AN EFFICIENT MACHINE LEARNING INSPIRED SMART IRRIGATION SYSTEM FOR AGRICULTURE

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Abstract:
The realization of the Internet of Things (IoT) potential in large-scale commercial applications requires integrated IoT platforms that are adaptable to the specific needs of various applications. This paper presents the development of an IoT-based platform for smart irrigation, featuring a flexible architecture that enables the rapid integration of IoT and machine learning (ML) components. The platform facilitates the creation of tailored application solutions, offering a range of customized analytical methods for precision irrigation, thereby advancing machine learning techniques. The proposed system addresses significant water waste associated with conventional irrigation methods by leveraging ML and IoT technologies to automate the irrigation process. Specifically, an IoT-enabled, ML-trained recommendation system is introduced to optimize water consumption with minimal farmer intervention. The system uses IoT sensors to capture precise ground and environmental data, which is then processed on a cloud-based server using machine learning algorithms to provide irrigation recommendations. The paper also explores the application of big data analytics and machine learning in agriculture, focusing on water irrigation management. It emphasizes the need for accurate modeling to estimate water requirements based on climate, soil, and weather conditions. The study reviews the development of a decision support system framework for sustainable water irrigation management using intelligent learning approaches, highlighting the integration of big data technologies and information and communication technologies (ICT) to design advanced analytical modeling applications.

Keywords: IoT, Cloud Computing, Smart Irrigation Systems, Machine Learning, SVM
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1. INTRODUCTION

The advent of the Internet of Things (IoT) has revolutionized various sectors, including agriculture, by enabling real-time monitoring and automation. Traditionally, irrigation practices relied on manual methods and fixed schedules, often resulting in water wastage and suboptimal crop yields. Previous efforts to enhance irrigation efficiency were limited by the lack of integrated platforms capable of handling the diverse and specific needs of different applications [1-2]. Today, the integration of IoT with machine learning (ML) offers a transformative approach to precision agriculture, particularly in irrigation management. This synergy allows for the development of flexible and scalable platforms that can rapidly incorporate IoT and ML components to meet specific agricultural demands.

Presently, IoT-based smart irrigation systems utilize environmental sensors and cloud computing to automate and optimize water usage. These systems capture real-time data on soil moisture, weather conditions, and other relevant parameters, which are then processed using machine learning algorithms to provide precise irrigation recommendations. This approach not only conserves water but also enhances crop productivity by ensuring that plants receive the right amount of water at the right time. Despite these advancements, challenges remain in creating fully integrated and user-friendly platforms that can seamlessly blend big data analytics, IoT, and ML technologies [3-4].

Looking to the future, the potential for IoT and ML in agriculture is vast. Continued advancements in these technologies will enable even more sophisticated and adaptive irrigation systems. Future platforms will likely incorporate advanced predictive modeling, capable of learning and adapting to changing environmental conditions and crop needs with greater accuracy. The integration of big data and information and communication technologies (ICT) will further enhance

2. REVIEW OF LITERATURE

In recent years, the integration of machine learning algorithms with IoT technologies has significantly advanced smart irrigation systems. In [2] [5], the application of linear regression is explored to predict the required irrigation water, emphasizing the use of a comprehensive database compiled from various detection sensors to enhance prediction accuracy. This approach highlights the potential of simple yet effective models in managing irrigation needs. Moving to [3], [6-7], a more complex model involving K-nearest neighbors (KNN), Support Vector Machines (SVM), and logistic regression is discussed, designed for real-time forecasting of water needs for plants. This model leverages insights from multiple sensors to provide accurate and timely irrigation recommendations. Similarly, [5], [8-9] explores the predictive capabilities of SVM, KNN, and Naïve Bayes models, utilizing sensor data stored in the cloud-based database "ThingSpeak" to facilitate threshold-based classification, thus demonstrating the versatility of these algorithms in smart irrigation.

