Fuzzy logic system for drug storage based on the internet of things: a survey

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ABSTRACT

The rapid development of internet of things (IoT) technology over the course of recent history has made it possible to connect a large number of smart things and sensors, as well as to establish an environment in which data can be seamlessly exchanged between them. This has led to an increase in the demand for data analysis and storage platforms such as cloud computing and fog computing. One of the application areas for the internet of things that has garnered a lot of interest from the business world, academic institutions, and the government is healthcare. The IoT and fuzzy logic are being used in the medical business to improve patient safety, the overall quality of care, and the overall efficiency of medical operations. The most important healthcare studies that are pertinent to pharmacies have been used as the basis for this research. The purpose of this research is to investigate recent advancements in medical modules, remotes, and detector patterns, as well as current innovations in IoT and fuzzy logic-based health care, and current policies from around the world, with the intention of determining how well they support the long-term growth of IoT and fuzzy logic in healthcare.

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1. INTRODUCTION

Health is the most important thing to anybody on the planet, and if there is a problem with one's health, medicine and medications come to the rescue. When a person is given a list of medications and pharmaceuticals that must be purchased to preserve the patient's life, the drug shop comes into action. There are times when a corporation provides medicine to a government or other drug stores where the pharmaceuticals are of low quality and you have no idea where they are stored. There is currently no appropriate drug management in place. The users have no idea where the medications are kept or how good they are. To avert such scenarios, a prescription or treatment is prescribed. The monitoring model is employed [1]. An increase in job stress and a loss in personal time have resulted in a rise in drug and prescription dependency [2]. The medicine must be kept in a safe environment to avoid contamination and degradation. Throughout its storage and usage, the product's stability stays within the prescribed range. Precautions should be taken while dealing with the impacts of the atmosphere, moisture, heat, and light [3].

One of the most crucial parts of patient treatment is the maintenance of medical materials. The manufacture and storage environment of pharmaceutical items can have a substantial impact on their quality. High temperatures and relative humidity are the two most important factors in medication breakdown Rhesus (RH). Temperature, humidity, air quality, length, and production process parameters can all have an impact on the final quality, and hence the salability, of a product or batch of products. A refrigeration plant is often used for a variety of things that require cool storage, and it must be regularly monitored to ensure that the right temperatures are maintained. drugs must be stored in an environment that is both acceptable and auditable. Drug and medication control and monitoring models can be used to avoid such events and save the patient's life. Drug control and monitoring use fuzzy control to read the values of the internet of things (IoT) sensor and transmit them back to the responsible person based on temperature and humidity in the sensor data and the prediction algorithm [4]-[9]. There were not enough papers produced on drug storage environment control systems; thus a field is critical to patient life; therefore, a survey on this field is vital. The main objective of this survey is to analyze numerous papers in order to choose the most effective method for controlling temperature and humidity in drug storage using fuzzy logic and a microcontroller.

2. LITERATURE REVIEW

When a patient's life is in jeopardy, pharmaceuticals and medicines are critical resources for preserving it. It is necessary to monitor the supply of pharmaceuticals and medicines regularly to ensure a consistent and high-quality supply. Many medicines and pharmaceuticals are brought into the shop; however, they are frequently taken to fulfill one's greed, expire, or are stashed in unknown spots throughout the business. To avoid a catastrophe like this and save the patient's life, a drug and medicine monitoring model can be utilized. To keep track of the pharmaceuticals and medicines in the shop, the model employs radio frequency identification (RFID) and IoT technologies. This strategy will alter the traditional smart drug store operating paradigm, resulting in improved patient safety outcomes [10].

Smart system based on open-source technologies which estimate water demand by measuring soil parameters including ambient factors, soil temperature, and, soil moisture as well as data from Internet weather forecasts. ambient factors, soil temperature, and, soil moisture, relative humidity, and ultraviolet (UV) light radiation are all measured by sensor nodes in the agricultural lands. The suggested state's intelligence is built on a complex algorithm that takes into account both visible data and weather prediction variables including air temperature, humidity, UV, and precipitation for the foreseeable future. For computing storage module device (SMD), the support vector regression (SVR) with the k-means strategy outperforms the SVR approach in terms of accuracy and mean squared error as shown in Table 1 [11].

