Semiconductor Optoelectronics, *Vol. 42 No. 1 (2023), 200-211*
https://bdtgd.cn/

Semiconductor Optoelectronics
ISSN: 1001-5868

DECISION SUPPORT SYSTEM BASED AUTOMATED IRRIGATION USING MACHINE LEARNING AND ADRIANO APPLICATIONS

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Abstract
The rise in water concerns and the need for proper methods of agricultural care are important issues that must be dealt with the utmost propriety. An intelligent agricultural irrigation system has been proposed in the current study, keeping these factors in mind. The current strategy is to design a decision-support system built on an embedded system integrated with machine learning. A LSTM model that learns from a crop recommendation dataset has been developed for precise decision-making in an irrigation management plan. On the other hand, an Adriano Uno-based embedded system has been designed for testing the decision made by the LSTM model. The results of the experiment reveal that the LSTM model has been trained with an accuracy of around 96.98% for decision-making with regard to irrigation.
Keyword: Smart irrigation, LSTM model, Adriano Uno, Decision support system.

1. Introduction

Significant progress has been made throughout human history to increase agricultural productivity with scarce resources and labor demand. However, despite all of these attempts, the large population rate prevented supply and demand from matching. According to projections, the total population of the globe is estimated to reach 9.8 billion in 2050, an increase of around 25 percentages from the current number. In addition to this, it is expected that the trend of urbanization will persist at an exponential rate, with over 70 percentage of the total world's population (now 49%) predicted to live in cities by 2050. This will definitely result in an increase in income levels many times higher than they are now, which will increase the need for food and the quality of that food, particularly in emerging nations.
Furthermore, crop cultivation is becoming equally important for industry as it is for nourishment. For all of these, a closer look needs to reveal each crop's unique qualities that may be assessed individually in terms of both quality and quantity. Soil type, nutritional content, irrigation flow, pest resistance, and other factors all contribute to a soil's suitability and capacity for a specific crop. Hence, farmers require innovative, technologically based strategies to produce better from less land and with fewer hands in order to meet these demands with a variety of challenges.
Nowadays, humans have reached the limit of normal cognitive abilities due to the development

of technology and are now attempting to combine the functions of a natural brain with those of an artificial one. The continually exploration of the same technology created a immaculate field called "artificial intelligence. With that, the term IoT refers to "thing to thing" communication. The three key goals of this technology are system cost reduction, automation, and connectivity. The collaboration of all three including embedded systems, artificial intelligence, and the agricultural industry can results to sort the various challenges of world for upcoming food quantity and quality needs. Farming with intelligence, crop managing with intelligence, irrigation with intelligence, and greenhouses with intelligence examples of embedded intelligence integrated with machine learning in the agriculture sector.

Previously various smart irrigation systems have been developed based on machine learning and IoT techniques for example, the author [1] has suggested an automated irrigation system using IoT technology. The author has used "machine-to-machine (M2M)" communication and enabled the devices, objects, and other items to link to each other and also send data to servers. The KNN (K-Nearest Neighbor) classification model was implemented in this work to analyze the data obtained through the sensors in order to forecast when to irrigate the soil with water. As a result, the author has built an intelligent IoT-based irrigation system that is fully automated and created using inexpensive embedded devices like the Raspberry Pi 3 and Arduino Uno. Similarly, the author of [2] has also developed an automated irrigation system. The author was motivated by the recent wave of developments in information and communication technology (ICT) and the utilization of Internet of Things technologies and developed the cutting-edge irrigation management system. For this author had firstly measured various metrological properties related to soil and weather like temperature, humidity, etc., and proposed an automated control features utilizing cutting-edge electrical technology and a microcontroller. These features let the pumping motor to turn on or off based on the value detecting for the earth's moisture content and a GSM phone line. The recent technological advancements must be used to efficiently manage water resources for agriculture and conserve existing ones as per [3]. For this, author has developed a model for multilevel farming around the urban areas with constrained cultivating space. For each level, the author provided a local node with a unique local DCS system, detector, and actuators that are tailored to the chosen crop. All such neighbourhood nodes utilize wireless communication to connect to a central node. The central node is actually linked to cloud server that stores and transfer the received data. The user can evaluate and monitor the irrigation system using cloud-based data analysis and monitoring. These experimental findings indicate lower water use and better energy efficiency.

