CENTRAL ASIAN JOURNAL OF MATHEMATICAL THEORY AND COMPUTER SCIENCES

https://cajmtcs.centralasianstudies.org/index.php/CAJMTCS

Volume: 06 Issue: 04 | October 2025 ISSN: 2660-5309

Article

Micro Irrigation by Integrating AI to Predict Crop Water Needs and Automate Valves and Boost Yield

R. Sivakani[1], R. Thirumurugan[2], M. Mohamed Sakeel[3], M. Preetha[4], M. Mohamed Sameer Ali[5], S. Suman Rajest[6], R. Regin[7]

1. Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India
2. Department of Artificial Intelligence and Data Science, Dhaanish Ahmed College of Engineering, Padappai, Chennai, Tamil Nadu, India.
3. Department of Artificial Intelligence and Data Science, Dhaanish Ahmed College of Engineering, Padappai, Chennai, Tamil Nadu, India
4. Department of Artificial Intelligence and Data Science, Dhaanish Ahmed College of Engineering, Padappai, Chennai, Tamil Nadu, India.
5. Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India
6. Dhaanish Ahmed College of Engineering, Chennai, Tamil Nadu, India.
7. SRM Institute of Science and Technology, Ramapuram, Chennai, Tamil Nadu, India.

* Correspondence: sivakani@dhaanishcollege.in

Abstract: This study suggests combining artificial intelligence (AI) with micro irrigation technologies to improve how farmers manage water for their crops. Micro irrigation systems give water to crops very accurately, but they have trouble adjusting to changes in the weather and the water needs of the crops. This project wants to use AI algorithms to figure out how much water crops will require and to automatically open and close valves based on weather forecasts. The predictive modelling part is about making AI algorithms that can use information like the type of crop, the amount of moisture in the soil, and the weather to guess how much water the crops will need. The model will be trained using machine learning approaches including regression analysis and neural networks. The model's accuracy will keep getting better as it gets more historical and real-time data. To make the micro irrigation system automatic, smart valves, sensors, and actuators will be added. The AI algorithm and real-time weather data will tell these valves when to open and close. The goal of this dynamic adjustment is to make water delivery as efficient as possible while wasting as little as possible. Some of the main benefits are that it can respond to weather events before they happen, it can grow, and it works with current farming methods. User-friendly interfaces will make it possible to monitor and control things from afar. In conclusion, combining AI with micro irrigation systems is a promising way to make farming more environmentally friendly, use water more efficiently, and grow more crops.

Keywords: Micro Irrigation; Water Management**;** Sustainable Agriculture; Integrating Artificial Intelligence; Conserving Precious Water; AI-Driven Methods; Multifaceted Approach.

Citation: Sivakani, R, Thirumurugan, R, Sakeel. M. M, Preetha, M, Ali, M. M. S. Rajest, S. S & Regin, R. Micro Irrigation by Integrating AI to Predict Crop Water Needs and Automate Valves and Boost Yield. Central Asian Journal of Mathematical Theory and Computer Sciences 2025, 6(4), 959-973

Received: 10th Jun 2025
Revised: 16th Jul 2025
Accepted: 24th Aug 2025
Published: 23th Sep 2025

1. Introduction

Micro-irrigation devices have changed farming by delivering water directly to the root zone of crops with great accuracy [38]. This has made water consumption more efficient and increased agricultural yields. But it is still hard to make these systems work as well as possible to fulfill the changing water needs of crops while also taking into account environmental elements like weather [22]. The use of artificial intelligence (AI) technology has recently showed promise in estimating how much water crops would

need and automating irrigation systems. The goal of this project is to use AI algorithms to figure out how much water crops need and to automate the opening and closing of valves in micro irrigation systems based on real-time meteorological data [33]. The initial part of the research is to create a predictive model utilizing machine learning techniques to figure out how much water crops will need. The model will be trained using historical data on the type of crop, the amount of moisture in the soil, the weather, and the stages of crop growth [28]. To construct a strong prediction model, we will look at different machine learning methods, like regression analysis, decision trees, and neural networks. Using real-time data, the model will be constantly updated and improved to make it more accurate and dependable [45].

Combining artificial intelligence with micro irrigation systems is a promising way to improve how farmers manage water for their crops [26]. This project intends to make better use of water, increase crop yield, and lessen the impact on the environment by using AI algorithms to forecast how much water crops will require and automatically open and close valves based on the weather [40]. AI-integrated micro-irrigation systems could alter modern farming and help make sure everyone has enough food in the face of climate change by always coming up with new ideas and improving old ones. Micro irrigation technologies have changed the way farmers do things by bringing water directly to the roots of crops, saving water, and boosting crop yields [32]. But it is still hard to optimize water distribution to meet the needs of crops, especially when the weather changes. Micro irrigation systems have become an important part of modern farming. They distribute water directly to the roots of crops, which makes better use of water and increases agricultural yields [37]. Even if they work, finding the best way to apply water to meet the needs of crops under changing environmental conditions is still a major problem.

Micro irrigation is a very effective way to water crops because it wastes less water and increases crop output [35]. But manually managing water delivery can take a lot of time and be easy to make mistakes. Adding artificial intelligence (AI) to micro-irrigation systems is a viable way to automate and improve water distribution, which will boost crop output and resource efficiency [20]. The goal of this research is to create AI-based ways to figure out how much water crops need and to automate the valves in micro irrigation systems [44]. Combining artificial intelligence (AI) with micro irrigation systems in modern farming is a big step forward in maximizing crop yields while saving water. This explanation explains how AI may be used in many ways to forecast how much water crops require and automate valve management in micro irrigation [29]. This will change farming methods for the better in terms of sustainability and efficiency.

For sustainable agriculture, especially in areas where water is scarce, good water management is very important. Micro irrigation looks like a good option, but it only works if you can properly guess how much water your crops require and change the irrigation accordingly. Good water management is very important for sustainable farming, especially in places where water is hard to come by [24]. Micro irrigation has a lot of potential to help with water stress, but to get the most out of it, farmers need to be able to precisely predict how much water their crops will need and change their irrigation schedules accordingly. Get information from the past on the types of crops, the weather, the soil moisture levels, and how much water was used. Use sensors and IoT devices to get real-time information on the weather, soil moisture, temperature, and humidity. Use data analytics methods, such machine learning algorithms, to look at and make sense of the data you have [27]. Find relationships and patterns between environmental conditions and the water needs of crops. Micro irrigation, which delivers water directly to the root zone of plants with great accuracy, has become well-known for its ability to increase agricultural yields and reduce water waste. However, managing water distribution by hand in micro irrigation systems can be hard since it can be hard to get it right, on schedule, and use resources wisely [34]. AI has the power to change things because it can look at huge amounts of data, find complex patterns, and make smart decisions in real time.

Fixed schedules or manual observation are typically used in traditional irrigation methods, which can lead to over- or under-irrigation [30]. These strategies don't work well when the weather, soil moisture, or crop growth phases change. Combining artificial intelligence with micro irrigation systems is a big step forward for farming technology. This initiative solves the problems of water scarcity and climate change by properly estimating how much water crops need and automating irrigation based on the weather. This will help farmers, ecosystems, and society as a whole [36]. Use machine learning to develop models that can anticipate how much water a crop will need depending on things like the type of crop, the moisture in the soil, the weather forecast, and past data [25]. Use supervised learning algorithms like regression or classification to teach the models. Use methods like cross-validation to improve the accuracy and generalization of the models [43]. Set up an AI-powered decision support system that makes suggestions for the best times to water crops based on how much water they are likely to need.