Table 1. SMD based on sensor data and prediction algorithm [11]

Date	SMD based on sensor data	Predicted SMD using SVR	Predicted SMD using a proposed algorithm (SVR + k-means)
15-11-2017	1.236227211	0.807615	0.9741
16-11-2017	0.928945011	845376	0. 0.8265
17-11-2017	0.681400791	0.673736	0.9026
18-11-2017	0.433856571	1.037236	0.9632

A fuzzy temperature control technology that employs a microcontroller to govern a non-linear dynamical system even without the use of any additional software was developed. In contrast to many other fuzzy controllers which function on computer systems and also contain dozens or even hundreds of rules, It has been shown that a certain field level communications (FLC) with a small number of rules and a straightforward implementation can handle a temperature control problem with ambiguous dynamics or different time delays. The heating coil current does have a duty cycle of 49%, based on the data [12].

Based on sensor data readings, a hardware moisture sensor avionics suite employs fuzzy logic as the decision-making process to manage the air conditioning configuration to keep the server room humidity and temperature stable. A microprocessor was utilized in the system to gather sensor data like electricity voltage, humidity, and temperature from a sensor. The system measures electricity voltage, humidity, and temperature while autonomously sending the data via the hyper text transfer protocol (HTTP) protocol to a cloud server, permitting authorized users to view sensor data through mobile or web-based monitoring applications (PCs, laptops, smartphones). The finished product is when the humidity is between 45 and 60%, the fuzzy produces an output of 1, revealing standard humidity, and the cooling system is set to cool mode; moreover, when the humidity exceeds 60 percent, the fuzzy produces an output of>1, suggesting high humidity, and the air conditioning system is set to dry mode [13].

PharmDE is an expert system that assesses the risk of drug-excipient incompatibility using knowledge. To store incompatibility data, PharmDE first created a knowledge database with 532 datasets from 228 publications. Then, based on information, research, and discoveries, 60 drug-excipient interaction limitations were developed. Therefore, due to an organic mix of database searching and rule-based incompatibility risk prediction, the PharmDE drug-excipient incompatibility database now comprises 532 data items related to 200 medicines and 123 excipients. IST yielded 163 collected data items (30.6%), whereas thermal technical implementation provided 127 data items (23.9%), combining the two equipment analysis methods produced 97 data items (18.2%), and other procedures such as in vivo testing and dissolution testing generated 145 data items (27.3%) [14].

The recommended system, which is based on a wireless sensors network (WSN), was installed in many greenhouse areas to improve plant growth conditions while decreasing energy and water usage. This link uses broadcast random forest (RF) transmission to provide data from the plant environment, like temperature and soil humidity, to a server (Raspberry Pi). A fuzzy logic controller (FLC) analyzes the data and then produces an intelligent and optimum irrigation decision. The proposed system can control and monitor irrigation inside the greenhouse anywhere and at any moment by utilizing a human machine interface (HMI) established under IBM's Node-RED. The suggested method was utilized to irrigate tomato plants in the actual world. In comparison to techniques 1, 2, and 3, the farmer may save 46.81%, 26.41%, and 65.22% of production costs, respectively [15].

Internet of things-based irrigation system that uses fuzzy logic to minimize thewatering frequency and boost crop output rate. A Mamdani fuzzy controller joins data from the environment like temperature sensors and soil sensors, after which applies fuzzy rules to regulate the flow of water from the water pump and deliver water just at the appropriate time and frequency. This may be built and programmed using MATLAB. Fuzzy logic and IoT technologies were combined to develop an intelligent irrigation solution for conserving water and improving irrigation control in high-water-stress areas. Using trapezoidal and triangle element functions depends on Mamdani fuzzification, the produced fuzzy controller efficiently calculates the irrigation time and duration for a certain crop. The fumigation control application kept the soil wet above a predetermined level with smooth changes, avoiding device weariness and saving water and power. The gadget was also tracked in real-time using a massive ZigBee wireless network [16].

