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Smart irrigation systems using IoT, ML

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Abstract: In India a very vast population is dependent on farming activities and most of them still uses traditional methods of irrigation. Water availability plays main role in this sector. As the world is advancing and population of India is on the rise scarcity of water is becoming a common problem in most part of the country.

This paper presents a comprehensive overview of the current state of research regarding smart irrigation systems utilizing IoT technology and ML algorithms. The major area of the system incorporates data collection from sensors to monitor critical parameters in real-time such as soil moisture, temperature, weather conditions. The data collected from these sensors is processed, analyzed and utilized to make smart decisions, automate and optimize the irrigation process, so that consumption of water in the farm fields can be regulated in such a way that water wastage is reduced to minimum. The paper also discusses the challenges associated with the implementation of sensor-based irrigation systems. and proposes potential solutions to address these challenges. This research highlights the importance of developing and promoting sustainable agricultural practices aims to ensure access to clean water and sanitation for all.

Keywords: - IoT (internet of things), ML (Machine Learning), LDR (light dependent register), DHT (Dihydrotestosterone), UART (Universal Asynchronous Receiver/Transmitter).

I. INTRODUCTION

In India Agriculture is a State subject due to which farmers are dependent on the implementation of government schemes by the states, For example Providing Soil Health Cards to Farmers so they can know the nutrient value of the soil for any particular crop. Although these schemes are being implemented on the ground but due to lack of resources, knowledge and literacy a majority of traditional farmers are not able to take full advantage of the schemes and thus bear loss of production.

In the domain of irrigation farmers are mostly dependent on rainwater, ground water and irrigation canal systems. Of total 500 million acres of arable land in India, about 100 million acre is irrigated through ground water, nearly 80% of that is wasted due to inefficient methods. Over and Under irrigation are a major cause of lower yield. We aim to develop irrigation systems utilizing the Internet of Things (IoT) that have the potential to revolutionize the way in which crops are watered, leading to significant improvements in crop production, quality and sustainability. By integrating sensors and actuators into an IoT network, farmers in India can automate their irrigation processes and make smart-driven decisions to optimize water usage and save electricity and machine life. This paper offers a comprehensive overview of IoT-based smart irrigation systems in India, encompassing essential components, and the latest technological advancements in the field. Furthermore, we delve into the advantages associated with smart irrigation systems, such as enhanced water management practices, amplified crop yields, and diminished water wastage. Considering the escalating global demand for sustenance and freshwater resources, coupled with India's substantial agricultural potential, the development and implementation of IoT-driven smart irrigation systems emerge as a critical imperative for achieving sustainable agriculture and ensuring food security within the country.

This study aims to present a smart irrigation system that utilizes Raspberry Pi Pico as its central control unit and ML techniques to make decisions. The proposed system integrates various sensors including a soil moisture sensor, a temperature sensor (LM35), a light sensor (LDR), and a humidity sensor (DHT11). The data gathered from the aforementioned sensors is transmitted to the central control unit, where it undergoes

thorough processing and analysis to facilitate informed decisions pertaining to water pump control. Moreover, the integration of ML technology further augments the system, enabling real-time data logging and monitoring through a web API. The proposed smart irrigation system presents various advantages, encompassing enhanced water utilization efficiency, diminished water wastage, and elevated crop productivity. Notably, the system exhibits remarkable adaptability and scalability, rendering it suitable for diverse agricultural applications.
The aim to address the limitations of previous smart irrigation systems that were proposed using various devices such as ESP8266, Arduino, ZigBee, GSM, GPRS, and smartphones. We believe that their proposed system offers a low-cost and efficient solution for smart irrigation, which can help optimize water usage by switching the irrigation motor ON/OFF automatically. The system can be easily replicated and adapted to various agricultural settings, making it a valuable contribution to the field of smart agriculture and sustainable agriculture practices.

II. LITERATURE REVIEW

Many scholars have researched various technologies to modernize irrigation system. Their findings have stimulated studies in modernizing the irrigation system.