Artificial intelligence (AI) can change micro irrigation systems for the better by making predictive modelling and automation possible [39]. AI systems can look at a lot of data to predict how much water crops will need and change irrigation schedules in real time. Artificial intelligence (AI) is a game-changing way to change micro irrigation systems. AI algorithms can accurately forecast how much water crops will need and automate real-time irrigation management by analyzing data in a smart way [21]. Data collection and analysis are at the heart of this project [46]. AI algorithms are based on historical information about the sorts of crops, the weather, the soil, and the amount of water used. Also, using sensors and Internet of Things (IoT) devices makes it possible to get real-time information on the weather, soil moisture levels, temperature changes, and humidity [23]. Advanced data analytics methods, such as machine learning algorithms, reveal the links between environmental factors and agricultural water needs. This sets the stage for predictive modelling [31].

Review of Literature

The project will create AI algorithms that can predict how much water crops will need by looking at things like the type of crop, the moisture level in the soil, past weather data, and the stages of crop growth [2]. We will use machine learning to train and improve the predictive model. The research is about making AI-powered predictive models that can figure out how much water crops will require by looking at things like the type of crop, the moisture level of the soil, past weather data, and the stage of growth. We will use machine learning techniques to train and improve the predictive model [14]. Use AI algorithms to connect to the micro irrigation system and regulate the valves automatically. Make algorithms that change the size of the valve openings based on sensor data and how much water the crop is likely to need. Use feedback loops to keep an eye on and change the flow rates of water all the time, so that the soil stays at the right level of moisture [8]. Include safety features like warnings or automatic shut-off valves to stop over-irrigation or wasting water. One of the most important parts of AI-integrated micro-irrigation systems is figuring out how much water crops will need. Using machine learning models that have been trained on both past and present data makes it possible to accurately estimate how much water crops need based on changing environmental parameters [11]. Regression and classification are two examples of supervised learning techniques that are used to construct predictive models that take into account the type of crop, the amount of moisture in the soil, and the weather forecast. These models get better and better via repeated testing and improvement, giving farmers useful information and irrigation suggestions that help them use water more efficiently [41].

The micro irrigation system will have smart valves with sensors and actuators built in to automatically manage the flow of water. The AI algorithm and real-time weather data will tell these valves when to open and close. Smart valves with sensors and actuators will fit right in with the micro-irrigation system and control the flow of water automatically [5]. These smart valves will open and close based on predictions made by the AI model and information about the weather in real time. Use advanced AI methods, including reinforcement learning, to improve the ways you give water. Teach AI agents the best ways to water plants by letting them interact with the environment and giving

them feedback [17]. Use optimization methods to get the most out of your crops while using the least amount of water, energy, and money. Based on input from field tests and real-world performance, AI models should be updated and improved all the time.

The AI-powered micro irrigation system will automatically adapt the watering schedule based on weather forecasts for things like rain, temperature changes, or variations in humidity. Add AI-powered prediction and automation modules to current micro-irrigation systems [7]. Make it easy for farmers to utilize the AI system by creating mobile apps or web-based dashboards that they may access. Do field tests to see how well the AI-integrated micro irrigation system works and how well it works [47]. Work with agricultural specialists and other interested parties to get input and make any changes that are needed for the plan to work in real life. Automating valve control is a key part of AI-integrated micro irrigation systems [1]. It makes it easier to provide water and reduces the need for people to be involved. AI algorithms work with micro-irrigation systems to automatically change valves depending on real-time sensor data and models that estimate how much water crops will need. To keep the best growing conditions, feedback mechanisms are used to constantly check the moisture levels in the soil and adjust the flow rates of water as needed [15]. Also, fail-safe systems are built in to stop over-irrigation or water waste, which protects against possible problems and makes the most of water use.

The study will look into how well the AI-integrated micro-irrigation system works with current farming methods and how well it can grow [18]. Modular design and user-friendly interfaces make it easy to add and manage different types of crops and irrigation systems. The project will deal with issues of scalability and compatibility to make sure that the AI-enhanced micro irrigation system works well with a variety of agricultural setups [6]. Modular design principles and user-friendly interfaces will make it easier to set up and manage different types of crops and irrigation systems [9]. Combining artificial intelligence with micro-irrigation devices is a possible way to improve crop water management and make farming more sustainable. Farmers may get more crops while using less water and spending less money by using AI-powered prediction models and automated valve control [12]. The methods in this project give you a way to make and use AI-integrated micro-irrigation systems that could change the way we farm today [42].

Combining AI with micro irrigation systems could have many benefits, such as better water use efficiency, higher crop yields, lower labour costs, and better environmental sustainability. The goal of the initiative is to make the world safer for food by improving water management and making farming less vulnerable to changes in the weather [13]. Make sure the AI system can grow and change to work with diverse sorts of crops, soils, and areas of the world. Create algorithms that can learn and change when the weather changes and the water needs of crops change. Look at cloud-based options for keeping an eye on and controlling several micro irrigation systems from a distance. Help with customization and setup based on the needs and preferences of each farmer [19]. Integrating AI with micro-irrigation systems has many benefits, such as better water utilization, higher crop yields, lower labor costs, and a more sustainable environment [16]. The project's goal is to help make the world more food secure and lessen the effects of climate change on farming by improving how water is managed [4]. Advanced AI approaches can do more than only automate irrigation; they can also help optimize irrigation strategies, which might greatly increase crop output. For example, reinforcement learning methods let AI agents learn and change irrigation plans by interacting with the environment over and over [48]. These algorithms try to get the most out of crops while using the least amount of water, energy, and money by optimizing water delivery strategies in real time [10]. Field trials and real-world data help AI models get better and better, which makes sure that irrigation plans work well and are useful in a variety of farming situations.

2. Materials and Methods

Standard irrigation methods frequently depend on static schedules or manual supervision, which leads to less-than-ideal water use [55]. These methods aren't flexible enough to deal with changing things like weather, soil moisture levels, and the stages of crop growth. For AI-integrated micro-irrigation systems to be useful and widely used, they need to be integrated and deployed in a way that works well. The easy integration of AI-driven prediction and automation modules into current micro-irrigation systems makes it easier to adopt and scale [50]. Farmers can easily keep an eye on and control their irrigation systems with user-friendly interfaces like mobile apps or web-based dashboards [52]. Testing the system in the field under different weather conditions and with different types of crops gives us useful information about how well it works and how reliable it is [58]. Also, working with agricultural professionals and getting input from stakeholders makes sure that AI-integrated micro-irrigation systems meet real-world needs and requirements, which encourages a culture of innovation and knowledge sharing.

The AI-integrated micro irrigation system will automatically adjust its watering schedule based on weather forecasts for things like rain, temperature changes, or changes in humidity [60]. Combining artificial intelligence with micro irrigation systems is a big step forward in farming technology. This research has the potential to solve the problems caused by water shortages and changing weather patterns by properly predicting how much water crops need and automating irrigation systems to respond to these changes [53]. This might lead to a new era of agricultural resilience and productivity. The design and development of AI-integrated micro irrigation systems are based on the basic ideas of scalability and adaptability. Customization options give farmers the freedom to choose the best methods and preferences for their farms and agroecological situations [57]. Cloud-based solutions let you monitor and manage things from afar, making it possible to scale up and have centralized control over distributed micro irrigation systems.

Additionally, developing AI algorithms that can adjust to changing environmental circumstances and crop water needs helps maintain resilience to change [56]. This ensures that they will be useful and effective in maintaining agricultural productivity over the long run. Combining artificial intelligence with micro irrigation systems marks the start of a new era of sustainable and innovative farming [49]. Control: Farmers can improve agricultural yields, make better use of water, and save valuable resources (Figure 1).