A fuzzy algorithm was verified using MATLAB and iFogSim toolkit simulations optimum scheduling. The fuzzy-based scheduling architecture that has resulted in virtual machine manager (VMM) client ratings has provided application code, as demonstrated by the MATLAB fuzzy toolbox, and validated the concept. rather than offering an iFogSim toolbox to facilitate task relocation and device scalability. The method output in MATLAB was assessed using several thousand randomly generated sets of work on the fluid inference technique, producing VM ratings and total accuracy of 36.23%. The best results are for "Excellent," which has an accuracy rating of 54.55%. The lowest results for "Bad" are 20%. The solution to properly processing data in the cloud utilizing IoT-powered data mining is fog computing. Edge computing is the key.iFogSim was used to test the proposed approach. The approach compares and checks the actual task scheduling using current dynamic algorithms, validating and upgrading the quality of service (QoS) parameters [17].

Internet of things devices provides real-time input data. The drips from the smart farm irrigation system were monitored and controlled remotely using an android phone. Zigbee is a wireless technology that allows nodes to interact with one another (sensor, base station, and hub). The application uses web-based Java toolkits to handle and show data in real-time on the network server. Remote applications can monitor and operate an irrigation system using wireless field irrigation system monitoring and management. Cloud computing has emerged as a viable option for smart sensor networks' huge volumes of data. The gadget is automatically and manually designed. For decision-making and behavior monitoring, real-time sensing information is analyzed on a cloud server. On the farmers' smartphones, the Android app lets the user track the farm's regulating activities and manage irrigation [18].

A single bottle was created to provide water for hygienic consumption while also ensuring that the water was of acceptable quality. The initial prototype of the bottled water was created as a combination of hardware and a mobile phone app, and it was evaluated for its capacity to track objectives and occurrences. Smart bottled water may identify the quality of the drink, user usage data, and the position of the container's water resources. The pH and sediment sensor data were used to assess the cleanliness of the stream in the smart one. Data from the ultrasonic, button and moisture sensors are used to combine information relevant to a single beverage case, such as fluid and acceptance. Additionally, a smartphone app was created that uses sensor data to track the source of water locations and monitor water consumption. The bottle and the user are also connected through the smartphone app [19].

Plan, assess, and validate a unique software-defined IoT management (SDIM) approach for managed connected sensor networks. SDIM was created for supporting WSN installations, with a focus on heavy IoT deployments in which centralized system control for cloud-based WSNs is not scalable properly. The newly announced software-defined networking (SDN) topology aggregation (SDTA), however, enables SDIM to be utilized for cloud-based tracking and control across all IoT domains. The authors show that SDIM employs such cutting-edge IoT management strategies on large-scale simulation IoT networks as well as field testing depending on efficiency measures like the time needed to supply multi-access edge computing marginal efficiency of capital (MEC) units. Relevant SDIM will minimize average provision time by 60-80%

in comparison to network configuration protocol (NETCONF) Light and 46-60.3% in comparison to lightweight M2M (LWM2M) [20].

To create virtual groups of agents that can communicate with one another while observing crops. Farmers can use a low-cost sensor architecture to optimize and monitor crop production by reducing the number of resources the crops use at any given time. To achieve the equipment's limited communication and processing functionality, the technique employs the Pangea architecture. Using sensors, we'll build a system that can collect data from its surroundings such as wind, wetness, pH, humidity, solar radiation, and temperature. One of the most important effects of the strategy is that the solution may combine several sensor inputs. and provide context-aware responses. In the suggested smart irrigation system, the motor accounts for 9.72% of the overall irrigation duration, while manual flood irrigation and drip irrigation account for 27.78% and 16.67% irrigation duration, respectively [21].

A unique design method was used to create the interval type-2 mixed T-S adaptive fuzzy controller. In the setting of uniformly bounded variables, the overall global stability of a closed-loop system is examined using Lyapunov's synthesis. The proposed strategy merges the nonlinear approximation capability, the dynamic fuzzy system's local linearity, and the adaptive fuzzy control method of the linear system. The membership function does not have to be exactly specified in this manner, removing the requirement for fuzzy adaptive control to be dependent on the membership functions simulations, the proposed type-2 T-S combination adaptive fuzzy controller exceeds the type-1 T-S fuzzy adaptive control technique. Moreover, the type-2 fuzzy system needs fewer criteria to deal with unknowable internal interference and erroneous estimation than the type-1 approach, and the membership function doesn't quite meet strict criteria [22].