A paper by D. Bhattacharjee, O. Prakash and H. Islam focus on the design and development of wireless smart fertilizer dispensary systems utilizing ZigBee and GSM technology. The prototype models consist of a field station equipped with ATMEGA 328 embedded platforms, four solenoid valves, driver circuits, ZigBee and GSM modules. Overall, the system provides a cost-effective and power-optimized solution for flexible fertilizer dispensary, seamlessly integrated with drip irrigation systems. [1]

In a paper L. M. Lonescu, A. G. Mazare, G. Serban, D. Visan and A. Lita on Intelligent Command of An Underground Irrigation and Fertilization System highlight an innovative solution for intelligent control of underground irrigation and fertilization, highlights the advantages of this method, which allows for improved control over agricultural practices. The proposed system utilizes input parameters related to soil quality, such as humidity, temperature, and pH, along with intelligent algorithms to optimize irrigation and fertilizer application. [2]

A moderate review about the requirement of wireless sensors in agriculture is discussed by Aqeel-ur-Rehman, Abu Zafar Abbasi b and Zubair Ahmed Shaikh (2014). The paper discusses WSN technology and other applications in the field of agriculture. [3]

V. M. Larios, R. Michaelson, A. Virtanen, J. Talola, R. Maciel and J. R. Beltran wrote Best practices to develop smart agriculture to support food demand with the rapid urbanization trends in Latin America (2019), the study specifically investigates methods to reduce water consumption in agricultural fields located near metropolitan areas by integrating traditional techniques with biochemistry and the Internet of Things (IoT). [4]

AlirezaFarhadi and Ali Khodabandehlou (2016), present a research paper which is concerned with a distributed model predictive control (DMPC) method. It is based on a distributed optimization method with two-level architecture for communication. The paper is concentrated on communication technologies used for forecasting. [5]

A paper by George Mois, SilviuFolea, and TeodoraSanislav (2017), discusses remote sensing and wireless sensor networks for gathering data about the environment. It claims that refinement of the protocol and the addition of mesh networking capabilities to BLE devices will enhance the functionality of the system in irrigation. The findings are useful, as they can be well incorporated in smart irrigation system. [6]

G. Nagarajan, R. I. Minu (2017) worked on to automate the whole wireless sensor network (WSN) system with a control over water pumps and dripper valves. This system leaves a large scope for study as it has not practically involved smart phone app for real time data display and other facilities. A User Interface system and design of the mechanical structure also needs to be incorporated in it. [7]

P. Durga, G. Narayanan, B. Gayathri, M. V. Ramesh and P. Divya (2017), presents that the field of wireless sensor networks is advancing rapidly, and its application in agriculture has gained significant importance. While many research problems and solutions have been explored in this field, most of them focus on single crop scenarios. [8]

Francesco Fabiano Montesanoa, Marc W. van Ierselb, Francesca Boaria (2018), discuss prototype cloud-connected system for wireless, sensor-based irrigation management, which worked well for farming of basil. Their approach to irrigation can be adopted for other species if combined with precise information. [9]

III. SCHEMATIC DIAGRAM OF RESEARCH WORK

The system setup involves connecting ESP to the Wi-Fi network and initializing components such as pins of Raspberry PI with sensors, Relays and LEDs. Time synchronization is established using the `ntptime` library to ensure accurate timestamps for weather data. Weather data is fetched from the OpenWeatherMap API by defining the function `get_weather()` with specified parameters. The obtained JSON response is processed to extract relevant weather information. The data is displayed on an LCD screen, and serial data from the UART interface is read to process Realtime information from sensors. ThingSpeak integration is performed by sending a JSON payload to the ThingSpeak IoT platform using the provided write API key. The system operates in a continuous loop, refreshing data with 30-second intervals, allowing real-time monitoring and analysis for optimized smart irrigation practices.