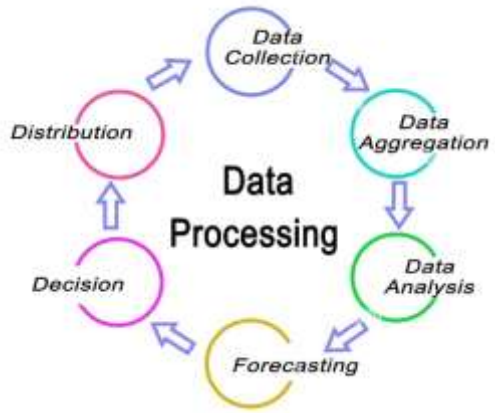

Figure 1: Data Processing

User Interface-Web-based Interface: Create an easy-to-use interface that can be accessed by web browsers [54]. This will let farmers check the system's status and change settings from anywhere. Mobile App: You may also make a mobile app that makes it easy to access the controls and data visualization for the irrigation system. Necessary for numerical computing, allowing for fast array operations and math functions [51]. SciPy: Has advanced scientific computing features including optimization and statistical analysis [59].

3. Results and Discussion

Using AI techniques in precision irrigation systems (Ahmed El-Shafie, Ehsan Heidari, Manfred Koch, and Ali Khaledi Nasab, 2020). It talks about how well they can anticipate how much water crops require and how to best schedule irrigation [83]. This sets the stage for using AI in micro-irrigation systems. Machine learning algorithms can help you manage your irrigation smartly (Tharaka Prabath Amarathunga, Chanaka Ruwan Jayasinghe, and Joon-Ho Lee, 2019). It talks about how algorithms like decision trees, support vector machines, and deep learning models are used to figure out how much water crops need and to automate the process of watering them [73]. The research looks at how well these methods work and talks about how they could improve micro irrigation systems. Combining artificial intelligence with precision farming to manage irrigation [96]. It talks about how AI can help figure out how much water crops will require by looking at things like soil moisture, weather, and plant physiology.

The report also talks about how AI-driven decision support systems and automation technologies could be used in micro-irrigation, and what their pros and cons might be [89]. The micro irrigation system has many parts, including artificial intelligence that can estimate how much water crops will require and automate valves. The process starts with sensor nodes in the field that gather real-time information about the weather, soil moisture, and the health of the crops [67]. A central controller unit with AI algorithms gets this data and uses it to make decisions and analyze it. The AI algorithms look at the data and make predictions about how much water each sort of plant needs based on its type, stage of growth, and the weather. The controller then sends orders to the actuators that control the irrigation valves to change the flow of water based on what is expected to happen. The system may also have a user interface that lets you keep an eye on things and make changes if you need to [78]. Overall, this architecture allows for precise irrigation, which saves water while maximizing crop yield through smart automation (Figure 2).

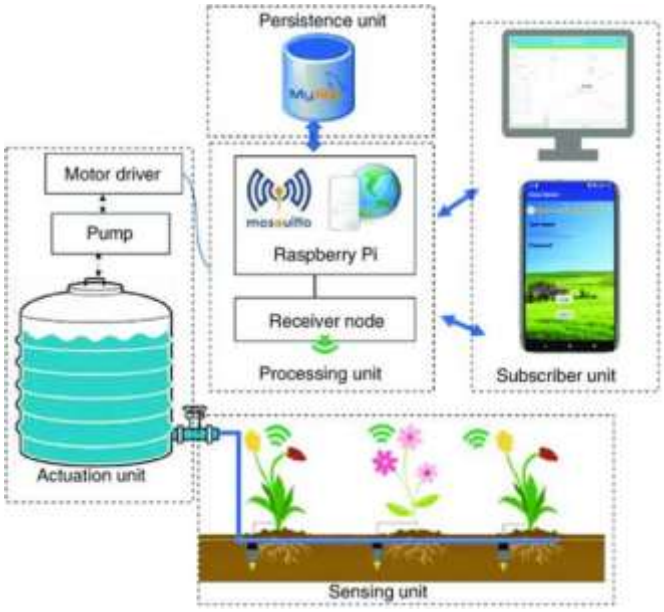

Figure 2: System Architecture

Collect relevant information, such as past weather patterns, soil moisture levels, types of crops, irrigation schedules, and other factors that determine how much water crops need [72]. To keep the data accurate and reliable, you should clean and preprocess it to make sure it is complete and consistent. Adding artificial intelligence (AI) to micro irrigation systems is a revolutionary way to improve crop water management and boost agricultural productivity. This all-encompassing solution includes a systematic way to use AI to estimate how much water crops will require and automate valve control, which changes the way irrigation is done.

Find the most important factors that affect crop water needs and valve automation. These include meteorological conditions (temperature, humidity, and rainfall), soil type, crop type, and irrigation system settings. If you need to, use feature engineering to get helpful information and make new features [66]. During the predictive modeling phase, we create machine learning models that are both accurate and strong enough to figure out how much water crops need [95]. Using supervised learning methods like regression or classification, models are trained on past data and tested to make sure they are reliable and can be used in other situations.

Choose the right machine learning or deep learning algorithms to figure out how much water crops need and to manage the valves automatically. Think about using methods like regression, classification, time series analysis, and reinforcement learning. Use the data you obtained and cleaned to train the models, and then check how well they work using the right assessment criteria [77]. Automation of valve control is a key part of AI-integrated micro irrigation systems. It makes it easier to provide water and reduces the need for people to be involved. Valves are automatically adjusted based on real-time sensor data and prediction forecasts of how much water crops will need, thanks to seamless connection with AI algorithms. Feedback systems keep an eye on the moisture levels in the soil all the time and change the flow rates of water as needed to keep the best growing conditions [88]. Fail-safe systems, on the other hand, stop over-irrigation or wasting water, which makes sure that water is used efficiently and resources are saved.

Choose the right deep learning or machine learning algorithms to anticipate how much water crops require and operate the valves automatically. Think about using methods like regression, classification, time series analysis, and reinforcement learning. Use the obtained and pre-processed data to train the models, and then check how well they work using the right assessment criteria. Also, using advanced AI approaches to improve irrigation plans makes the system work better and increases crop yields. AI agents may improve irrigation practices by interacting with the environment over and over again, which maximizes agricultural output while lowering water use, energy use, and operational expenses [61]. continuing optimization and adaptation to changing environmental conditions are made possible by the continuing enhancement and refinement of AI models based on field experiments and empirical data.

Create ways for AI models to talk to sensors, actuators, and control units in a micro irrigation system. Use the predictions made by the AI models to make decisions in real time using algorithms. Conduct rigorous integrated system testing under various environmental conditions and crop situations to assure its dependability and resilience [94]. Field tests and comparisons with traditional irrigation methods should be used to check the accuracy of crop water projections and the usefulness of valve automation. For AI-driven micro irrigation systems to work in the real world, integration and deployment must be done quickly and effectively [65]. Mobile apps and web-based dashboards are examples of user-friendly interfaces that make it easy to monitor and control irrigation activities. Testing in the field under a wide range of situations and with different types of crops gives us important information about how well the system works, how reliable it is, and how effective it is.

Stakeholder involvement also encourages collaboration with agricultural specialists, stakeholders, and end-users, making sure that everyone's needs and wants are met and creating an environment where new ideas and knowledge can be shared [84]. The design and development of AI-integrated micro irrigation systems are based on the ideas of scalability and adaptability. Customization options provide you the freedom to adapt to different farming methods, tastes, and areas [71]. Cloud-based solutions make it possible to monitor and administer various micro-irrigation systems from a distance, making it easier to scale up and handle everything from one place [99]. AI algorithms are also made to change with changing weather and crop water needs, so they will always be useful and effective in keeping agricultural productivity high.

