in this factor, a PH sensor is used to measure the acidity in the solution; an IoT gate way is used to connect the field devices with the wireless Internet networks which could be wide area network (WAN) or a remote controlled device; the device can be an integration of IoT with cloud computing and sensors, and other resource combined will be managed by the cloud computing along with raspberry pi sensor which is a module to which various sensors such as the temperature and humidity are interfaced and also other will be the provision for the GSM-based automatic irrigation system for the efficient use of resources and crop planning; and when it comes to the operation of the system initially, the user registration is compulsory for the verification, and then, the admin checks the data provided by the user and allows to control the system; raspberry pi kit takes the sensor values and sends to Google spread sheet attached to the raspberry pi kit, the Google spread sheets used for maintaining real-time information and a data related to crop saved on these sheets, and then with ANN algorithm, sensor values maintain on Google spread sheets, compare according to threshold values, and check which crop is suitable for soil; this process is distributed in modules, this proposed system is best suitable for the crop selection based on the soil quality, and unwanted water wastage things are completely eliminated [7].

Cloud computing, or in its functional sense, online information distribution is the general name given to services that provide common information sharing between computing devices. In this respect, cloud computing is not a product, but a service. It is the sharing of software and information from the underlying source, and the use of existing information services over the information network (typically from the Internet) from computers and other devices in a similar way to electricity distributors. Zhao proposed a system that allows farmers to remotely monitor the data of the environment and plants obtained from greenhouses by sending them to mobile devices via the internet via sensors [8]. Duan discussed on the characteristic agricultural data which agricultural information management system can be used for agricultural production processes [9]. In the study, information about the smart agricultural management information system was given to make sensitive management decisions on issues such as crop cultivation, fertilization and input costs. Ying and Hao used IOT technology with the help of cloud computing method and proposed a smart cloud computing method to process data from different IOT devices [10]. They reported that the obtained data can be stored in cloud data centers and these data can be processed using smart large servers to solve the necessary problems. Qirui proposed an agricultural information service model based on agricultural expert systems in order to provide accurate and efficient agricultural information services to users through web browsers [11]. Hori et al. gave information about the cloud system established by Fujitsu ltd for the agricultural sector and designed a cloud model for agricultural applications. In addition, they explained how the products should be priced and sold for the farmers using the developed model. Researchers have used prototype web and mobile phone applications for production-sales planning, operational planning management, information support and cultivated land data management functions [12]. The researchers reported that the PDCA (Plan-Do-Check-Act) cycle used in agricultural applications will make significant contributions to the development of cloud services.

One of the factors that spoils the standard of agricultural production is that the soil structure varies from region to region. Apart from region to region variability, no land has a homogeneous structure in itself. When a production area is examined carefully, it can be easily observed that the plants develop very well in places, they are weak in places, even drying and deaths occur in places. So, what is it that creates these differences within the same land? Of course, the reason for these differences is the physical, chemical and biological structure of the soil that can change in every decare, even every square meter. In fact, this variability lies in the emergence of many elements of smart agriculture. Smart agriculture is a technique that enables soil and product management to increase agricultural productivity, and minimize the damage to the environment by using resources more economically. In this context, it is aimed to give up classical production and to implement an application method that handles the land with an in-homogeneous and variable approach. The main factor aimed here is to use the inputs applied in agricultural production where they are needed, when and in quantity. Smart agriculture is a modern agricultural production technology that is based on the intervention to be made to the needs that differ spatially and temporally in the area where the crop is cultivated in an agricultural enterprise, taking these location and time criteria into consideration. Intelligent agriculture aims to prevent waste of resources, increase the gross yield of the product and minimize the environmental pollution caused by production with the use of improved information and control systems. Intelligent agriculture techniques can be used in almost every period of crop production from tillage to harvest. Among the goals of smart agriculture is to reduce chemical costs such as fertilizer and medicine; protecting the environment by reducing these uses; providing high quantity and quality products; Ensuring a more efficient flow of information for business and breeding decisions and establishing a record order in agriculture. It is aimed to maximize productivity with the Internet of Things in agriculture. As natural resources are used at the required level, the cost is reduced. Similarly, with the smart systems on the farm, all factors required for production are analyzed and presented to the producer simultaneously. In this way, resource wastage is prevented and quality products are produced. In addition, rapid decision-making mechanisms are created with machines that communicate with each other and work synchronously. Producers are given the opportunity to manage and monitor the entire farm from a tablet or phone, and by reducing the work force, and also more productivity, quality and natural production opportunities are created.