An IoT- technology for irrigation system has also been porposed in [4] called a smart irrigation system. The irrigation system developed in this work has used open-source software to estimate a field's irrigation needs by monitoring various ground parameters such as moisture in the soil, temperature, and ambient variables, as well as data from online weather forecasts. A deep learning integrated IoT smart irrigation system has been developed in [5]. In this research, author has proposed a deep learning-based irrigation system that can recognize different plant types and adjust watering requirements for every type of plant accordingly. A crop monitoring system integrated with crop irrigation has been developed by the author [6]. The suggested approach intends to use automation along with IoT technology to make farming smart.. It has been suggested in this paper that a Raspberry Pi-based automatic irrigation IOT solution be used to modernize and increase crop output. The authors in [7] emphasize that the largest consumer of freshwater worldwide is irrigation for agriculture. They all need the support of technologies to optimize their water needs and reduce their energy consumption, resulting in enhanced crop quality. With the objective of improving smart management of water supply in the context of precision irrigation, the SWAMP project has been developed based on IoT technologies. The proposed application has been tested through pilots in Brazil, Spain, and Italy. The SWAMP view is presented in this study.

The author of [8] believes that employing the machine learning and the Internet of Things can be utilized to optimize irrigation water use. Based on the same IoT-driven smart irrigation system, the author of this work has suggested how to implement machine learning algorithms to anticipate the future soil moisture of a field in order to optimize water usage for irrigation purpose For forecasting the soil moisture, the data obtained from the farms through filed sensors, such as sensors for air temperature, sensors for air humidity sensors, sensors for soil moisture, sensors for soil temperature, and radiation sensors, as well as online weather forecast information, has been used. The effectiveness of various ML methods for forecasting future soil moisture is examined, and the GBRT results are quite promising. The suggested methods might be a key area of investigation for maximizing irrigation water use.

An advanced irrigation system based on IoT has been proposed by [9]. In order to fully utilize the Internet of Things' (IoT) potential for large-scale commercial operations, the proposed work has been suggested. The proposed framework provides a chance to develop machine learning methods by enabling a variety of customized analytical approaches for accurate irrigation. It is possible to foresee effects on many stakeholders, such as IoT specialists who will benefit from system use and farmers who would experience cost savings and safer agricultural yields. A minimal-cost smart irrigation system based on an IoT intelligent module has been proposed by [10]. As most Indians have been relying on agriculture for their livelihood and it also accounts for a significant portion of the Indian economy, water is the most valuable resource for India and it must be protected using advanced technology. For this IoT, techniques can be proposed that have even become essential to Industry 4.0 but have limited use in applications of smart farming. The author of this work has created an inexpensive, intelligent technology for smart irrigation. The technology has characteristics including admin mode for user engagement, one-time setup for irrigation schedule estimation, decision making system based on neural-network, remote data monitoring, etc. The results of the suggested system depict that it gives the necessary smartness to consider the input from the sensor at the time and conceal the irrigation schedule for effective irrigation. The system even from a distance, employing the MQTT and HTTP to keep the user updated on the state of the crop. The proposed system is advantageous due to its sophistication, affordability, and portability, making it appropriate for greenhouses, farms, etc. Further in [11], the author has proposed, as usual, machine learning and IoT for irrigation systems to work efficiently. The proposed solution in this work is developed on the Internet of Things (IoT), which is found to be a more affordable and accurate way to address the needs of the farm. For the objective of making easy management of the irrigation issues and also to be more effective, a monitoring system has been developed that focuses on resolving over-irrigation and soil erosion, along with crop-specific irrigation issues.