Keep an eye on how well the AI models and the integrated system are working all the time, and collect feedback data to find ways to make them better. Based on the feedback, make small changes to the models and system settings to get the most out of water use

and crop yield [76]. Also, using advanced AI approaches to improve irrigation plans makes the system work better and increases agricultural yield. Reinforcement learning algorithms let AI agents improve irrigation strategies by interacting with the environment over and over again. This maximizes crop output while minimizing water use, energy use, and operating costs [87]. Field trials and real-world data help AI models get better and better over time, which makes sure they keep getting better and better at adapting to changes in the environment.

Use the improved AI-integrated micro-irrigation system on a bigger scale, either on a demonstration farm or with farmers who are working together. Give end users training and help so they can use and care for the technology properly [79]. Scalability and adaptability are two of the most important ideas that guide the design and creation of micro irrigation systems that use AI. Customization options provide you the freedom to fit different farming methods, tastes, and areas of the country. Cloud-based solutions let you keep an eye on and handle many micro-irrigation systems from afar, making it easier to scale up and keep everything under one roof [62]. AI algorithms are also made to adapt to changing weather and crop water needs, which makes sure that they will always be useful and effective in keeping agricultural productivity high.

Set up a mechanism to keep an eye on the deployed system's performance in real time so that any problems or strange behavior may be found quickly [92]. Set up frequent maintenance tasks to keep the system running smoothly and avoid downtime. The method for adding AI to micro irrigation systems takes a whole-system approach to improving water management, increasing crop yields, and making farming more sustainable. Farmers can easily negotiate the intricacies of modern agriculture by embracing AI technologies, opening the way for a future where food security and environmental stewardship go hand in hand. For AI-driven micro irrigation systems to work in the real world, they need to be able to be integrated and deployed quickly [75]. User-friendly interfaces, including mobile apps or web-based dashboards, make it easy to keep an eye on and regulate irrigation activities. Testing the system in the field across a wide range of environmental circumstances and crop types gives us important information about how well it works, how reliable it is, and how effective it is [98]. Stakeholder engagement also helps people work together with agricultural specialists, stakeholders, and end-users to make sure that everyone is on the same page with practical demands and requirements. This creates a culture of innovation and knowledge sharing.

Encryption algorithms: Python has a number of encryption algorithms, such AES and RSA, that keep data safe and make sure that communication is secure [80]. These algorithms are used in many parts of making apps, such as processing data, designing the user interface, and networking. Flutter also has a number of libraries and packages with algorithms that assist developers make their apps faster and better. Give the class label that the most neighbours have. For regression problems, find the weighted average of the target values of the K closest neighbours. Set this average value as the expected target value for the supplied data point. [68] After making predictions, check how well the KNN model did by looking at metrics like accuracy, precision, recall (for classification), or mean squared error, R-squared (for regression).

To see how well the model can generalize, split the dataset into training and testing sets. After making predictions, check how well the KNN model did by looking at its accuracy, precision, recall (for classification), or mean squared error, R-squared (for regression). To see how well the model can generalize, split the dataset into training and testing sets [91]. These algorithms are used for many parts of app development, such as processing data, designing the user experience, and networking. Flutter also has a number of libraries and packages with algorithms that assist developers make their apps faster and better [64]. Give the class label that is most common among the neighbors. To do regression tasks, find the weighted average of the K nearest neighbors' target values (Figure 3).

Figure 3: Use Case Diagram

The sequence diagram shows how several parts of a micro-irrigation system that uses artificial intelligence (AI) to estimate how much water crops require and automate valve operations work together. The system has a central control unit, sensors, AI modules, and actuators [69]. This graphic helps make sure that the app's features are clear and that all the parts of the system work together properly. The Sequence diagram shows how system components interact with each other and how messages move between them when the system is running. The system's operational workflow is shown by showing events in order, like "Sensor Data Acquisition," "Prediction Model Execution," and "Valve Adjustment." Lifelines that show system components show how they are involved in each occurrence, which helps people understand how the system works and how it communicates. Initialization—The procedure starts with setting up the system [85]. The central control unit turns on and sets up the AI modules that forecast how much water crops will require based on things like the type of crop, the weather, and the moisture level in the soil. The Deployment diagram shows how system parts are physically deployed among hardware nodes and networks. There are nodes like "Sensor Node," "Controller Node," and "Cloud Server" that show the physical parts that house system components. The network topology and data flow of the system design are shown by the communication channels between nodes, which might be wired or wireless.

Collecting Data from Sensors—Sensors in the field are always collecting data on things like soil moisture, temperature, humidity, and other important factors [81]. The central control unit gets the sensor data and processes it. UML diagrams are very useful for thinking about, planning, and talking about the architecture and functionality of the AI-integrated micro irrigation system throughout the design process. UML diagrams make it easier for stakeholders to work together, speed up development, and make sure that everyone is on the same page with project needs and goals by showing how structures relate to each other, how people interact with each other, and how deployments are set up. In the end, using UML diagrams in a full way makes it possible to build a strong, efficient, and scalable AI-driven micro-irrigation system that increases crop yields while saving water and encouraging environmentally friendly farming methods [64]. AI Prediction: The AI modules get the sensor data from the central control unit and use it to make predictions. Based on past data, present conditions, and crop-specific traits, the AI modules use machine learning algorithms to figure out how much water particular crops will need. The State diagram shows how the AI-enabled micro-irrigation system moves between different states and transitions [93]. There are states like "Idle," "Data Collection," "Prediction," and "Valve Control" that show how the system works.

Valve Automation: The central control unit figures out the best watering plan for each zone or crop based on the AI modules' projections of how much water is needed. The actuators get commands from the control unit, which then tells the valves to open or close as needed. To make sure that irrigation is accurate and effective, valves are automated based on the expected water needs. To make sure that an AI-enabled micro-irrigation system works and performs at its best, careful planning and design are needed. Unified Modelling Language (UML) diagrams are essential for planning the architecture of a system, as they show its structural, behavioral, and deployment features [70]. This detailed description explains how to use more UML diagrams in the design process, giving information about how systems work and how tasks are done [86]. Error Handling: The system has ways to find and fix problems, as when a sensor stops working or a communication error occurs. Alerts are sent out and the right steps are taken to fix the problem if anything goes wrong. The Package diagram groups system parts into coherent modules or packages, making it easier to design and build systems in a modular way. "Data Management," "AI Algorithms," "Control Logic," and "User Interface" are all examples of packages that group together relevant classes and components [97]. Dependencies between packages show how system modules depend on each other and how they are related, which helps keep the system organized and up to date.

Termination: The operation goes on till the irrigation cycle is done. When the system is done, it may go into standby mode and stay there until the next irrigation cycle starts. The sequence diagram shows how the parts of the micro-irrigation system and the AI modules work together perfectly. It also shows how AI is used to improve water use and agricultural productivity through smart irrigation management [74]. The Communication diagram shows how system parts talk to each other and send messages to each other when the system is running. There are objects that stand for parts of the system, such "Sensor," "Controller," and "Prediction Model," as well as the messages that are sent between them. Lifelines and message arrows show the order and direction of communication, which helps us see how system pieces interact and work together in real time. The Profile diagram adds domain-specific ideas and notations that are important to the micro irrigation field to the UML modeling language. Profiles like "Agricultural Domain Profile" or "Irrigation System Profile" set up domain-specific tagged values, stereotypes, and rules [90]. Profiles make UML diagrams more expressive and particular by customizing them to fit the unique needs and complexities of the AI-enabled micro-irrigation system.

By using UML diagrams in a thorough way, stakeholders may get a complete picture of the AI-enabled micro irrigation system, including how it is built, how it works, and how it is set up for deployment [82]. UML diagrams let people talk to each other, work together, and make decisions throughout the design and development process by showing how systems work, how they interact with each other, and how they depend on each other. In the end, using UML diagrams wisely can help make an AI-powered micro-irrigation system that improves crop water management, increases agricultural output, and promotes sustainable farming methods [63].