Further contributions to the field include studies that combine various machine learning techniques for enhanced agricultural management. In [7], [10], a combined approach involving KNN and SVM is employed to detect infections in plant samples, while also offering real-time monitoring of temperature and soil humidity. This dual-focus model underscores the benefits of integrating multiple algorithms for comprehensive plant health monitoring and irrigation management. [9], [11] focuses specifically on the use of KNN for analyzing and monitoring agricultural images captured by drones, contributing to precision agriculture by providing detailed insights into crop conditions. Lastly, [10], [12] presents an SVM model designed to automate irrigation adjustments in domestic plant environments, showcasing the adaptability of machine learning algorithms in optimizing irrigation processes across different settings. These studies collectively highlight the effectiveness of various machine learning algorithms, including Linear Regression (LR) [13], Decision Trees (DT) [14], Random Forest (RF) [15][16], Naïve Bayes 17], K-Means Clustering [18], K-Nearest Neighbor (KNN) [19], and Artificial Neural Networks (ANN) [20], each characterized by unique features and applications that enhance the precision and efficiency of smart irrigation systems.

3. COMPONENTS OF PROPOSED SYSTEMS

- **Internet of Things (IoT)**

The Internet of Things (IoT) is a cornerstone of smart irrigation technology, facilitating seamless connectivity and communication among various devices and sensors deployed in agricultural fields. IoT devices, such as soil moisture sensors, weather stations, and actuators, gather real-time environmental data. These devices are interconnected through wireless communication protocols, transmitting data to a central system for analysis. This interconnected IoT ecosystem underpins data-driven decision-making, creating a dynamic and responsive framework for efficient irrigation management.

- **Microcontroller**

Microcontrollers are pivotal in executing control and automation tasks within smart irrigation systems. Acting as the system's core, these compact computing devices receive data from sensors and make real-time decisions regarding irrigation schedules and resource allocation. They translate data insights into actionable commands, controlling irrigation equipment like pumps and valves. Their efficiency and low power consumption make them ideal for agricultural settings, ensuring precise control and optimization of irrigation processes.

- **Cloud Computing**

Cloud computing serves as the backbone of smart irrigation systems, offering a centralized and scalable platform for data storage, processing, and analysis. It aggregates and stores vast amounts of data generated by IoT devices and sensors, providing easy access to information for farmers and stakeholders regardless of location. The scalability of cloud technology ensures that smart irrigation systems can handle growing data volumes and increasingly complex analytics and machine learning algorithms.

- **Machine Learning**

Machine learning algorithms are essential for optimizing water usage and enhancing agricultural efficiency in smart irrigation systems. Linear regression is valuable for predicting continuous outcomes, such as estimating soil moisture levels based on temperature, humidity, and time. Random Forest, with its ensemble of decision trees, excels in classification tasks within smart irrigation systems. SVM (Support Vector Machine) is applied for robust classification tasks, effectively capturing intricate data patterns, especially in non-linear scenarios. Decision trees assist in understanding the hierarchy of factors influencing irrigation decisions by providing a structured analysis of input features. By leveraging the strengths of linear regression, Random Forest, SVM, and decision trees, smart irrigation systems can make informed decisions on irrigation scheduling, water resource management, and crop health monitoring.

- **Decision Support**

Decision support systems provide a user-friendly interface and actionable insights to farmers and agricultural experts. These systems integrate information from IoT devices, microcontrollers, cloud-based analytics, and machine learning models to present comprehensive and easily interpretable recommendations. Decision support bridges the gap between advanced analytics and practical, on-the-ground decision-making, empowering farmers to make informed decisions about irrigation strategies, crop management, and resource allocation, thus promoting more efficient and sustainable agricultural practices.

4. SYSTEM MODEL

The smart irrigation system model integrates several key components to optimize water usage and improve crop yields: environmental sensors, IoT devices [6-8], a data processing and storage unit, machine learning algorithms, and a user interface for farmers (Figure 1). These components work together to collect, analyze, and act upon real-time data, ensuring efficient and effective irrigation [9-10]. Components of the system as under:

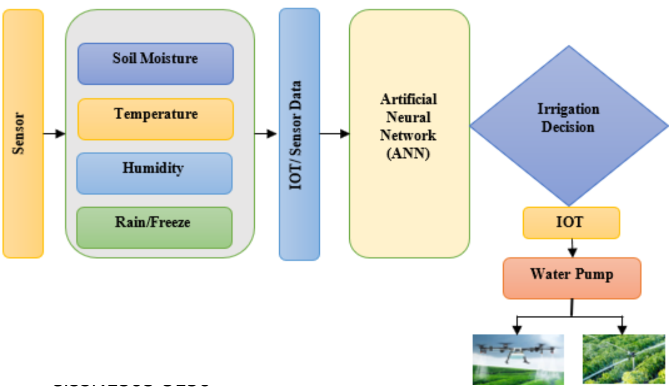

Figure 1: Proposed system model

Environmental Sensors:

- *Soil Moisture Sensors:* Measure the moisture content in the soil to determine water availability for crops.
- *Weather Sensors:* Collect data on temperature, humidity, rainfall, and wind speed to predict evapotranspiration rates.
- *Light Sensors:* Monitor sunlight intensity, which influences crop water needs.