Typically, automatic plant irrigation systems take decisions upon their judgments of static models created from the traits of the plant; further, a model's training mechanism exposes the mathematical relation between the natural conditions used to determine the irrigation habit, and it gradually improves as more and more irrigation data is added to the model. Motivated by the same thing, the author of [12] employed 4 different machine learning models to assess the performance of the irrigation model and modified the gradient boosting regression trees (GBRT) technique for Internet of Things solution. Further to test the performance of whole system, the author has put a test bed for the cloud-based decision service, mobile client, and sensor edge. For enhanced irrigation on farms, the author [13] has developed an intelligent irrigation system. As IoT components and systems has been employed for agriculture and they can contribute to the modernization of information and communication in intelligent farming, based on the same, the author of this work has considered the factors that have been taken into account for optimal crop growth. These factors include the type of soil, moisture in the soil, minerals and nutrients presented, temperature, light, oxygen, etc. All such parameters can be sensed by a variety of sensors. The data obtained for all of the factors using the sensor has been sent to the cloud study, which takes into consideration these parameters for data analysis. The suggested approach worked more effectively and was put into use on the Thingspeak IoT cloud platform. A smart irrigation system using an Arduino and machine learning techniques has been proposed by [13]. In the present research, it has been proposed to utilize the Internet of Things and machine learning in order to address the various irrigation issues such as increased soil salinity, water contamination, etc. In this work, the hardware is made up of many sensors, which include the temperature sensor, a humidity sensor, a pH sensor, a pressure sensor controlled by an Arduino or Raspberry Pi module, and a bolt IOT module. The author claimed that farmers will use less field water as a result of the preset temperature sensor's ability to predict the local weather. The pH sensor can detect the pH of the soil on a regular basis and determine whether or not the soil requires additional water. The paper's main goals were to create an irrigation system automatically and save water for later use. An artificial intelligence-based smart irrigation system has been developed by [15]. The author has found that effective methods need to be proposed to monitor moisture levels, improve water use, and boost yields. He has discussed many cutting-edge methods for combining IoT and artificial intelligence in agricultural irrigation systems. This article presents the various parts of the modern irrigation system, many comparison metrics, and its requirements. At the end of this article, numerous problems, obstacles, and the future course of the research into the smart irrigation system were described. From the literature survey, it has been found that numerous smart irrigation systems have been developed previously. Most of the smart irrigation systems that have been reported previously are based on cutting-edge technologies such as IoT technology and machine learning techniques. However, a precise decision support system to judge the water requirement by the soil in fields as per the needs of the crop has not been proposed. Motivated by the same, author in the present research work has proposed a decision support system for regulating irrigation based on an intelligent system developed using machine learning and IoT-based platforms.

Either numerous smart irrigation systems has been developed previously but precise irrigation still a big challenge in agriculture. Motivated from the same, the present research work has been proposed to develop a smart or intelligent system for regulative irrigation based on machine learning and embedded systems. For the present work, the study has explored how artificial neural networks (ANN) might help in managing the irrigation system. For this, LSTM models have been developed. Further, a comparative decision will be made between ANN models' predictions for irrigation and a decision made by an embedded system composed of sensor units (temperature, humidity, and soil moisture sensors) and value units. It will result in an effective decision-support system for irrigation water management planning for water-sensitive crops. This decision support system will be a novel and effective approach to irrigation water management planning without involving human intervention.

The major contributions of the present research work are.