Applications of IoT in agriculture science decrease the human time, scales down the human efforts, and provide the easiness and effectiveness for the mechanism. Suppose that we apply in the irrigation area, we put the humidity sensors and the threshold sensors send the information to your mobile phone and then connect to the IoT when the humidity range increases, then you can turn off the water meter. There are many categories of industries that use these technologies for improved performance, such as automobiles, communications, food, medical, marine, defense and the most important agricultural industries. The use of these technologies contributes to food safety, environmental sustainability, good agricultural practices (GAP), computer artificial intelligence, decision-making, GPS and increased agricultural efficiency, as well as to crop protection and integrated management of pests and where possible crop management of pests and diseases. The application equipment can be chosen depending on these variables and the application equipment meets microbial protection so that the agriculture equipment will be selected. In addition, new innovations are being launched day by day and their implementations have also steadily expanded. The area of agriculture has tremendous potential for emerging technology such as artificial intelligence (AI) and the Internet of Things (IoT) to be implemented. By integrating this, smart systems would be able to make choices based on prior experience and understanding. This operation is made simpler by smart and automated machines. The AI contains many problem-solving logics and approaches such as fuzzy logic, artificial neural networks (ANN), neuro-fuzzy logic, and expert systems, of which the ANN approach is more commonly used and prescribed. Recently, fuzzy logic has found many applications and efficient results in smart agriculture and IoT [13, 14, 15, 16, 17]. We will use neutrosophic logic [18] in this study, which is a useful and practical extension of fuzzy logic. The topic of indeterminacy beyond the principles of fuzzy logic is often taken into account by neutrosophic logic.

2 Neutrosophic Logic Fundamentals

In classical set theory, an element either belongs to a set or not. The membership of elements in a set is interpreted in binary terms according to a divalent case. In fuzzy set theory, introduced by Zadeh [19], a gradual assessment of the membership of elements in a set is permitted by a membership function which takes values in the real unit interval $[0, 1]$. In fuzzy set theory, classical divalent sets are usually called crisp sets. Fuzzy set theory is a generalization of the classical set theory. IFS are sets whose elements have degrees of membership and non-membership. IFS have been introduced by Atanassov [20] as an extension of the notion of fuzzy set, which itself extends the classical notion of a set. Neutrosophic set theory is a generalization of intuitionistic fuzzy set, crisp set, fuzzy set, para-consistent set, dialetheist set, paradoxist set, tautological set based on Neutrosophy [18]. An element $x(T, I, F)$ belongs to the set in the following way: it is true in the set with a degree of $t \in [0, 1]$, indeterminate with a degree of $i \in [0, 1]$, and it is false with a degree of $f \in [0, 1]$.

We will now give some definitions of the fundamental concepts related to our study.

Definition 2.1. [19] Given a universal set U and a generic element, denoted by x, a *fuzzy set* X in U is a set of ordered pairs defined as

$X = \{(x, \mu_X(x))|x \in U\}$, where $\mu_X : U \longmapsto [0, 1]$ is called the *membership function* of A and $\mu_X(x)$ is the *degree of membership* of the element x in X.

Definition 2.2. [20] An *intuitionistic fuzzy set* X over a universe of discourse U is represented as

$X = \{(x, \mu_X(x), \nu_X(x))|x \in U\}$, where $\mu_X : U \longmapsto [0, 1]$ and $\nu_X : U \longmapsto [0, 1]$ are called respectively the *membership function* of A and the *non-membership function* of A for x in X. The *degree of non-membership* of the element x in X is defined as $\mu_X(x) = 1 - \nu_X(x)$.