A smart irrigation system that uses the worldwide mobile communication infrastructure to help farmers irrigate their agricultural lands global system for mobile (GSM). Based on task situations such as soil humidity, ambient temperature, and the motor's power supply condition (mains or solar), this system delivers acknowledgment signals. A fuzzy logic controller is used to estimate input data (such as soil moisture, temperature, and humidity) and generate motor condition results. In addition, the device turns off the engine to save energy when rain is forecast and also protects the crop grown with solar panels from the constant rain. According to the data, the smart irrigation system utilizes its motor for 9a .72% irrigation period, compared to 16.67% for drip irrigation and 27.78% for manual flood irrigation, respectively [23].

The IoT and machine intelligence are at the heart of healthcare systems. A medical decision support system, system is intelligent enough to sense and understand data from a patient. A system is a low-cost option for individuals who live in remote areas; it consists of an Arduino Uno equipped with a heart rate sensor, a body temperature sensor, a pulse rate sensor, and wireless sensor network communication near field communication (NFC) (WSN). The outcomes of fuzzy logic are impacted by temperature when temperature =high accuracy=97.8%, temperature=medium accuracy=91.5%, and temperature=low accuracy=89.1% [24].

The important aim of the suggested paper is to include artificial intelligence (AI) technologies, like fuzzy systems and neural network systems, into a safe healthcare monitoring system, allowing it to function as an intelligent medical system that prioritizes health indications obtained from edge devices. The proposed framework includes a trust climate for accumulating verified physiological parameters from a person's blood, which will then be transmitted via the GSM module to Azure IoT hub, where the raw data is transformed into linguistic representation and the patient's status is derived utilizing logic-based algorithm instructed in a fuzzy-based inference system (FBIS). As a consequence, entropy measurements were analyzed and found to average roughly 2.25, indicating that key-generation uniqueness efficacy is rather high [25].

System instability may be managed by using an intelligent controller that can manage and monitor water temperature over a predetermined period to decrease overshoot and absolute inaccuracy and increase temperature tracking capabilities. However, most industries lack a robust and dependable monitoring system that can detect when the temperature of the water rises. At various stages of operation, the temperature of bottled water is regulated via fuzzy logic. This operational failure might be remedied by using an FLC to create a model that will manage and monitor the temperature of the water processes, hence improving temperature control in the bottled water industry. To improve the industry's operational mechanisms, the MATLAB program was utilized to perform simulations to provide temperature control in the bottled water business. The results of the mathematical model may then be used to train this model, which can subsequently be used to manage and monitor the Water Temperature. The temperature of the bottled water with and without the FLC was 850 °C and 650 °C, respectively. The temperature rose by 200 °C. Through these results, it is clear that utilizing an FLC produces better outcomes than not employing fuzzy logic [26].

3. METHOD

This section discusses many instruments utilized in the smart drug store model, including internet of things, sensors, and communication technology, to offer the relevant specifics of the specific technology. A suggested drug storage humidity and temperature control system employing fuzzy logic as the decision making to maintain drug storage humidity and temperature by controlling the setting of a fan and air conditioner based on sensor data measurement is proposed in this system. We obtained sensor data such as smoke, temperature, light, electrical voltage, and humidity from a sensor integrated with a microcontroller in this system.

3.1. Internet of things (IoT)

The IoT is expanding, making it easier to link equipment and devices over the network, which might be incredibly valuable in automated irrigation systems as well as tracking leakage or failures. [27], [28]. The three tiers which comprise the IoT architecture are the application layer, the physical layer, and the network layer [29]. At the physical layer, sensors take data from the surrounding environment and then convert this into useful data. Time-sensitive data, in contrast, side, must be handled immediately [30]. Instead, to reduce network congestion, the data should be stored on the web. At the network level, values are gathered and processed onto digital streams for analysis [31]. Offering particular services to the user falls under the purview of the user-facing layer [32].

3.2. Internet access

For any work to be completed, internet connectivity is required in the model. Everything from receiving observed data to transmitting information to the cloud needs internet access. The model's backbone is the internet. There are several methods for providing Internet access; however, the IEEE 802.15.4 mechanism is reasonably simple to use and understand for customers [33]-[40].