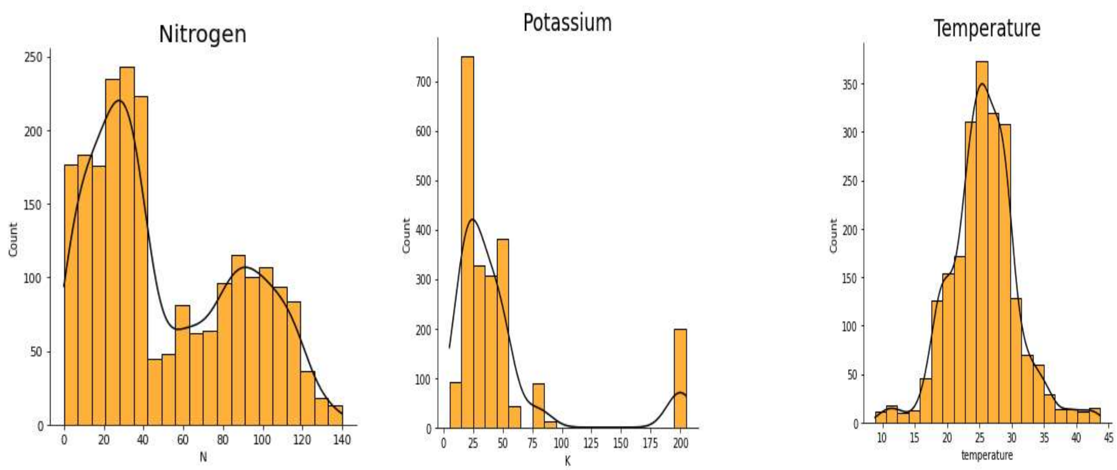
1. A best decision support system for water irrigation management based on embedded system integrated with machine learning has been developed.
2. A LSTM model has been developed from scratch for predicting trustworthy assessment of the water requirements of actively developing crop.
3. An embedded system based on Adriano uno has been proposed for decision making in water irrigation purposes.
4. To conduct a performance assessment of the proposed intelligent water irrigation system in terms of scarce availability of water resources and labour.

2. Material and methodology

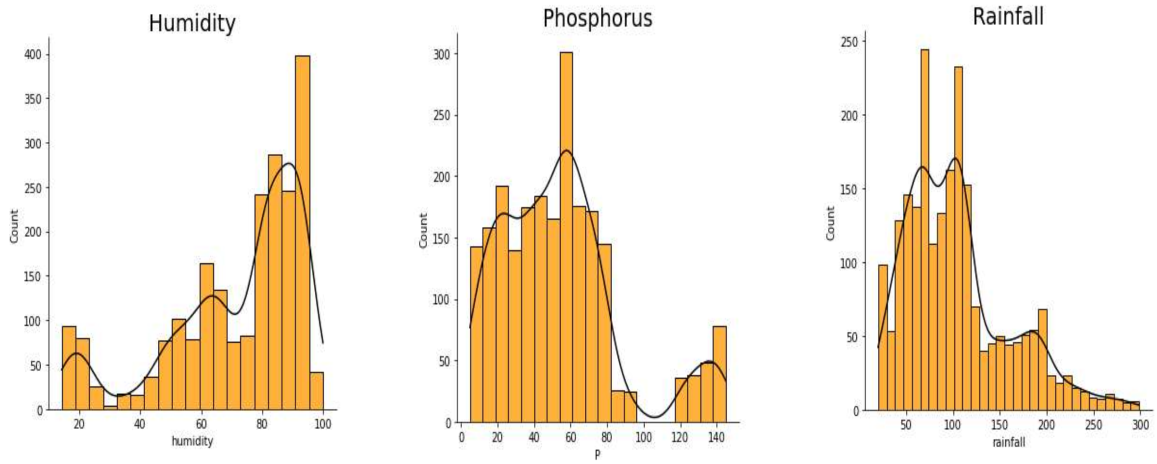
For the proposed research work the material and methodology used has been described in the following sections.

2.1 Dataset used

For the present research work, crop recommendation dataset has been used. The dataset has available publically. The attributes of the given dataset are nitrogen, potassium, phosphorus, humidity, PH level, rainfall, and temperature. The detailed visualization of each of these attributes is given below in the dataset.