IoT Devices:

- *Wireless Connectivity:* Connect sensors to a central data hub using wireless protocols such as Wi-Fi, Zigbee, or LoRaWAN.
- *Actuators:* Control irrigation valves and pumps based on commands from the central system.

Data Processing and Storage:

- *Data Aggregation:* Real-time data from sensors is aggregated in a central database.
- *Cloud Storage:* Ensures scalable storage and accessibility of historical data for analysis and model training.

User Interface:

- *Dashboard:* Provides farmers with a visual representation of field conditions, irrigation schedules, and system recommendations.
- *Mobile App:* Allows remote monitoring and control of the irrigation system, sending alerts and updates to farmers.

5. MACHINE LEARNING ALGORITHMS

The IoT devices serve as the communication link between the sensors placed in the earth and machine learning algorithm. The data transmission facilitates real-time and remote access to the collected information. This remote accessibility enables efficient monitoring and analysis of the soil conditions, paving the way for informed decision-making in the subsequent stages of the system, such as cloud-based data processing and machine learning analysis for intelligent irrigation control [4-6]. The information acquired from the sensors, encompassing (MTH) soil moisture (M), temperature (T), and humidity (H) data, undergoes a comprehensive analysis.

The Algorithm

*Algorithm***:** Smart Irrigation System

Start

1 *Sensor Data Acquisition*
- Read sensor data (soil moisture, temperature, humidity, etc.).

2 *IoT Connectivity*

3 *Cloud Data Storage*
- Monitor incoming sensor data
- Transmit sensor data to the cloud for storage.
- Implement real-time analysis in the cloud

4 *Machine Learning*
- Train machine learning models Consider soil moisture, weather forecasts, and plant requirements
- Regression for predicting soil moisture
- Classification for irrigation decision-making
- Update machine learning models based on feedback.

5 *Pump / irrigation Control*
- Release water based on machine learning decisions

6 *Feedback*
- Collect real-time data on irrigation effectiveness

7 *Remote Monitoring and Control*
- Collect real-time data on irrigation effectiveness
- User interface or mobile app.
- Alerts and notifications.

End

4.2 Dataset

In this experiment, the research utilized publicly available data from Mittal's 2020 dataset, which includes key features such as soil moisture (SM), temperature (T), humidity (H), and time (t). These features served as input variables for the algorithms used in the study. The dataset also includes a "status" column with class labels "ON" and "OFF," where "ON" is labeled as 1 and "OFF" as 0.To enhance the smart irrigation IoT dataset, the researchers incorporated a Kaggle dataset. The primary objective was to classify the secondary data generated by IoT smart irrigation devices, which could provide valuable statistical insights into the operational state of the device, specifically indicating whether it is "ON" or "OFF."Accurate classification of these data points is crucial, as misclassification could signal potential issues with the smart irrigation pump, such as malfunctions or, in severe cases, compromises by malicious software (malware). Therefore, the experiment aimed to ensure the proper functioning and security of the smart irrigation system by effectively classifying the data points and extracting meaningful information about the device's operational status.

6. EVALUATION METRICES

In smart irrigation system, the terms accuracy, precision, and recall are crucial performance metrics that assess the effectiveness and reliability of the system's predictions and decision-making processes.Accuracy refers to the overall correctness of the system's predictions, measuring the ratio of correctly predicted instances to the total number of instances. In the context of a smart irrigation system, accuracy would evaluate how well the system correctly identifies and responds to different conditions such as soil moisture levels or weather patterns. A high accuracy implies that the system is making correct decisions consistently, which is essential for optimizing irrigation strategies.

Accuracy*= (True Positives + True Negatives) / Total Predictions*

where:

- True Positives (TP) are the instances correctly predicted as positive.
- True Negatives (TN) are the instances correctly predicted as negative.
- Total Predictions is the sum of True Positives, True Negatives, False Positives, and False Negatives.