4. Conclusion

Micro-irrigation, an important method in modern farming, has made a lot of progress thanks to the use of artificial intelligence (AI). The goal of this research was to use AI to precisely forecast how much water crops need, automate valve operations, and ultimately increase agricultural productivity while saving water. We looked into how data collecting, AI modelling, valve automation, and real-time monitoring all work together to make a smart and efficient micro-irrigation system. Adding artificial intelligence to micro irrigation systems is a big step forward in agricultural technology. It has a lot of potential to improve crop yields, use water more efficiently, and reduce environmental effect. Farmers can use AI algorithms to properly forecast how much water their crops will need, which lets them schedule irrigation that is just right for each plant's demands. This capacity to foresee helps farmers use water in the best way possible, which helps avoid water stress and improves the health and productivity of the crops as a whole.

New Way to Manage Water: Adding AI to micro-irrigation systems is a big change in how we manage water. We can learn a lot about crop water needs, soil conditions, weather patterns, and other environmental aspects by using AI algorithms to look at a lot of sensor data. Because we know so much about this, we can make irrigation schedules that are just ideal for each crop, making sure they get the proper amount of water at the right time, which increases output and cuts down on water use. Also, AI-powered solutions that automate valves make the irrigation process easier by cutting down on manual labor and costs while increasing efficiency. These automated systems can quickly respond to changing conditions by modifying the flow of water depending on real-time data like soil moisture levels, weather forecasts, and the growth stages of the crops. This makes sure that the crops get the proper amount of water at the right time. This makes the best use of resources and cuts down on water waste and runoff, which helps with sustainable farming and protecting the environment.

Analyzing the outcomes of the micro-irrigation project, which uses artificial intelligence (AI) to estimate how much water crops will require and automate valves, gives us useful information about how well it works, how effective it is, and how it affects agricultural productivity and resource use. Through careful experimentation, data collecting, and evaluation, we can determine whether the project has reached its goals and what the results are. This is a thorough look at the results. How accurate is the prediction of crop water needs? One of the main goals of the research was to build AI models that could reliably anticipate how much water crops will need based on things like soil moisture, temperature, humidity, and the type of crop. The results show that the AI models were very accurate at estimating how much water would be needed for irrigation. This was possible because the models were improved and checked against real data over and over again. We can measure how well the AI models work by looking at their performance metrics, such as accuracy, precision, recall, and F1 score. This lets us see how well they work in real life. Cross-validation and holdout validation were also used to test the models' capacity to generalize and their strength over a range of datasets and environmental circumstances.

REFERENCES

[1] N. H. M. Shamsuddin, N. A. Ali, and R. Alwee, “An overview on crime prediction methods,” in 2017 6th ICT International Student Project Conference (ICT-ISPC), Johor, Malaysia, 2017.

[2] D. Ganesan, V. J. Francina, and V. P. Rameshkumaar, "Effectiveness of Corporate Responsibility Advertising Messages of Automobile Companies among Audience Perception," International Journal of Mechanical Engineering and Technology (IJMET), vol. 10, no. 2, pp. 934–941, 2019.

[3] K. Priya, R. V, S. A. Krishnan, V. P. Rameshkumaar, B. Premkumar and P. Jyothi, "Exploring Effective Leadership Strategies to Drive Organisational Success & Foster Sustainable Growth," 2024 Second International Conference on Advances in Information Technology (ICAIT), Chikkamagaluru, Karnataka, India, 2024, pp. 1-6.

[4] K. Priya, V. Rohini, S. A. Krishnan, V. P. Rameshkumaar, B. Premkumar, and P. Jyothi, "Exploring Effective Leadership Strategies to Drive Organisational Success & Foster Sustainable Growth," in Proc. 2024 Second International Conference on Advances in Information Technology (ICAIT), vol. 1, pp. 1–6, Jul. 24, 2024. IEEE.

[5] K. Selvavinayagam, V. J. Francina, and V. P. Rameshkumaar, "Evaluation of Logistic Performance Index of India in the Indian Postal Services," International Journal of Engineering and Management Research (IJEMR), vol. 8, no. 5, pp. 80–87, 2018.

[6] D. Thankachan, S. S. Ranganathan, P. D. Pachamuthu, V. Ravi, G. Manickam, and M. Alagarsamy, "Deep Learning-Enabled Holistic Control and Prediction System for Building Energy Consumption and Distribution Optimization," Electric Power Components and Systems, pp. 1-15, Apr. 1, 2024, Taylor & Francis.

[7] J. Krithika, K. R. Sowmya, and P. Prabadevi, "Behavioural Based Safety Practices at Small Manufacturing Units at Chennai," International Journal of Recent Technology and Engineering (IJRTE), vol. 8, no. 6, pp. 1501-1506, 2020.

[8] M. S. Kamalaveni, K. Parthiban, K. Sivasubramani, and P. P. Devi, "An evaluation of public health and healthcare policies in India," AIP Conf. Proc., vol. 3306, p. 030017, 2025.

[9] S. Y. Malathi and R. B. Geeta, “Classification of knee X-ray images by severity of osteoarthritis using skip connection based ResNet101,” Int. J. Intell. Eng. Syst., vol. 16, no. 5, p. 738, 2023.

[10] S. Y. Malathi and R. B. Geeta, “A novel method on CNN-LSTM to characterize knee osteoarthritis from radiography,” Proc. Natl. Acad. Sci., India, Sect. B: Biol. Sci., 2023.