(a) (b) (c)



(d) (e) (f)

Figure 1: Dataset visualization for (a) Nitrogen (b) Potassium (c) temperature (d) Humidity rainfall (e) Phosphorous (f) rainfall

2.2 Dataset Splitting into training and testing set

The neural network, as is well known, is a learning-based approach on a given dataset. Hence, for the efficient learning of the same, the given dataset needed to be split into two sets. The first set is a training set, and the second set is a testing set. A 2 split of dataset often involves testing or statistical analysis of the data in one part and training the algorithm in the other. Data splitting is a crucial component in data science, especially when building models from data. For the present research work, a 4:1 ratio has been employed for splitting the dataset into training and testing sets. That means 80% of total data entries have been employed in the training set for improving the learning of the model, and the remaining 20% of data entries have been employed in the testing set for evaluating the learning of the model.As a result, the training set consists of 1760 entries (row) for 8 different parameters from the dataset, while the testing set consists of the remaining 441 entries (row).

2.3 Proposed LSTM Model's

A LSTM model has been developed for the preset work. The model has composed of hidden layer and three denser layers. The complete model description in term of learning parameters and layers has been presented below figure 2

```
Model: "sequential"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
lstm (LSTM)                  (None, 50)                10400
_________________________________________________________________
dense (Dense)                (None, 26)                1326
_________________________________________________________________
dense_1 (Dense)              (None, 10)                270
_________________________________________________________________
dense_2 (Dense)              (None, 6)                 66
=================================================================
Total params: 12,062
Trainable params: 12,062
Non-trainable params: 0
_________________________________________________________________
```

Figure 2: Layer's description of LSTM model

2.4 Simulation parameters

The various parameters for proposed LSTM model simulation on given dataset has been given below.

Table 2: Simulation Parameters of the Model

Parameters	Value
Input Shape	8,1
Model	Sequential
Layers	50
First Dense Layers	10
Second Dense Layers	6
Activation Function for First Dense Layer	Relu
Activation Function for Second Dense Layer	Softmax
Loss Function	Sparse categorical crossentropy
Optimizer	Adam
Metrics	Accuracy
Epochs	10

2.5 Proposed embedded system

Here, an Arduino UNO is being used as the controller. A microcomputer board called the UNO is founded on the ATMEGA 328P. For saving code, the ATMEGA 328P contains 32kB of flash storage. The board features a USB port, an ICSP circuit, 14 digital input and output pins, 6 analogue inputs, a quartz crystal operating at 16 MHz, and a reset button. The Arduino software allows the programming of the UNO.
The components details of the proposed embedded system are given below.

2.5.1 Soil moisture sensor

The moisture content of the soil is measured using a soil-moisture sensor. Low level (0V) will be the content is delivered when the moisture in the soil value detected by the sensors exceeds the predefined threshold, and high level (5V) will represent the content is delivered when it falls below the threshold value. The current soil moisture measurement is immediately read from the digital pin to determine whether it is above the threshold or not. With the use of a potentiometer, the threshold voltage can be controlled.

2.5.2 Sensor DHT11

The DHT11 sensor is used to measure temperature and humidity. It measures the ambient air using a thermistor and a capacitance humidity sensor. This sensor is reasonably priced, uses little power, and allows for signal transmission up to 20 metres.
The proposed embedded system is shown in figure 3 given below