3.3. Sensors

The employed sensors will observe the environment around the drug store as well as the environments of the drugs and medicines and send the results to the microcontroller [20]. Table 2 lists all of the sensors and their properties that were utilized in the 'Smart Drug Store' model. Sensors are critical in gathering all of the essential information [41]-[49].

Table 2. Sensors used [10]

SENSOR	USAGE	SENSOR NAME	ATTRIBUTES
Temperature sensor	Store temperature	TMP100, LM35DZ, DHT11	Voltage- 3~5 V Accuracy- ±20 C
Humidity sensor	Store humidity	DHT11, DFR0066	Voltage- 3~5 V Accuracy – 5%
Fire	To prevent any fire occurrence in the store	DFR0076	Voltage- 3.3~5 V Responsive time -15 Size- 22×30mm
Light sensors	level of light	LDRLM393	5V or 3.3V

3.4. Wireless communication technology

Wireless technology is utilized to communicate between the controller and the sensor from the controller to the cloud [50]. In every collaborative circumstance, several technologies have been deployed. Wireless networking technology is also employed for information exchange [51]. In sensor-controller communication, sensors are remotely linked to the microcontroller using either the Zigbee protocol or the universal asynchronous receiver/transmitter (UART) protocol [52]. ZigBee is a wireless transmission technology. It is designed for multi-channel control systems [53]. Alarm and illumination control are also included, as well as minimal energy usage. ZigBee is based on the IEEE standard 802.15.4 [54], which defines the physical layer of access control and media for low-rate wireless personal area networks (WPANs). When sensors are positioned far away from the control system, the Zigbee protocol is used to communicate between sensor nodes and the controller in smart water systems [55]. Long-range communication technologies like as 3G and the internet [56] allow for controller-centralized data storage communications. Some of the previous work was aimed at sending SMS alerts to users about water quality. For the general packet radio service (GPRS) module coupled to the controller, the suggested solutions need the use of an extra subscriber identity module (SIM) card [57]. The added costs of using a SIM card are one of these systems' drawbacks. In addition, the user location is unable to store or retrieve large amounts of data [58]-[66].

3.5. The fuzzy logic control module

To establish the patient's state, the central hub is linked to the fuzzy logic control module, which translates raw input to language variables. Figure 1 illustrates the components of its fuzzy inference controller. A fuzzy controller system will evaluate the linguistic priority of patients that have been classified based upon the overall condition to determine whether patients require higher intensive treatment than others. The first stage is to create and construct hardware sensor nodes enabling health monitoring, followed by modeling or simulation for elevated indicators for 200 patients. Furthermore, secure front-end user access and protection are required for the reception and transmission of health information, and also the researchers suggest an analysis of the security challenges confronting the health system, in addition to a design for maintaining, accessing, and transmitting health data [67].

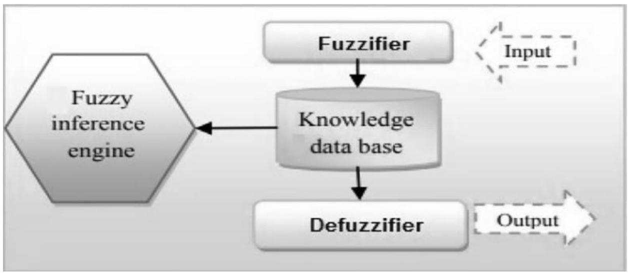

Figure 1. The components of fuzzy logic controller [25]

4. RESULTS AND DISCUSSION

The current study looked at several components of the IoT-based technology system. The survey benefitted from a fuzzy logic approach for decision-making that is simple to use and install. Table 3 in *appendix* shows an overview of ways that fuzzy logic and sensors are used. As seen in Table 3 in *appendix*, each paper has its approach and equipment. Each of these techniques is used to provide information about each article based on a variety of factors, as well as to provide methods that each item uses. As we said in the beginning, the bulk of the approaches is based on fuzzy logic. Furthermore, devices and controllers are also employed. The sensors will collect data, and the fuzzy logic will generate a request based on this information. This is the same approach that we've seen in all of the ways that employ it. Depending on the sensor and controller, there are a variety of approaches. In addition, there's fuzzy logic. A variety of sensors are employed in the controller, with a significant number of these sensors being integrated and used in controllers, fuzzy logic, and other applications. Table 3 compares various studies that employ sensors and controllers in their systems.