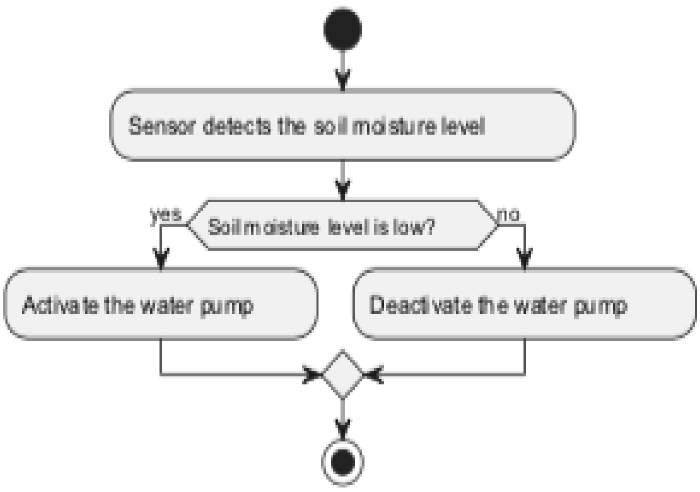

Fig 01 - Schematic Diagram of the System

Methodology: Making a smart irrigation system requires several input parameters. We have considered the humidity, temperature, weather and light sensor data to predict the moisture level of the irrigation system. If a moisture level crosses a certain threshold, the water pump is turned off and if the moisture level drops down the threshold, the water pump is turned on. To develop a model, we started with simple machine learning models such as Support Vector Regression, Decision Tree Regression and Random Forest Regression. The result was unsatisfactory as the non-linearity of the data affected the models. The moisture level ranged from 0 to 70 and it made a simple machine-learning model either to overfit or fail to predict correctly. This led to the introduction of deep learning, and we have used a simple deep learning-based model.

The chosen deep learning model was a simple 7-layer deep neural network whose architecture can be found in Fig-02 and Fig-03. Still, after training, the accuracy was less thus, we introduced scaling and scaled the data of humidity, temperature, weather and light sensor using a standard scaler. This boosted the accuracy of the model.

```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Linear-1                [-1, 1, 32]             128
            Linear-2               [-1, 1, 128]           4,224
            Linear-3               [-1, 1, 256]          33,024
            Linear-4               [-1, 1, 512]         131,584
            Linear-5              [-1, 1, 1024]         525,312
            Linear-6                 [-1, 1, 1]           1,025
================================================================
Total params: 695,297
Trainable params: 695,297
Non-trainable params: 0
```

Fig 02

```
Net(
  (fc1): Linear(in_features=3, out_features=32, bias=True)
  (fc2): Linear(in_features=32, out_features=128, bias=True)
  (fc4): Linear(in_features=128, out_features=256, bias=True)
  (fc5): Linear(in_features=256, out_features=512, bias=True)
  (fc6): Linear(in_features=512, out_features=1024, bias=True)
  (fc7): Linear(in_features=1024, out_features=1, bias=True)
)
```

Fig 03

IV. FLOW CHART

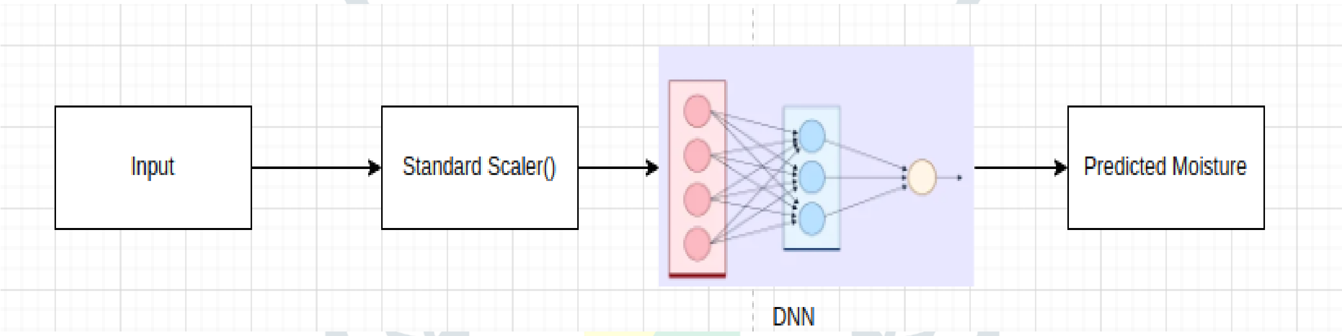

Fig 04

The above Fig - 04 is the flow chart of how our model is trained to predict the moisture value.