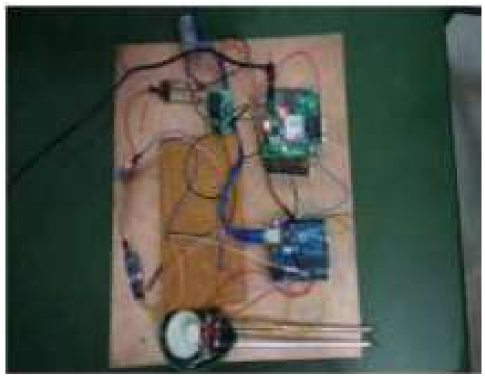


Figure 3: Proposed Embedded system

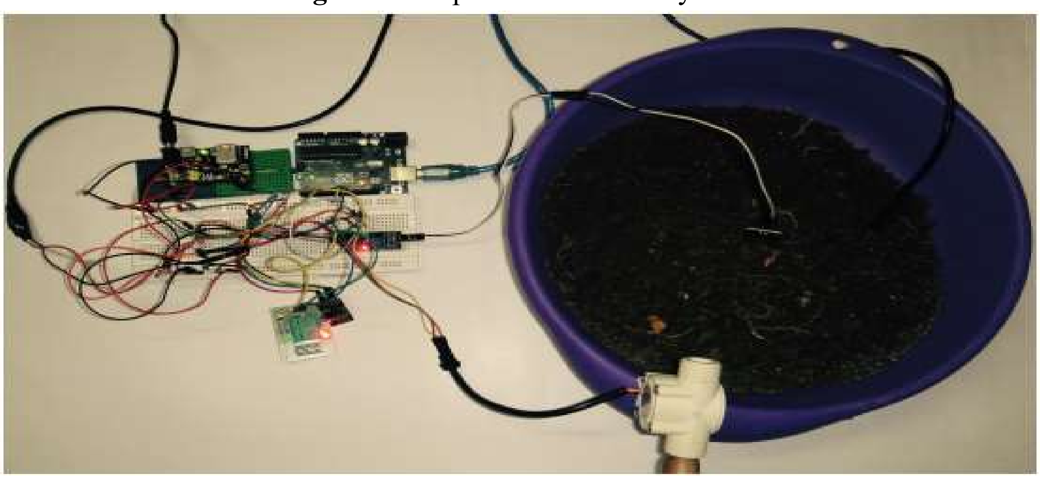


Figure 4: Proposed embedded system in field

3. Decision support system

Using the proposed LSTM model and embedded system, a decision support system has been developed. The flow chart for the decision support system has been shown in figure 5.

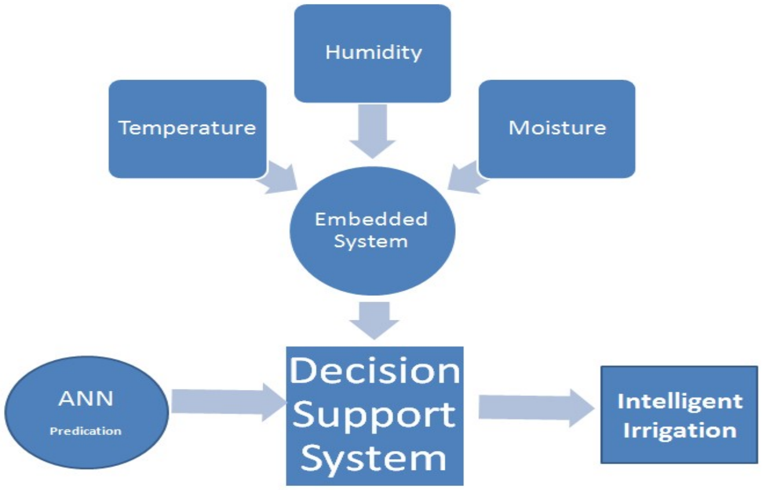


Figure 5: Decision support system

The proposed model of a decision support system gives an irrigation water management planning model based on LSTM whose decision has been compared with a prototype embedded system composed of sensor units (temperature, humidity, and soil moisture sensors) and value units for effective decision-making regarding irrigation.

4. Results analysis

In this section detailed analysis of results obtained has been discussed.

4.1 Results of Training and Testing Accuracy

As discussed the proposed model has been trained using 1760 entries (row) for 441 different parameters from the dataset, while the testing using consists of the remaining 441 entries (row). After running the model for 10 epochs the results of training and testing accuracy has been presented below in figure 6