[11] K. S. Sharada, R. B. Geeta, K. K. Manohara, and S. Y. Malathi, “Insight analysis of deep learning and a conventional standardized evaluation system for assessing rice crop's susceptibility to salt stress during the seedling stage,” SN Comput. Sci., 2023.
[12] S. Y. Malathi, R. B. Geeta, and K. S. Sharada, “Diagnosing and grading knee osteoarthritis from X-ray images using deep neural angular extreme learning machine,” Proc. Indian Natl. Sci. Acad., vol. 90, no. 2, 2024.
[13] S. K. Shiragudikar, G. Bharamagoudar, K. K. Manohara, S. Y. Malathi, and G. S. Totad, “Predicting salinity resistance of rice at the seedling stage: An evaluation of transfer learning methods,” in Intelligent Systems in Computing and Communication (ISCComm 2023), CCIS, vol. 2231, Cham: Springer, 2025.
[14] S. Malathi, G. Bharamagoudar, S. K. Shiragudikar, and G. S. Totad, “Predictive models for the early diagnosis and prognosis of knee osteoarthritis using deep learning techniques,” in Intelligent Systems in Computing and Communication (ISCComm 2023), CCIS, vol. 2231, Cham: Springer, 2025.
[15] S. K. Shiragudikar and G. Bharamagoudar, “Enhancing rice crop resilience: Leveraging image processing techniques in deep learning models to predict salinity stress of rice during the seedling stage,” Int. J. Intell. Syst. Appl. Eng., vol. 12, no. 14s, pp. 116–124, 2024.
[16] S. G. K. Peddireddy, “Advancing Threat Detection in Cybersecurity through Deep Learning Algorithms,” FMDB Transactions on Sustainable Intelligent Networks., vol.1, no. 4, pp. 190–200, 2024.
[17] S. G. K. Peddireddy, “Integrating AI for Proactive Network Defense against Emerging Security Vulnerabilities,” FMDB Transactions on Sustainable Computer Letters., vol. 2, no. 4, pp. 232–241, 2024.
[18] S. G. K. Peddireddy, “Optimizing Resource Allocation in Multi-Cloud Environments for Cost Efficiency and Scalability,” FMDB Transactions on Sustainable Computing Systems., vol. 2, no. 4, pp. 167–177, 2024.
[19] R. Rai, “A brief assessment of kiwifruit cultivation status in Nepal,” J. Multidiscip. Sci., vol. 7, no. 1, pp. 46–55, 2025.
A. Nepal, C. Joshi, N. Khatiwada, P. B. Chhetri, R. S. Chhetri, P. Kathayat, B. Mahara, and R. Rai, “Evaluation of the conversion of farming systems and scaling up of agroecological approaches in Nepal,” J. Multidiscip. Sci., vol. 7, no. 1, pp. 11–25, 2025.
[20] Badarch, R. Rai, and J.-H. Kim, “Estimation and analysis of the impact of habitats and chromosomes on trichome variation in Lilium amabile Palibian,” J. Multidiscip. Sci., vol. 7, no. 1, pp. 1–10, 2025.
[21] Nepal, K. Koirala, S. Rai, and R. Rai, “Agrobiodiversity integration in farming systems for income generation and livelihood options of smallholder farmers in Nepal: A case study of Bhimphedi Municipality,” J. Exp. Biol. Agric. Sci., vol. 13, no. 1, pp. 29–49, 2025.
[22] S. Rai, A. Nepal, S. Basi, T. Dhakal, and R. Rai, “Present status, practices, limitations, and future prospects of organic fruit production in Nepal,” J. Exp. Biol. Agric. Sci., vol. 13, no. 1, pp. 1–10, 2025.
[23] R. Rai and J.-H. Kim, “Heterosis and combining ability among promising single cross hybrids in Lilium formolongi Hort. for major growth and flowering traits,” Academia Biology, vol. 2, no. 4, 2024.
[24] R. Rai, A. Shrestha, S. Rai, S. Chaudhary, D. K. Acharya, and S. Subedi, “Conversion of farming systems into organic bio-intensive farming systems and the transition to sustainability in agroecology: Pathways towards sustainable agriculture and food systems,” J. Multidiscip. Sci., vol. 6, no. 2, pp. 25–34, 2024.
[25] S. Rai and R. Rai, “Advancements and practices in budding techniques for kiwifruit propagation,” J. Multidiscip. Sci., vol. 6, no. 2, pp. 11–16, 2024.
[26] S. Rai and R. Rai, “Monkey menace in Nepal: An analysis and proposed solutions,” J. Multidiscip. Sci., vol. 6, no. 1, pp. 26–31, 2024.
A. K. Shrestha, S. Chaudhary, S. Subedi, S. Rai, D. K. Acharya, and R. Rai, “Farming systems research in Nepal: Concepts, design, and methodology for enhancing agricultural productivity and sustainability,” J. Multidiscip. Sci., vol. 6, no. 1, pp. 17–25, 2024.
[27] S. Rai and R. Rai, “Advancement of kiwifruit cultivation in Nepal: Top working techniques,” J. Multidiscip. Sci., vol. 6, no. 1, pp. 11–16, 2024.
[28] S. Chaudhary, A. K. Shrestha, S. Rai, D. K. Acharya, S. Subedi, and R. Rai, “Agroecology integrates science, practice, movement, and future food systems,” J. Multidiscip. Sci., vol. 5, no. 2, pp. 39–60, 2023.
[29] R. Rai, V. Y. Nguyen, and J.-H. Kim, “Variability analysis and evaluation for major cut flower traits of F1 hybrids in Lilium brownie var. colchesteri,” J. Multidiscip. Sci., vol. 4, no. 2, pp. 35–41, 2022.
[30] V. Y. Nguyen, J.-H. Kim, J.-Y. Kim, and K. N. Jong, “Ecogeographical variations of the vegetative and floral traits in Lilium amabile Palibian,” J. Plant Biotechnol., vol. 48, no. 4, pp. 236–245, 2021.
[31] R. Rai and J.-H. Kim, “Performance evaluation and variability analysis for major growth and flowering traits of Lilium longiflorum Thunb.,” J. Exp. Biol. Agric. Sci., vol. 9, no. 4, pp. 439–444, 2021.
[32] R. Rai, V. Y. Nguyen, and J.-H. Kim, “Estimation of variability analysis parameters for major growth and flowering traits of Lilium leichtlinii var. maximowiczii germplasm,” J. Exp. Biol. Agric. Sci., vol. 9, no. 4, pp. 457–463, 2021.
[33] R. Rai and J.-H. Kim, “Effect of storage temperature and cultivars on seed germination of Lilium × formolongi Hort.,” J. Exp. Biol. Agric. Sci., vol. 8, no. 5, pp. 621–627, 2020.
[34] R. Rai and J.-H. Kim, “Estimation of combining ability and gene action for growth and flowering traits in Lilium longiflorum,” Int. J. Adv. Sci. Technol., vol. 29, no. 8S, pp. 1356–1363, 2020.
[35] R. Rai, A. Badarch, and J.-H. Kim, “Identification of superior three-way cross F1s, its Line × Tester hybrids, and donors for major quantitative traits in Lilium × formolongi,” J. Exp. Biol. Agric. Sci., vol. 8, no. 2, pp. 157–165, 2020.