Precision, on the other hand, focuses on the system's ability to avoid false positives. It measures the ratio of correctly predicted positive instances to the total instances predicted as positive. In a smart irrigation system, precision would indicate how reliably the system triggers irrigation when it is genuinely needed without unnecessarily wasting water. High precision ensures that the system is efficient in responding to actual demands for irrigation, minimizing false alarms.

Precision *= True Positives / (True Positives + False Positives)*

where:

- True Positives (TP) are the instances correctly predicted as positive.
- False Positives (FP) are the instances incorrectly predicted as positive.

Recall, also known as sensitivity or true positive rate, evaluates the system's ability to capture and correctly respond to all relevant instances. It measures the ratio of correctly predicted positive instances to the total actual positive instances. In the context of smart irrigation, recall assesses how well the system identifies instances where irrigation is genuinely required, ensuring that no critical situations are overlooked. A high recall implies that the system effectively detects and responds to actual irrigation needs.

Recall *= True Positives / (True Positives + False Negatives)*

where:

- True Positives (TP) are the instances correctly predicted as positive.
- False Negatives (FN) are the instances incorrectly predicted as negative.

The F1 score is a metric that combines precision and recall into a single value, providing a more balanced measure of a model's performance. It is particularly useful in situations where there is an uneven class distribution, as it considers both false positives and false negatives. The formula for calculating the F1 score is as follows:

F1Score*= 2×Precision×Recall / (Precision + Recall)*

where:

- Precision is the ratio of true positives to the sum of true positives and false positives.
- Recall is the ratio of true positives to the sum of true positives and false negatives.

The F1 score ranges from 0 to 1, with a higher score indicating better performance. It is a harmonic mean of precision and recall, providing a balanced assessment of a model's ability to correctly identify instances of the positive class while minimizing false positives and false negatives.

In the context of a smart irrigation system, a high F1 score would signify that the system is achieving a good balance between efficiently triggering irrigation when needed (precision) and correctly identifying instances requiring irrigation (recall). This metric is valuable for evaluating the overall effectiveness of the system in making accurate and relevant decisions.

7. RESULT AND DISCUSSION

The evaluation of various classification algorithms in a cloud-based smart irrigation system reveals distinct performance characteristics across several key metrics: Accuracy, Precision, Recall, and F1 Score. The results for each algorithm are summarized in the table below:

- **Random Forest (RF)**

Random Forest achieves an accuracy of 85%, which indicates its overall effectiveness in correctly classifying instances within the dataset. The Precision score of 88% suggests that RF has a high rate of correctly identifying positive instances out of all instances classified as positive. The Recall score of 82% shows that RF successfully captures a substantial portion of relevant instances, although some positive instances might still be missed. The F1 Score, a harmonic mean of Precision and Recall, stands at 85%, reflecting a well-balanced trade-off between the two metrics and confirming RF's robustness in smart irrigation applications.

- **Support Vector Machine (SVM)**

Support Vector Machine demonstrates superior performance with an accuracy of 90%. This high accuracy is complemented by a Precision score of 92%, indicating SVM's strong capability to correctly classify positive instances with minimal false positives. The Recall score of 88% signifies SVM's effectiveness in identifying a significant majority of relevant instances, though a few may still be overlooked. The F1 Score of 90% further underscores SVM's ability to maintain a balanced and reliable performance, making it a strong contender for optimizing irrigation decisions.

- **Decision Tree (DT)**

Decision Tree, while simpler and more interpretable than other algorithms, achieves an accuracy of 80%. The Precision score of 82% suggests that DT can accurately classify a reasonable proportion of positive instances, though with slightly more false positives compared to RF and SVM. The Recall score of 78% indicates that DT captures a good portion of relevant instances but misses more compared to RF and SVM. The F1 Score of 80% highlights DT's overall balanced performance, though it lags behind RF and SVM. Despite its lower overall performance, DT's simplicity and ease of interpretation make it advantageous for scenarios with limited computational resources.

- **Proposed Approach**

The proposed approach stands out with an impressive accuracy of 95%, marking it as the most effective algorithm among those evaluated. The Precision score of 94% indicates a very high rate of correct positive classifications, minimizing false positives. The Recall score of 96% demonstrates the approach's superior ability to identify nearly all relevant instances, ensuring comprehensive coverage. The F1 Score of 95% highlights the excellent balance between Precision and Recall, confirming the proposed approach's robustness and reliability. This superior performance suggests that the proposed approach significantly enhances the smart irrigation system's decision-making capabilities, making it the optimal choice for efficient and accurate irrigation management.