Definition 2.3. [18, 21] Let U be a universe of discourse. A *neutrosophic set* is defined as

$$N = \{(x, T(x), I(x), F(x)) : x \in U\},$$

which is identified by a *truth-membership function* $T_N : U \longmapsto]0^-, 1^+[$, *indeterminacy-membership function* $I_N : U \longmapsto]0^-, 1^+[$ and *falsity-membership function* $F_N : U \longmapsto]0^-, 1^+[$.

Definition 2.4. [22, 23] Let U be a universe of discourse. A *single valued neutrosophic set* is defined as

$$N = \{(x, T(x), I(x), F(x)) : x \in U\},$$

which is identified by *a truth-membership function* $T_N : U \longmapsto [0, 1]$, *indeterminacy-membership function* $I_N : U \longmapsto [0, 1]$ and *falsity-membership function* $F_N : U \longmapsto [0, 1]$ with $0 \leq T_N(x) + I_N(x) + F_N(x) \leq 3$. A *single-valued neutrosophic number* (SVNN) is denoted by $a = (T, I, F)$.

Definition 2.5. [18, 21] Let $A^* = \{(x, T(x), I(x), F(x)) : x \in A\}$ and $B^* = \{(y, T(y), I(y), F(y)) : y \in B\}$ be neutrosophic elements. $NR = \{((x, y), T(x, y), I(x, y), F(x, y)) : (x, y) \in A \times B\}$ is a neutrosophic relation on A^* and B^*.

2.1 Geometric Modeling on Neutrosophic Sets

Geometric modeling has a wide range of applications. Although mathematical models are expressed with differential equations, nowadays, geometric modeling tools are used as modeling tools [24]. One of them is Bèzier curves. In neutrosophic sets one can apply this to visualize data from a given neutrosophic set. Neutrosophic Bèzier curves are generated based on the control points from one of $TC = \{(x, y, T(x, y))\}, IC = \{(x, y, I(x, y))\}$ and $FC = \{(x, y, F(x, y))\}$ sets. Thus, there will be three different neutrosophic Bèzier curve models for a neutrosophic relation and variables x and y. A neutrosophic control point relation can be defined as a set of $\mathrm{n}+1$ points that shows a position and coordinate of a location and is used to described three curve which are denoted by $NR_{p_i} = \{NR_{p_0}, NR_{p_1}, \ldots, NR_{p_n}\}$ and can be written as

$$\{((x_0, y_0), T(x_0, y_0), I(x_0, y_0), F(x_0, y_0)) \,..\, , \ldots, ((x_n, y_n), T(x_n, y_n), I(x_n, y_n), F(x_n, y_n))\}$$

in order to control the shape of a curve from a neutrosophic data.

Definition 2.6. A neutrosophic Bezier curve with degree n was defined by Taş and Topal [22] .

$$NB(t) = \sum_{i=0}^{n} \binom{n}{i} (1-t)^{n-i} t^i NR_{p_i}, t \in [0, 1]$$

Definition 2.7. Neutrosophic Bézier surfaces [23] are generated by the control points from one of sets

$$TC = \{(x, y, T(x, y)) : x \in A, y \in B\}$$
$$IC = \{(x, y, I(x, y)) : x \in A, y \in B\}$$
$$FC = \{(x, y, F(x, y)) : x \in A, y \in B\}$$

Thus, there will be three different Bézier surface models for a neutrosophic relation and variables x and y. A neutrosophic control point relation can be defined as a set of $(n+1)(m+1)$ points that shows a position and coordinate of a location and is used to describe three surface which are denoted by

$$NR_{P_{ij}} = \{NR_{P_{00}}, NR_{P_{01}}, \ldots, NR_{P_{\text{num}}}\}$$

and can be written as quadruples

$$\{((x_i, y_j), T(x_i, y_j), I(x_i, y_j), F(x_i, y_j)) : i = \mathbf{0}, \ldots, n, j = \mathbf{0}, \ldots, m\}$$

in order to control the shape of a curve from a neutrosophic data.