V. RESULTS AND DISCUSSION

During training, we have used a 7-layer deep neural network. We have used Adam Optimizer to optimize the parameters. The dataset has been divided in the ratio of 75 to 25 as a training and testing set and another 10% of the training set is used as a validation set to perform 10-fold cross validation. The model is trained on total of 100 Epoch and the loss function used is MSE loss while the metric to judge the training process is L1 loss. The test set validates the result by plotting the curve for prediction, as seen in Fig - 05. Figures 6 and 7 proposed the best loss function and number of hidden layers respectively.

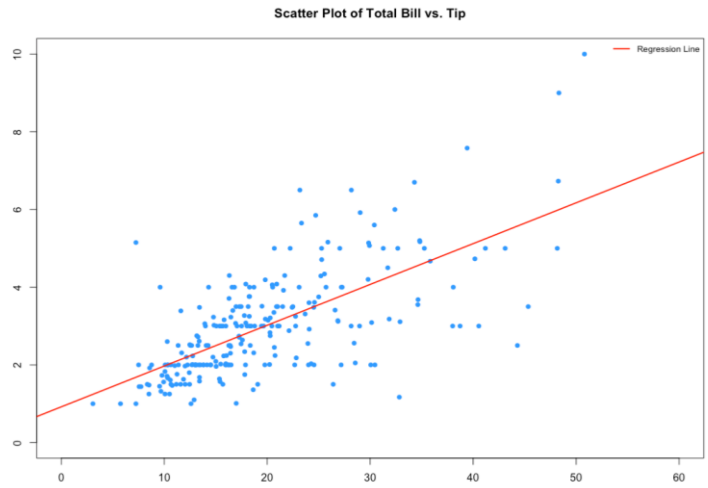

Fig 05

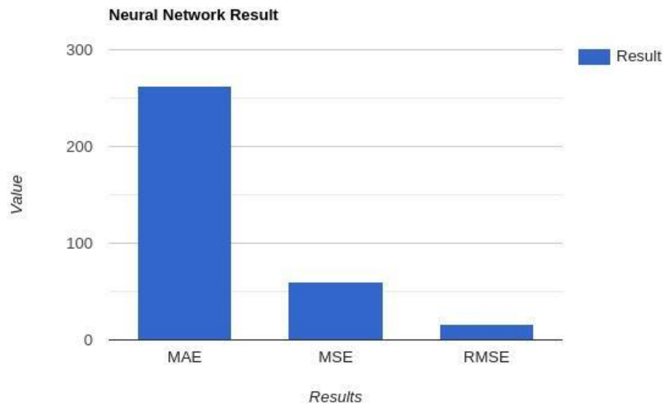

Fig 06

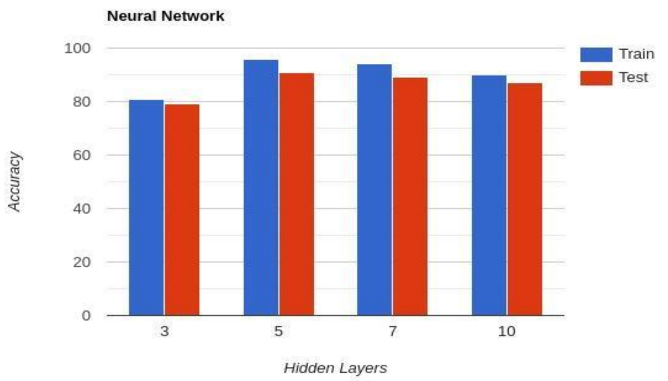

Fig 07

Our work outperforms the results of simple machine learning which can be seen in figures 8, 9 and 10 models which concludes that our approach is superior and can be used to perform the prediction of moistures.