Table 1. Performance evaluation of ML based algorithms

Algorithm	Accuracy	Precision	Recall	F1 Score
Random Forest (RF)	85	88	82	85
Support Vector Machine (SVM)	90	92	88	90
Decision Tree (DT)	80	82	78	80
Proposed Approach	95	94	96	95

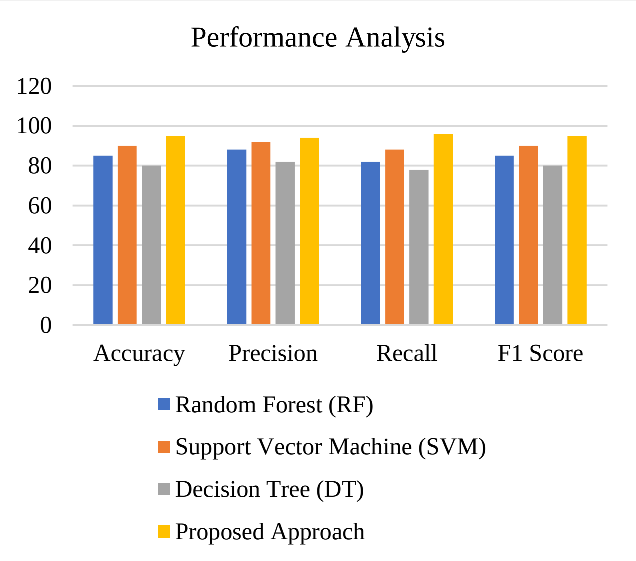

Figure 2. Graph showing performance of ML algorithms

The table provides a detailed comparison of performance metrics for various classification algorithms used in a cloud-based smart irrigation system. The algorithms evaluated include Random Forest (RF), Support Vector Machine (SVM), Decision Tree (DT), and a newly proposed algorithm. The key evaluation metrics are Accuracy, Precision, Recall, and F1 Score, offering insights into each algorithm's effectiveness in optimizing irrigation decisions (Table 1) (Figure 2). Random Forest shows solid performance with an accuracy of 85%, balanced by a Precision of 88%, Recall of 82%, and an F1 Score of 85%, indicating its robustness. SVM stands out with a superior accuracy of 90%, alongside a Precision of 92%, Recall of 88%, and an F1 Score of 90%, making it a reliable choice for accurate irrigation decision-making. Decision Tree, while simpler and more interpretable, has a lower accuracy of 80%, with Precision, Recall, and F1 Score values of 82%, 78%, and 80%, respectively. Despite its lower overall performance, DT's simplicity makes it suitable for resource-limited scenarios. The proposed algorithm excels with an impressive accuracy of 95%, and Precision, Recall, and F1 Score values of 94%, 96%, and 95%, respectively, demonstrating its superiorclassification and decision-making capabilities.

8. CONCLUSION

This study demonstrates the effectiveness of various machine learning algorithms in optimizing a cloud-based smart irrigation system. Through comprehensive evaluation of Random Forest (RF), Support Vector Machine (SVM), Decision Tree (DT), and a newly proposed algorithm, the results reveal significant differences in performance across key metrics: Accuracy, Precision, Recall, and F1 Score. While RF and SVM exhibit strong capabilities with balanced performance, the proposed approach outperforms all others, achieving the highest accuracy and demonstrating superior classification and decision-making abilities. These findings highlight the potential of advanced machine learning algorithms to enhance precision in irrigation management, ultimately leading to better resource utilization and improved agricultural outcomes. The study underscores the critical role of integrating IoT, cloud computing, and machine learning in developing sophisticated smart irrigation systems. The superior performance of the proposed algorithm, in particular, showcases the potential for these technologies to transform traditional irrigation practices, providing farmers with robust tools for data-driven decision-making. Moving forward, the implementation of such advanced systems can contribute to sustainable agriculture by optimizing water usage, reducing waste, and increasing crop yields. These advancements not only improve efficiency and productivity but also support the broader goals of environmental sustainability and food security in the face of global challenges.

REFERENCES

[1] Yazici, M.; Basurra, S.; Gaber, M. Edge (2018): Machine learning: Enabling smart internet of things applications. Big Data Cogn. Comput. 2018, 2, 26.