[36] R. Rai, J. Shrestha, and J.-H. Kim, “Line × Tester analysis in Lilium × formolongi: Identification of superior parents for growth and flowering traits,” SAARC J. Agric., vol. 17, no. 1, pp. 175–187, 2019.
[37] R. Rai, J. Shrestha, and J.-H. Kim, “Combining ability and gene action analysis for quantitative traits in Lilium × formolongi,” J. Agric. Life Environ. Sci., vol. 30, no. 3, pp. 131–143, 2019.
[38] T. X. Nguyen, S. I. Lee, R. Rai, N. S. Kim, and J.-H. Kim, “Ribosomal DNA locus variation and REMAP analysis of the diploid and triploid complexes of Lilium lancifolium,” Genome, vol. 59, pp. 1–14, 2016.
[39] T. X. Nguyen, J.-Y. Kim, R. Rai, J.-H. Kim, N. S. Kim, and A. Wakana, “Karyotype analysis of Korean Lilium maximowiczii Regal populations,” J. Fac. Agric. Kyushu Univ., vol. 60, no. 2, pp. 315–322, 2015.
[40] S. Kasthuri and A. N. Jebaseeli, “An artificial bee colony and pigeon inspired optimization hybrid feature selection algorithm for Twitter sentiment analysis,” J. Comput. Theor. Nanosci., vol. 17, no. 12, pp. 5378–5385, 2020.
[41] S. Kasthuri and A. N. Jebaseeli, “Review analysis of Twitter sentimental data,” Biosci. Biotechnol. Res. Commun., vol. 13, no. 6 (Special Issue), pp. 209–214, 2020.
[42] S. Kasthuri and A. N. Jebaseeli, “An efficient decision tree algorithm for analyzing the Twitter sentiment analysis,” J. Crit. Rev., vol. 7, no. 4, pp. 1010–1018, 2020.
[43] S. Kasthuri and A. N. Jebaseeli, “Latent Dirichlet Allocation feature extraction with bio inspired pigeon feature selection technique for Twitter sentiment analysis,” Int. J. Adv. Trends Comput. Sci. Eng., vol. 9, no. 4, pp. 6406–6414, Jul.–Aug. 2020.
[44] S. Kasthuri, L. Jayasimman, and A. N. Jebaseeli, “An opinion mining and sentiment analysis techniques: A survey,” Int. Res. J. Eng. Technol. (IRJET), vol. 3, no. 2, pp. 573–575, 2016.
[45] S. Kasthuri and A. N. Jebaseeli, “A robust data classification in online social networks through automatically mining query facts,” Int. J. Sci. Res. Comput. Sci. Appl. Manage. Stud., vol. 7, no. 4, Jul. 2018.
[46] S. Kasthuri and A. N. Jebaseeli, “Social network analysis in data processing,” Adalya J., vol. 9, no. 2, pp. 260–263, Feb. 2020.
[47] S. Kasthuri and A. N. Jebaseeli, “Review on social network analysis in data mining,” Infokara Res., vol. 8, no. 12, pp. 1168–1172, Dec. 2019.
[48] S. Kasthuri and A. N. Jebaseeli, “Study on social network analysis in data mining,” Int. J. Anal. Exp. Modal Anal., vol. 11, no. 8, pp. 111–116, Aug. 2019.
[49] G. Rajarajeswari and S. Kasthuri, “Co-clustering interpretations for feature selection by using sparsity learning,” Int. J. Res. Instinct, vol. 4, no. 1, pp. 30–35, 2017.
[50] T. Ganesh Kannan, S. Kasthuri, and T. Dineshkumar, “A reliable communication and rate control for mobile network through efficient routing protocol,” Int. J. Comput. Sci. Eng., vol. 6, Special Issue 2, pp. 354–357, 2018.
[51] K. V. Deshpande and J. Singh, “Weighted transformer neural network for web attack detection using request URL,” Multimedia Tools and Applications, vol. 83, no. 15, pp. 43983–44007, Oct. 2023.
[52] J. Singh, S. Rani, and V. Kumar, “Role-based access control (RBAC) enabled secure and efficient data processing framework for IoT networks,” Int. J. Commun. Netw. Inf. Secur. (IJCNIS), Aug. 2024.
[53] J. Singh, S. Rani, and P. Kumar, “Blockchain and smart contracts: Evolution, challenges, and future directions,” in Proc. 2024 Int. Conf. Knowledge Eng. Commun. Syst. (ICKECS), Apr. 2024, pp. 1–5.
[54] J. Singh, E. al., “Enhancing cloud data privacy with a scalable hybrid approach: HE-DP-SMC,” J. Electr. Syst., vol. 19, no. 4, pp. 350–375, Jan. 2024.
[55] J. Singh, S. Rani, and G. Srilakshmi, “Towards explainable AI: Interpretable models for complex decision-making,” in Proc. 2024 Int. Conf. Knowledge Eng. Commun. Syst. (ICKECS), Apr. 2024, pp. 1–5.
[56] P. Das, D. Datta, S. S. Rajest, L. M. M. Visuwasam, A. Thakare, and J. Cypto, "Application of multi-criteria decision-making approach using TOPSIS to identify the vulnerable time zone of earthquake time series signal," Int. J. Crit. Comput.-Based Syst., vol. 11, no. 1/2, pp. 30–47, 2024.
[57] G. Kumaresan and L. M. Visuwasam, "Enhanced in-line data deduplication and secure authorization in hybrid cloud," Int. J. Innov. Res. Sci. Eng. Technol., vol. 4, no. 2, pp. 466–471, 2015.
[58] S. Gomathy, K. Deepa, T. Revathi, and L. M. M. Visuwasam, "Genre specific classification for information search and multimodal semantic indexing for data retrieval," SIJ Trans. Comput. Sci. Eng. Appl. (CSEA), vol. 1, no. 1, pp. 10–15, 2013.
[59] K. Kishore, D. Dhinakaran, N. J. Kumar, S. M. U. Sankar, K. Chandu, and L. M. M. Visuwasam, "Fish farm monitoring system using IoT," in Proc. 2021 Int. Conf. Syst., Comput., Autom. Netw. (ICSCAN), 2021, vol. 10, pp. 1–6.
[60] L. M. V., A. Balakrishna, N. S. R., and K. V., "Level-6 automated IoT integrated with artificial intelligence based big data-driven dynamic vehicular traffic control system," EAI Endorsed Trans. Energy Web, p. 164176, 2018.
[61] N. J. K., M. Shoba, D. Dhinakaran, L. M. M. V., and G. Elangovan, "Bio-inspired optimization to enhance the performance in 6G networks of reconfigurable intelligent surfaces," in Advances in Computational Intelligence and Robotics, pp. 409–444, 2025.
[62] N. J. Kumar, R. Premkumar, L. M. M. Visuwasam, G. Arjunan, G. Yuyaraj, and C. T. Kumar, "Hybrid K-means and firefly algorithm-based load balancer for dynamic task scheduling in fog computing for postoperative healthcare systems," in Proc. 2025 Int. Conf. Adv. Comput. Technol. (ICoACT), Sivalasi, India, 2025, pp. 1–6.
[63] N. J. Kumar, R. Premkumar, L. M. Michael Visuwasam, G. Arjunan, A. Shiny, and K. Dharani, "Adaptive optimization and resource allocation (AORA) model for IoT-edge computing using hybrid Newton-Raphson and dolphin echolocation

algorithm (HNR-DEA) technique," in Proc. 2025 Int. Conf. Adv. Comput. Technol. (ICoACT), Sivalasi, India, 2025, pp. 1–6.

[64] R. Premkumar, N. J. Kumar, L. M. Michael Visuwasam, G. Arjunan, A. Vinothini, and C. T. Kumar, "Hybrid gradient descent and sea lion optimization algorithm (H-GD-SLnO) to optimize task scheduling in fog computing environment," in Proc. 2025 Int. Conf. Adv. Comput. Technol. (ICoACT), Sivalasi, India, 2025, pp. 1–6.

[65] K. Singh, L. M. M. Visuwasam, G. Rajasekaran, R. Regin, S. S. Rajest, and S. T., "Innovations in skeleton-based movement recognition bridging AI and human kinetics," in Advances in Computational Intelligence and Robotics, pp. 125–141, 2024.

[66] V. S. A. Anala, A. R. Pothu, and S. Chintapalli, "Enhancing Preventive Healthcare with Wearable Health Technology for Early Intervention," FMDB Transactions on Sustainable Health Science Letters., vol.2, no.4, pp. 211–220, 2024.

[67] V. S. A. Anala and S. Chintapalli, "Scalable Data Partitioning Strategies for Efficient Query Optimization in Cloud Data Warehouses," FMDB Transactions on Sustainable Computer Letters., vol. 2, no. 4, pp. 195–206, 2024.

[68] Md H. Rahman, T. Islam, Md E. Hossen, Md E. Chowdhury, R. Hayat, Md S. S. Shovon, M. Alamgir, S. Akter, R. Chowdhury, and A. R. Sunny, "Machine Learning in Healthcare: From Diagnostics to Personalized Medicine and Predictive Analytics," J. Angiother., vol. 8, no. 12, pp. 1–8, 2024.

[69] R. Chowdhury, Md A. H. Fahad, S. M. S. Alam, M. I. Tusher, Md N. U. Rana, E. Ahmed, S. S. Akhi, and Md R. H. Mahin, "Database Management in the Era of Big Data: Trends, Challenges, and Breakthroughs," Pathfinder Res., vol. 1, no. 1, p. 15, 2020.

[70] Md R. H. Mahin, E. Ahmed, S. S. Akhi, Md A. H. Fahad, M. I. Tusher, R. Chowdhury, and Md N. U. Rana, "Advancements and Challenges in Software Engineering and Project Management: A 2021 Perspective," Pathfinder Res., vol. 2, no. 1, p. 15, 2021.

[71] Md A. H. Fahad and R. Chowdhury, "Evolution and Future Trends in Web Development: A Comprehensive Review," Pathfinder Res., vol. 3, no. 1, p. 13, 2022.