Definition 2.8. A neutrosophic Bézier surface [23] with degree $n \times m$ is defined by

$$\mathrm{NB}(u, v) = \sum_{i=0}^{n} \sum_{j=0}^{m} \left(\begin{array}{c} n \\ i \end{array} \right) (1-u)^{n-i} u^i \left(\begin{array}{c} m \\ j \end{array} \right) (1-v)^{m-j} v^i \mathrm{NR}_{p_{ij}}$$

Every set of TC, IC and FC determines a Bézier surface. Thus, we obtain three Bézier surfaces. A neutrosophic Bézier surface is defined by these three surfaces. So it is a set of surfaces as in its definition.

3 An Application in IoT and Smart Agriculture

In agriculture, topography study has an important place for the operation of the photosynthesis mechanism depending on the geographical location of the field and the climate type. The mechanism of photosynthesis is possible with the maintenance of factors such as sunlight, CO_2, H_2O, heat, glucose, and O_2 in an optimal process. Along with these, the wavelength of light, humidity and soil properties play an important role in the production efficiency of the plant. Especially when focused on sensitive agriculture field, the details of the data and precise measurements require positioning and application for the analysis of big data and the interpretation of these data and values is a difficult process. In this sense, we give some applications that are neutrosophic useful and manageable tools in IoT and Smart Agriculture in this section.

3.1 Neutrosophic Inference Engine Design in Smart Agriculture and IoT

Here, we give neutrosophic methods for data gathering and evaluating in Neutrosophic Inference Engine Design (NIED).

Remark 3.1. One needs to have the following three properties for a possible NIED. After the properties constructed, The next step will be built a NIED.

1. Neutrosophication and De-neutrosophication

   While doing data analysis with fuzzy, fuzzification of crisp data and then defuzzification is required. Using neutrosophy for more precise analysis, measurement and evaluation of data should also provide what has been done for fuzzy. Recently, different types of neutrosophic numbers have been proposed for modeling different applications and fields of study. For example, linear pentagonal neutrosophic and its de-neutrosophication was introduced by [25]. The authors gave a spanning tree graph property and removal area method for its de-neutrosophication.With this graph analysis, pentagonal structures can be evaluated smoothly. Another example is trapezoidal neutrosophic number. Chakraborty et al. analysed various types of linear and non-linear generalized trapezoidal neutrosophic numbers and introduced its de-neutrosophication technique in the paper [26]. They used removal area and mean interval method for purpose of de-neutrosophication. However, in agriculture like study era, there are many factors and parameters to be taken account. So, it is easy to see that neutrosophic numbers having different dimensions will be demanded. Therefore, there is a serious need occurring for a general form of de-neutrosophication for n-gonal neutrosophic numbers. We state it as a challenging open problem.

2. Data Clustering and Analysis

   Data classification (henceforth, clustering) is one of the most vital steps of data assessment and manipulation. Rashno et al [27] used neutrosophic sets to handle boundary and outlier points as challenging points of clustering methods. Li et al [28] introduced a novel suitable objective function, which is depicted as a constrained minimization problem based on a single-valued neutrosophic set, is built, and the

Lagrange multiplier method is used to solve the objective function. They also gave experimental results of the study and obtained that neutrosophic data classifier has a promising tool for data clustering and image processing. Taş et al [29] offered a very practical G-metric based method for data analysis of neutrosophic big data although neutrosophic data type (neutrosophic big data) are in massive and detailed form when compared with other data types. Long et al [30] proposed a new fuzzy clustering algorithm based on association matrix using the neutrosophic set. Basha et al and Kavitha et al [31, 32, 33] gave neutrosophic based prediction system and classifier.

3. Neutrosophic IF-THEN Rules

   Sunay et al [34] used Neutrosophic logic using IF-THEN rules in the risk/safety assessment for the first time. The study focused on linear trapezoidal neutrosophic number. The study of Basha et al [31, 32] identified with "IF-THEN" rules whose antecedents and consequences are composed of neutrosophic logic statements, instead of fuzzy logic ones.

According to [31], NIED includes three functions as the follow:

- Neutrosophication: construction of the neutrosophic knowledge-base by converting crisp inputs using the neutrosophic three membership functions: truth-membership, falsity-membership, and indeterminacy-membership.
- Inference Engine: The KB and neutrosophic "IF-THEN" rules are applied to get a neutrosophic output.
- De-neutrosophication: Converts the neutrosophic output of the previous step back to a crisp value using three functions analogous to the ones used by the neutrosophication.