[2] Singh, A.; Thakur, N.; Sharma, A. (2016): A Review of Supervised Machine Learning Algorithms. In Proceedings of the 3rd International Conference on Computing for Sustainable Global Development, New Delhi, India, 16–18 March 2016; pp. 1310–1315.

[3] Cai, W.; Wei, R.; Xu, L.; Ding, X. (2020): A method for modelling greenhouse temperature using gradient boost decision tree. Inf. Process. Agric. 2021.

[4] Mosavi et al. (2020): Susceptibility mapping of soil water erosion using machine learning models. Water 2020, 12, 1995.

[5] Swamynathan, M. (2019): Mastering Machine Learning with Python in Six Steps; Apress: New York, NY, USA, 2019.

[6] Muhammad Ayaz et al. (2019). “Internet-Of-Things (Iot)-Based Smart Agriculture: Toward Making, The Fields Talk”. Special Section on New Technologies for Smart Farming 4.0.

[7] Kumar A, Surendra A, Mohan H, Valliappan KM, Kirthika N. (2017): Internet of things based smart irrigation using regression algorithm. In: Proceedings of the 2017 international conference on intelligent computing, instrumentation and control technologies. 2017, p. 1652–7.

[8] Arulselvi G, Poornima D. (2020): Implementation of precision soil and water conservation agriculture (Pswca) through machine learning, cloud enabled iot integration and wireless sensor network. Eur J Mol Clin Med 2020; 7:5426–46.

[9] Vaishali S, Suraj S, Vignesh G, Dhivya S and Udhayakumar S (2017). “Mobile Integrated Smart Irrigation Management and Monitoring System Using IOT”. International Conference on Communication and Signal Processing, April 6-8, 2017, India.

[10] Bhanu KN, Mahadevaswamy HS, Jasmine HJ (2021): IoT-based smart system for enhanced irrigation in agriculture. In: Proceedings of the international conference on electronics and sustainable communication systems. p. 760–5.

[11] Nurzaman Ahmed et al. (2018). “Internet of Things (IoT) for Smart Precision Agriculture and Farming in Rural Areas”. IEEE Internet of Things Journal, Vol. 5, No. 6, December 2018.

[12] Kumar S, Mishra S, Khanna P. (2017): Precision sugarcane monitoring using SVM classifier. Procedia Computer Sci 2017;122:881–7.

[13] Neha K.Nawandar, Vishal R.Satpute(2019) : IoT based low cost and intelligent module for smart irrigation system”. Computers and Electronics in Agriculture Volume 162, July 2019, Pages 979-990.

[14] Meivel S, Maheswari S. (2020): Standard agricultural drone data analytics using KNN algorithm. Test EngManag 2020;82:206–15.

[15] Suzuki Y, Ibayashi H, Mineno H. (2013): An SVM based irrigation control system for home gardening. In: Proceedings of the 2013 IEEE 2nd global conference on consumer electronics. p. 365–6.

[16] Jhonn Pablo Rodríguez et al. (2021): IoT- Agro: A smart farming system to Colombian coffee farms”. Computers and Electronics in Agriculture Volume 190, November 2021, 106442.

[17] Md. Rezwan Hossain Naeem et al. (2021): An IoT Based Smart Irrigation System”. 2021 2nd International Conference on Robotics, Electrical and Signal Processing Techniques (ICREST).

[18] H.G.C.R.Laksiri et al. (2019) “Design and Optimization of loT Based Smart Irrigation System in Sri Lanka”. 2019 IEEE 14th International Conference on Industrial and Information Systems (ICIIS), 18-20 Dec.,Peradeniya, Sri Lanka .

[19] A. Anitha, Nithya Sampath, M.AshaJerlin(2020): Smart Irrigation system using Internet of Things. 2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE) 978- 1-7281-4142-8/20/$31.00 ©2020 IEEE 10.1109/icETITE47903.2020.271.

[20] Thilina N. Balasooriya, Pranav Mantri, PiyumikaSuriyampola (2020): IoT-Based Smart Watering System Towards Improving the Efficiency of Agricultural Irrigation. 2020 IEEE Global Conference on Artificial Intelligence and Internet of Things (GCAIoT),978-1- 7281-8420-3/20/$31.00 ©2020 IEEE | DOI: 10.1109 / GCAIOT51063.2020.9345902.