The results demonstrated that the output of fuzzy logic based on microcontroller Wemos D1 corresponds to the resulting modeling of fuzzy logic developed using FIS editor MATLAB, by an average AC mode set output standard deviation of 0.01225 and also an average AC temperature set output standard deviation of 0.03500 [13]. The temperature of the bottled water with and without the fuzzy logic controller was found to be 850 °C and 650 °C, respectively. The temperature rose by 200 °C. These findings suggest that utilizing a fuzzy logic controller produces better outcomes than not using fuzzy logic. Furthermore, the results revealed that the output with sensors implemented on a microcontroller is superior to the output without sensors, such as [26]. The conventional system relied on an automatically programmed irrigation system with no sensors. The new Orbit B-Hyve system, which features enhanced sensors and controls, was able to achieve 37% better outcomes, the results demonstrated that the output of fuzzy logic implemented on a microcontroller is superior to that of fuzzy logic not implemented on a microcontroller [21].

5. CONCLUSION

The Internet of Things has piqued the interest of both academics and industry in recent years. It has become a significant part of our lives. This survey is valuable for readers who want to learn more about IoT and fuzzy logic in the healthcare field. Everyone will have enough information to save people's valuable lives if they utilize the smart drug store. In addition, the smart drug store will assist in obtaining information about the store, as well as the products and remedies available. The smart drug store will also assist in the correct application of government rules and regulations. Furthermore, the smart drug store can save the lives of patients in an emergency. The smart drug store will become more efficient as sensing technology advances and covers all elements of monitoring drug store conditions. After analyzing all of the publications, it was discovered that each one has its approach, that each approach requires various instruments and techniques, that the most common stages are better employed in data preparation methods, and that different processes are used in preprocessing.

APPENDIX

Table 3. Comparison of the controller, and fuzzy logic techniques

Researcher	Year	sensors	Controller	Significant satisfied aims	Result
Gupta *et al*. [10]	2018	Sensors for temperature, humidity, fire, electricity control, and motion.	Raspberry pi	To avoid such events and protect the life of a patient, the medicine and drug monitoring system could be implemented.	This strategy will alter the traditional smart drug store operating paradigm, resulting in improved patient safety outcomes.
Goap *et al*.[11]	2018	The temperature of the soil, moisture of the soil, and air temperature and humidity.	In the server, the support vector regression (SVR)model and the k-means clustering method were employed (SMD)	A smart system based on open-source technology is proposed for anticipating irrigation demands in a field by measuring soil variables such as soil temperature and moisture.	When computing SMD, the SVR plus k-means method is more accurate and has a smaller mean squared error than the SVR method (table 1)
Singhala *et al*. [12]	2014	temperature sensor.	Fuzzy Logic Controller. Temperature control system.	Designed and constructed a fuzzy temperature controller that uses a microcontroller to regulate a non-linear dynamical system without the use of any extra software.	Z * = 130.95 defuzzification value the duty cycle of the fan speed is 51%. The heating coil current has a duty cycle of 49%.
Candore *et al*.[13]	2018	temperature and humidity.	Wemos D1 microcontroller, fuzzy logic	A server room humidity and temperature control system based on fuzzy logic and a microcontroller wemos d1 as an infrared transmitter remote control to manage temperature and mode configuration in an air conditioning unit were proposed to regulate server room humidity and temperature.	Whenever the humidity is between 45 and 60 percent, the fuzzy generates an output of 1, implying normal humidity, and also the air conditioner is given to cool mode; nevertheless, when the humidity exceeds 60 percent, the fuzzy generates an output of > 1, implying high humidity, and also the air conditioner is given to dry mode.
Wang *et al*. [14]	2021	-	PharmDE's functionalities	Created an expert system based on knowledge.	Pharma's database of drug-excipient incompatibility contains 532 data points for 200 medications and 123 excipients. It produced 163 data items (30.6%), whereas thermal screening methods produced 127 data items (23.9%), combining multiple instrument analysis methods produced 97 data items (18.2%), and other methods like in vitro test and dissolution test produced 145 data items (27.3%).
Benyezza *et al*. [15]	2021	DHT22 sensor humidity sensor.	Nano Arduino a fuzzy logic	The improvement of plant growth conditions as well as the decrease in water and energy use.	In comparison to techniques 1, 2, and 3, the farmer may save 46.81 percent, 26.41 percent, and 65.22 percent of production costs, respectively.
Mallikarjuna [17]	2020	wireless sensor networks	Arduino UNO	A fuzzy algorithm-based suggested feedback output	Vm ratings with a total accuracy of 36.23 percent.
Vithanage *et al*. [19]	2019	pH, turbidity	NodeMCU	Implemented to offer sanitary drinking water and ensure acceptable water quality.	Using fuzzy theory to fine-tune the water calculation objective and wisely recommended approach, the water bottle is being refined.
Mavromatis *et al*. [20]	2019	Wireless Sensor Network	Software Define Networking (SDN).	Plan, evaluate, and verify a unique software-defined IoT management (sdim) system for the control of interlinked sensor networks.	Average provisioning times should be reduced by 60-80%.