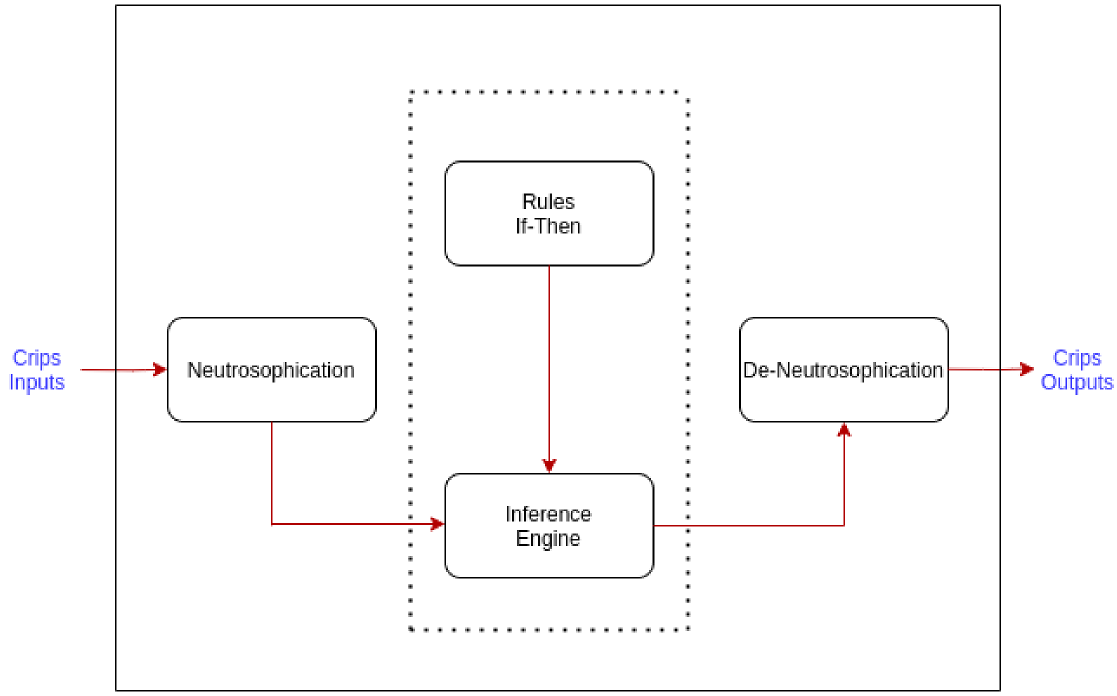

Figure 1: A flowchart for NIED mechanism

We now present our smart agriculture mechanism model integrated with the NIED system in order to monitor the functioning of the ecosystem after both irrigation and seeding in greenhouse or open field. The environment where we want the main process of cabinet to take place is controlled by the control unit. The control unit part is the part that has processors and has automation. Various sensors are available in the cabinet. These sensors make instant readings and transmit the data to the control unit. Since the system will work with electricity, it is particularly sensitive to electrical voltage fluctuations. If this happens, the system is bypassed. UPS is required to prevent this. This is provided by the voltage sensor. Sensors in the cabinet must work continuously. If one of them works abnormally, the system is bypassed. For this reason, it must be an air conditioner system. For example, if the humidity has decreased or the temperature has increased, the air conditioner system has to intervene. All of these should be related to the control unit and give all the information to it. If it fails, the bypass comes after the off mode and the system shuts down. In order to prevent this situation, the control unit should work in conjunction with the SOS system. When the data becomes abnormal, the control unit intervenes with commands to make the system regular. If the intervention is insufficient, SOS issues a command to the system. The SOS system sends alerts to Mobile Phone, PC etc systems via data network. Here, the security time is 30 minutes. When the control unit detects the error of the system, it activates the SOS system 30 minutes before it closes. NIED system takes place in the control unit and provide a communication decision process with SOS.