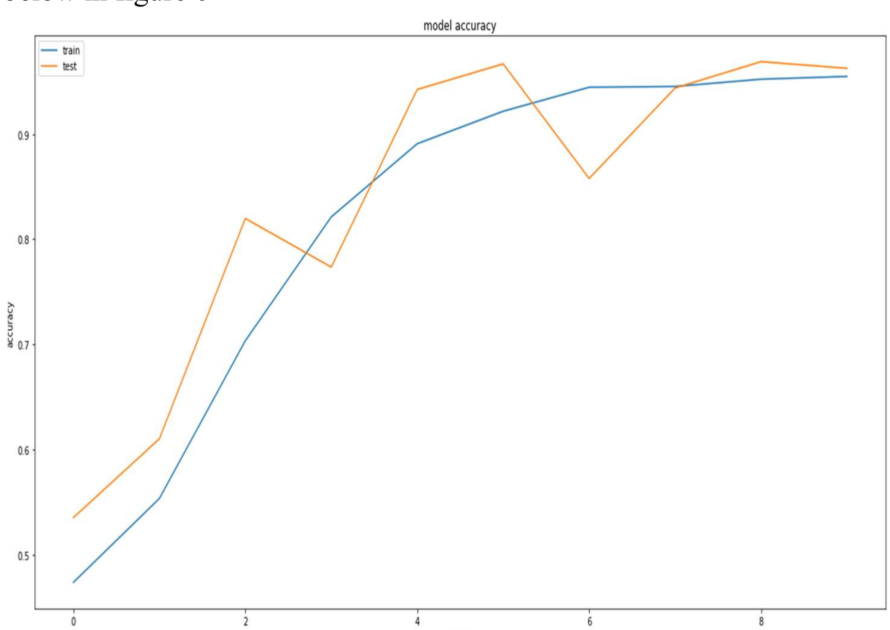


Figure 6: Training and testing accuracy graph of proposed LSTM model

As per the graph, the proposed LSTM model has achieved a training accuracy of up to 97.58% and a testing accuracy of 96.98% at 10 epochs.

Other than this the training loss and testing loss for the presented LSTM model has been shown in figure 7.

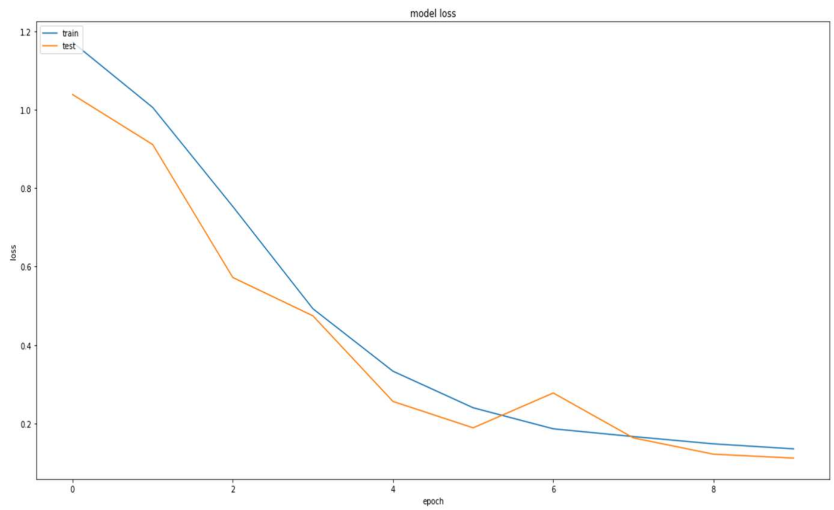


Figure 7: Training and testing loss graph of proposed LSTM model

As per the graph, the proposed LSTM's training and testing losses have been reduced as each epoch has been increased. As per the observation, at epoch 1, the total training and testing loss was 1.0187 and 0.9764, which has been reduced to 0.0645 and 0.0746 at the tenth epoch. Hence the proposed model has been successfully trained used the proposed dataset.

5. Conclusion

Using information from a current network of smart irrigation, LSTM models are utilized as a spot interpolation tool for water requirement predication for the crops. The approach is used with 7 metrological parameters. All such 7 parameters under study are N = Nitrogen P = phosphorous K = Potassium Temperature=The average soil temperatures for bioactivity range from 50 to 75F. Ph = A scale used to identify acidity or basicity nature; (Acid Nature- Ph<7; Neutral- Ph=7; Base Nature-P>7). The results show that the LSTM models show the effective performance. On the other hand, embedded system has also been designed with various sensors such as temperature, humidity and moisture along with Adriano uno microcontroller. When decision had been made through comparative prediction of proposed ANN and embedded system the results of ANN is found to be more effective.