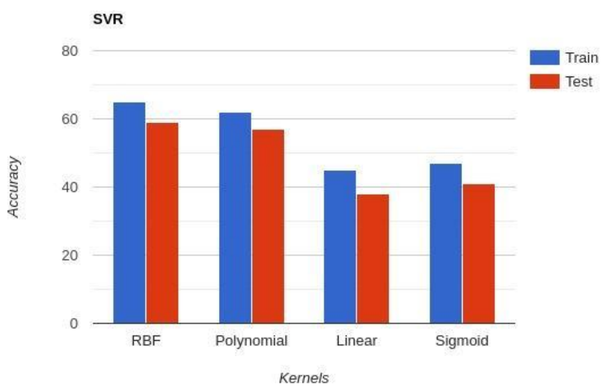

Fig 08

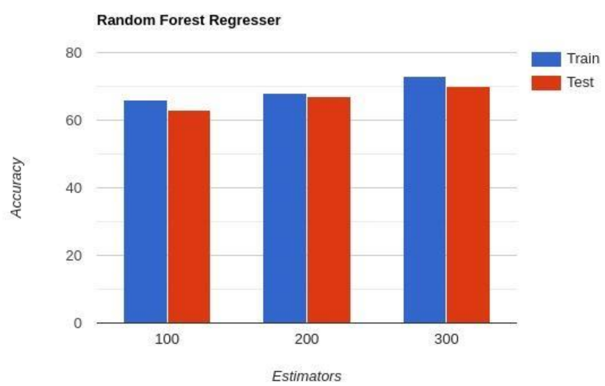

Fig 09

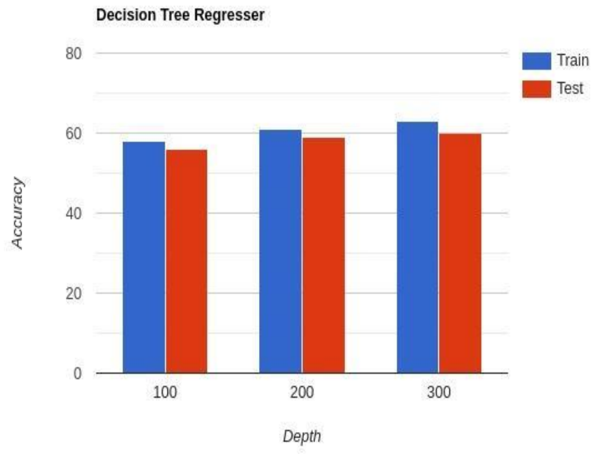

Fig 10

VI. THE OUTCOME OF THE PROPOSED SYSTEM

- Effective irrigation system that works on weather forecast using IOT.
- Cost effective Raspberry PI Pico and sensor-based irrigation system.
- Smart irrigation system comprising ML and IOT combination.
- Better crop yield and 15- 25% saving of water as compared to traditional irrigation methods.

Advantages:

- Optimized water usage.
- Promotes sustainable agriculture.
- Remote monitoring and control.
- Enhanced convenience.
- Reliable components
- A real time feedback control system
- Can be integrated with existing agricultural systems.
- Optimum expenditure
- Maximize crop yields.
- Protection of system from undesirable electrical activity
- Overall resource optimization.
- Reduced manual efforts

Applications:

- The system is useful for farmers and gardeners who do not have enough time to water their crops/plants.
- The project can be extended to greenhouses where GUI based supervision is possible.
- In agricultural lands with severe shortage of rainfall, this model can be successfully applied to achieve results with most types of soil.

VII. CONCLUSION

The developed System can be used in a variety of areas to optimizes the proper use of underground water and regulate the water supply based upon crop, nature of soil and weather conditions. This feature makes it very efficient. It is a technically advanced irrigation system which can use real-time data and forecast too. The Raspberry PI along with sensor and associated ML algorithm is capable of correlating real-time soil information with the OpenWeather API to irrigate the fields. The system is very advantageous as for small as well big farms, and for all types of crops.

VIII. REFERENCES

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