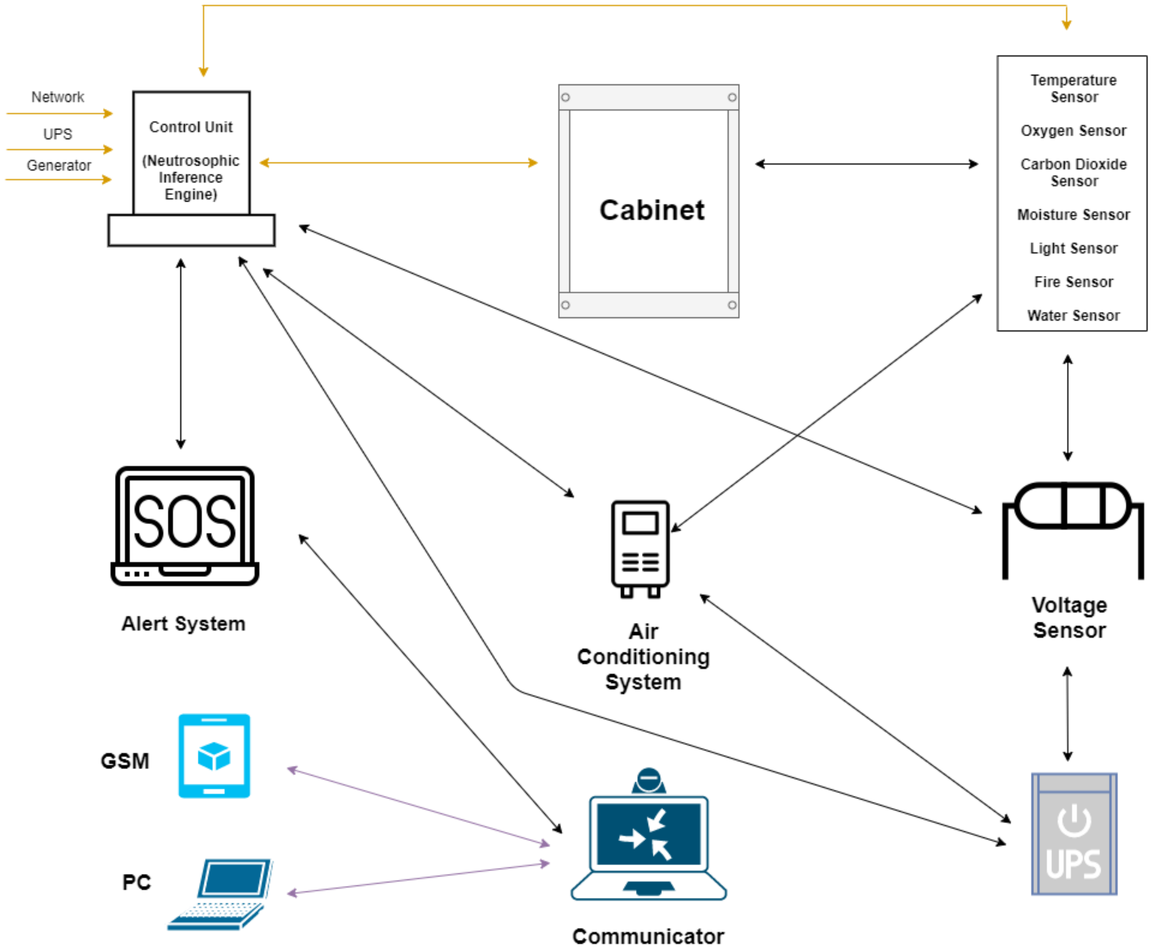

Figure 2: Smart Agriculture Mechanism Model

3.2 Visualization for Soil Surface and Topography

Neutrosophic Bézier surfaces are divided into three distinct form: truth;indeterminancy;falsity Bézier surfaces. Here we introduce new concept of them: geometric mean neutrosophic Bézier surface:

Control points are $GM(x, y) = \sqrt[3]{T(x, y).I(x, y).F(x, y)}$ in z-axis. So its vectorial form is $G(x, y) = (x, y, GM(x, y))$. This is an approximation to the neutrosophic data (see Fig.3). There are several methods to approximate values of data but this one is new in literature. Besides we give intersection curves of the truth-gm, indeterminacy-gm, falsity-gm in figure 4. The advantage of these Bézier curves / surfaces is that they can be written in matrix form. Thus, it can allow neutrosophic data to be matrix form and processed on a computer.