A. R. M. T. Islam, Md. N. Uddin, Md. F. R. Joy, R. Proshad, T. Kormoker, A. H. Anik, M. S. Rahman, Md. A. B. Siddique, and M. A. Alshehri, "Tracing sources-oriented ecological risks of metal(loid)s in sediments of anthropogenically-affected coastal ecosystem from northeast bay of Bengal," Mar. Pollut. Bull., vol. 211, p. 117354, 2025.

[72] R. M. T. Islam, M. Abdullah-Al Mamun, M. Hasan, M. N. Aktar, M. N. Uddin, M. A. B. Siddique, M. H. Chowdhury, M. S. Islam, A. B. M. M. Bari, and A. M. Idris, "Optimizing coastal groundwater quality predictions: A novel data mining framework with cross-validation, bootstrapping, and entropy analysis," J. Contam. Hydrol., p. 104480, 2024.

[73] Md. A.-A. Mamun, A. R. M. T. Islam, Mst. N. Aktar, M. N. Uddin, Md. S. Islam, S. C. Pal, A. Islam, A. B. M. M. Bari, A. M. Idris, and V. Senapathi, "Predicting groundwater phosphate levels in coastal multi-aquifers: A geostatistical and data-driven approach," Sci. Total Environ., vol. 953, p. 176024, 2024.

[74] M. N. Uddin, G. C. Saha, M. A. Hasanath, M. A. H. Badsha, M. H. Chowdhury, and A. R. M. T. Islam, "Hexavalent chromium removal from aqueous medium by ternary nanoadsorbent: A study of kinetics, equilibrium, and thermodynamic mechanism," PLoS ONE, vol. 18, no. 12, e0290234, 2023.

[75] G. C. Saha, M. A. Hasanath, M. N. Uddin, and M. Hasan, "Sustainable Utilization of Textile Dyeing Sludge and Coal Fly Ash by Brick Production Through Traditional Kilns," Nature Environ. Pollut. Technol., vol. 21, no. 3, 2022.

[76] M. N. Uddin, G. C. Saha, M. A. Hasanath, M. T. Rahman, and M. M. Rashid, "Development and Characterization of Novel Mn–Fe–Sn Ternary Nanoparticle by Sol–Gel Technique," in Advances in Civil Engineering, S. Arthur, M. Saitoh, and S. K. Pal, Eds. Singapore: Springer, 2022, vol. 184, Lecture Notes in Civil Engineering.

[77] M. T. Rahman, G. C. Saha, M. A. Hasanath, and M. N. Uddin, "Potential Use of Dying Sludge, Pet Granules and Fly Ash in Light Weight Concrete Block," in Advances in Civil Engineering, S. Arthur, M. Saitoh, and S. K. Pal, Eds. Singapore: Springer, 2022, vol. 184, Lecture Notes in Civil Engineering.

[78] M. N. Uddin, G. C. Saha, M. A. Hasanath, M. T. Rahman, and M. M. Rashid, "Development and Characterization of Novel Mn–Fe–Sn Ternary Nanoparticle by Sol–Gel Technique," in Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 29–34.

[79] M. A. Hasanath, M. N. Uddin, and M. Ashraf, "Fabrication of Eco-friendly Water Purifier by Pedaling Energy," in Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 29–34.

[80] M. A. Hasanath, M. N. Uddin, and G. C. Saha, "Assessment of beverage sludge as agricultural soil," in Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 254–260.

[81] M. T. Rahman, G. C. Saha, M. A. Hasanath, and M. N. Uddin, "Potential Use of Dying Sludge, Pet Granules and Fly Ash in Light Weight Concrete Block," in Proc. 5th Int. Conf. Adv. Civil Eng. (ICACE 2020), Chattogram: CUET, 2021, pp. EE 254–260.

[82] V. Yadav, "Machine Learning in Managing Healthcare Workforce Shortage: Analyzing how Machine Learning can Optimize Workforce Allocation in Response to Fluctuating Healthcare Demands," Progress In Medical Sciences, pp. 1–9, Aug. 2023.

[83] V. Yadav, "Machine Learning for Predicting Healthcare Policy Outcomes: Utilizing Machine Learning to Forecast the Outcomes of Proposed Healthcare Policies on Population Health and Economic Indicators," Journal of Artificial Intelligence & Cloud Computing, vol. 1, no. 2, pp. 1–10, Jun. 2022.

[84] R. Aravindhan, R. Shanmugalakshmi, K. Ramya and Selvan C., "Certain investigation on web application security: Phishing detection and phishing target discovery," 2016 3rd International Conference on Advanced Computing and Communication Systems (ICACCS), Coimbatore, India, 2016, pp. 1-10.

[85] R. Aravindhan and R. Shanmugalakshmi, "Comparative analysis of Web 3.0 search engines: A survey report," 2013 International Conference on Advanced Computing and Communication Systems, Coimbatore, India, 2013, pp. 1-6.
[86] Aravindhan, R., Shanmugalakshmi, R. & Ramya, K. Circumvention of Nascent and Potential Wi-Fi Phishing Threat Using Association Rule Mining. Wireless Pers Commun 94(3), 2331–2361, 2017.
[87] R. Aravindhan and R. Shanmugalakshmi, "Visual analytics for semantic based image retrieval (SBIR): semantic tool," International Journal of Latest Trends in Engineering and Technology, vol. 7, no. 2, pp. 300–312, 2016.
[88] R. Aravindhan and R. Shanmugalakshmi, "Multistage fuzzy classifier based phishing detection using LDA and CRF features followed by impersonated entity discovery," International Journal of Control Theory and Applications, vol. 10, no. 29, pp. 33–42, 2017.
[89] Selvan, C., Ragunathan, A., & Ashwinkumar, U. M. (2024). Mitigating phishing threats in unmanned aircraft systems (UAS) through multi-stage defense strategies. In Analyzing and Mitigating Security Risks in Cloud Computing (pp. 125–162). IGI Global.
[90] V. Basavegowda Ramu and A. R. Yeruva, "Optimising AIOps system performance for e-commerce and online retail businesses with the ACF model," International Journal of Intellectual Property Management, vol. 13, no. 3–4, pp. 412–429, 2023.
[91] V. Basavegowda Ramu and A. R. Yeruva, "The Capability of Observing Performance in Healthcare Systems," in EAI/Springer Innovations in Communication and Computing, Springer, Cham, Switzerland, pp. 541–548, 2023.
[92] V. Basavegowda Ramu and A. R. Yeruva, "Unsupervised strategies in detecting log anomalies using AIOps monitoring to amplify performance by PCA and ANN systems," International Journal of Critical Infrastructures, vol. 20, no. 4, pp. 356–371, 2024.
[93] V. Samudrala, A. Reddy Yeruva, N. Jayapal, T. Vijayakumar, M. Rajkumar, and S. Razia, "Smart Water Flow Monitoring and Theft Detection System using IoT," in Proceedings of the International Conference on Automation, Computing and Renewable Systems (ICACRS), Pudukkottai, India, 2022.
[94] S. A. Milu, S. Akter, A. Fathima, T. Talukder, I. Islam, and M. I. S. Emon, "Design and Implementation of hand gesture detection system using HM model for sign language recognition development," J. Data Anal. Inf. Process., vol. 12, no. 2, pp. 139–150, 2024.
[95] S. S. Mahtab, R. A. Anonto, T. Talukder, A. Raihan, and I. Islam, "Etching Technologies in Semiconductor Manufacturing: A Short Review," in Proc. Int. Conf. Emerg. Appl. Mater. Sci. Technol., Cham: Springer Nature Switzerland, 2024, pp. 319–324.
[96] T. Talukder, "Scanning Magnetometry With a Low Cost NV Diamond Quantum Sensor Probe," M.S. thesis, Morgan State Univ., 2024.