Table 3. Comparison of the controller, and fuzzy logic techniques (*continue*)

Researcher	Year	sensors	Controller	Significant satisfied aims	Result
VIllarrubia *et al*. [21]	2017	Soil, humidity, temperature, light, moisture, water level, and oxygen.	FL Implemented in mc ATmega328p with PANGEA multi-agent systems.	To create virtual groups of agents that can interact with one another while keeping an eye on crops farmers may optimize and monitor the development of the crops using a low-cost sensor architecture by reducing the number of resources the crops use at any one time.	The conventional approach relied on an irrigation system that was automatically programmed and had no sensors. The new orbit b-hyve system, which features enhanced sensors and controls, was able to achieve 37 percent better outcomes.
Hao *et al*. [22]	2020	-	fuzzy control	A novel design technique given by r was used to create the interval type-2 mixed t-s adaptive fuzzy controller	In simulations, the proposed type-2 t-s combined adaptive fuzzy controller surpasses the type-1 t-s fuzzy adaptive control technique. Furthermore, in comparison to the type-1 technique, the type-2 fuzzy system requires fewer rules to deal with unknown internal interference and incorrect approximation, and the membership function does not fulfill rigorous criteria.
Krishnan *et al*. [23]	2020	Sensors for humidity, temperature, soil moisture, rain, moisture of soil, and LDR.	FL implemented in Arduino	The motor is used for 9.72 percent of the entire time for water in the proposed smart irrigation system, whereas manual flood irrigation and drip irrigation use 27.78% and 16.67% of the overall irrigation period, respectively.	The motor is used for 9.72% of the overall duration of irrigation in the recommended smart irrigation system, while manual flood irrigation and drip irrigation use 27.78% and 16.67% of the overall irrigation period, respectively.
Hameed *et al*. [24]	2020	Heartbeat rate, Pulse rate, and Body temperature sensors.	Arduino UNO	When temperature = high accuracy = 97.8%, temperature = medium accuracy = 91.5 percent, and temperature = low accuracy = 89.1 percent, the results of fuzzy logic are affected by temperature.	When temperature = high accuracy = 97.8%, temperature = medium accuracy = 91.5 percent, and temperature = low accuracy = 89.1 percent, the results of fuzzy logic are affected by temperature.
El Zouka *et al*. [25]	2019	Temperature sensor (LM35), Blood pressure sensor (TCRT1000), and pulse oximeter sensor (TCRT1000) (SPD015GDN).	PIC16F877A microcontroller	The proposed study aims to incorporate artificial intelligence technologies like fuzzy systems and neural networks together into safe healthcare monitoring systems.	The entropy measurements were assessed and found to average roughly 2.25, indicating that the key-generation uniqueness' efficacy is rather high.
Vincent *et al*. [26]	2019	temperature controller	Fuzzy Logic Controller	This operational failure may be resolved by using an (FLC) to create a model which will monitor and manage the temperature of the water operation, thereby improving control of temperature in the bottled water industry.	The temperatures of the bottled water with and without the fuzzy logic controller were determined to be 850 degrees Celsius and 650 degrees Celsius, respectively. Temperatures increased by 200 degrees Celsius. The temperature rose by 200 degrees Celsius. These findings suggest that utilizing a fuzzy logic controller produces better outcomes than not using fuzzy logic.

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