References

1. Edordu, C. and Sacks, L., 2006, September. Self organising wireless sensor networks as a land management tool in developing countries: A preliminary survey. In *Proceedings of the London Communications Symposium (LCS 2006), London*.

2. Kim, Y., Evans, R.G. and Iversen, W.M., 2008. Remote sensing and control of an irrigation system using a distributed wireless sensor network. *IEEE transactions on instrumentation and measurement*, *57*(7), pp.1379-1387.

3. Gutiérrez, J., Villa-Medina, J.F., Nieto-Garibay, A. and Porta-Gándara, M.Á., 2013. Automated irrigation system using a wireless sensor network and GPRS module. *IEEE transactions on instrumentation and measurement*, *63*(1), pp.166-176.

4. Raura, G., Fonseca C, E.R. and Yoo, S.G., 2019, December. Smart Battery Charge: A Fiware Open Source Platform and Microcontroller Based IOT Application. In *International Conference on Applied Technologies* (pp. 270-281). Springer, Cham.

5. Roffia, L., Azzoni, P., Aguzzi, C., Viola, F., Antoniazzi, F. and Salmon Cinotti, T., 2018. Dynamic linked data: A SPARQL event processing architecture. *Future Internet*, *10*(4), p.36.

6. Alliance, L., 2017. LoRaWAN 1.1 Specification. *LoRa Alliance*, *11*, pp.2018-04.

7. Muangprathub, J., Boonnam, N., Kajornkasirat, S., Lekbangpong, N., Wanichsombat, A. and Nillaor, P., 2019. IoT and agriculture data analysis for smart farm. *Computers and electronics in agriculture*, *156*, pp.467-474.

8. Prabha, R., Sinitambirivoutin, E., Passelaigue, F. and Ramesh, M.V., 2018, March. Design and development of an IoT based smart irrigation and fertilization system for chilli farming. In *2018 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET)* (pp. 1-7). IEEE.

9. Pierce, F.J. and Elliott, T.V., 2008. Regional and on-farm wireless sensor networks for agricultural systems in Eastern Washington. *Computers and electronics in agriculture*, *61*(1), pp.32-43.

10. Njoroge, B.M., Fei, T.K. and Thiruchelvam, V., 2018. A research review of precision farming techniques and technology. *J. Appl. Technol. Innov*, *2*(9).

11. Maton, L., Leenhardt, D., Goulard, M. and Bergez, J.E., 2005. Assessing the irrigation strategies over a wide geographical area from structural data about farming systems. *Agricultural systems*, *86*(3), pp.293-311.

12. Shekhar, Y., Dagur, E., Mishra, S. and Sankaranarayanan, S., 2017. Intelligent IoT based automated irrigation system. *International Journal of Applied Engineering Research*, *12*(18), pp.7306-7320.

13. Rajkumar, M.N., Abinaya, S. and Kumar, V.V., 2017, March. Intelligent irrigation system—An IOT based approach. In *2017 International Conference on Innovations in Green Energy and Healthcare Technologies (IGEHT)* (pp. 1-5). IEEE.

14. Salvi, S., Jain, S.F., Sanjay, H.A., Harshita, T.K., Farhana, M., Jain, N. and Suhas, M.V., 2017, February. Cloud based data analysis and monitoring of smart multi-level irrigation system using IoT. In *2017 International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud)(I-SMAC)* (pp. 752-757). IEEE.

15. Goap, A., Sharma, D., Shukla, A.K. and Krishna, C.R., 2018. An IoT based smart irrigation management system using Machine learning and open source technologies. *Computers and electronics in agriculture*, *155*, pp.41-49.