Construction of Bézier surfaces in matrix form is done as follow:

Let $M = \begin{bmatrix} 1 & 0 & 0 & 0 \\ -3 & 3 & 0 & 0 \\ 3 & -6 & 3 & 0 \\ -1 & 3 & -3 & 1 \end{bmatrix}, U = \begin{bmatrix} 1 & u & u^2 & u^3 \end{bmatrix}, x = [x_{ij}], V = \begin{bmatrix} 1 \\ v \\ v^2 \\ v^3 \end{bmatrix}$

where M, U, x, V are the basis matrix of the cubic Bézier surface, matrix of u direction, control points in x-axis and matrix of v direction, respectively. So conversion into polynomial version is matrix multiplication: $U.M.x.M^t.V$. This is done for the y and z axes, respectively. The only thing that changes in this multiplication is the expressions of the control points on the axes.

Neutrosophic If-then rule can be adaptive for this type of visualization. The link between data and visualization is important for the end user. This type of information puts the user-oriented work forward in terms of sales.

Indeed, in this type of study, if it is desired to visualize instantaneous warning boundaries for the user, then the problem of what form the surfaces should be visually arises for what conditions of neutrosophic data and this is definitely an open problem.

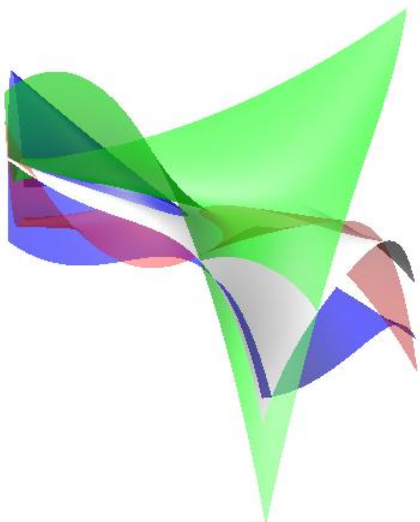

Figure 3: Neutrosophic Bezier surfaces:Truth(blue),indeterminacy(red),falsity(green) and geometric mean surface(gray)

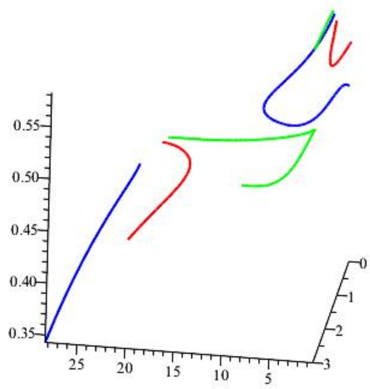

Figure 4: Intersection curves of t-gm(blue),i-gm(red),f-gm(green)

The smart mechanism in Figure 2 scans with the neutrosophic Bezier surface at certain time intervals for both seeding and irrigation of the soil. This scanning process can be included in the neutrosophic inference engine. With this scanning process, in addition to controlling the soil humidity, temperature, oxygen and carbon dioxide levels, it is checked whether the objects carried to the region by external factors such as wind or animal-human cause damage in the area. With the gray value for Figure 3, it is determined whether there is any change in the soil and on the surface in the scanning study.

4 Conclusion

This study has shown that neutrosophy theory can be used in IoT and Smart Farming systems and at what stages it can help and integrate within the working mechanisms of the systems.Especially, the information coming to the cloud computing or data pool within the systems can make uncertain data process-able with the help of neutrosophic. You can also find structures, models, and researches that can be used to do this processing. On the other hand, two open problems are left that will affect future directions for researchers and neutrosophic-based IoT, Cloud Computing and Smart Agriculture. One of the problems is the de-neutrosophication method for n-gonal neutrosophic numbers and the other is the visualization of the neutrosophic data using the geometric approach.

Conflicts of Interest: The authors declare no conflict of interest.

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