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Automatic Irrigation Using Artificial Intelligence

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Abstract
Agriculture automation is the main concern and emerging subject for every country. Many of the traditional AI models have been developed. However not a single solution has made its way onto a common farmers land, be it due to high costs or low efficiency. A complete system design for an Automatic Irrigation and Fertilizer Assistance system (i.e. AIFA system) is proposed, but rather than the system design the focus is how the AI brain of the AIFA system is to be designed and developed. The probability of crop failures is projected to be as much as 4.5 times higher by 2030 and up to 25 times higher by 2050. This number can be minimized by use of modern AI technology.

Keywords—Yield prediction · Smart farming · Precision agriculture · Smart irrigation · IoT · Temperature monitoring · Soil moisture · Crop · Artificial intelligence

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I. INTRODUCTION

India is mainly agrarian. Agriculture, or farming in specific, while has made a lot of progress in terms of technology, the majority of activities are still very labor intensive. Many innovations are being done in this field, most are out of the reach of an average farmer. Hence, the main aim of Automatic Irrigation and Fertilizer Assist System (AIFA) is to improve the lives of farmers, while improving the crop yields by making realistic use of technology that a small famer actually wants and can afford. Preventing crop failures is the top most priority. A major part of preventing crop failures is constant monitoring and caring for the crops, so the AIFA system will constantly monitor the crops through sensors and Artificial intelligence algorithm. To make most of the water available is the next important target rather than developing new ways of irrigation; the biggest challenge in this is that the AIFA system should be compatible to the current irrigation systems that the farmers use.

In the past few decades, a lot of development has been made in the field of agricultural automation. Kirtan Jha et al. 2018[1] gave a comprehensive review of intelligent irrigation systems that utilizes Artificial Intelligence and Machine learning concepts. Savita Chaudhary et al. 2019[2] established an autonomous irrigation system that uses machine learning and predictive algorithms to add intelligence, which can study rainfall patterns in the region and forecast weather conditions in order to adopt rainfall in the region to upgrade the existing concept of automatic drip irrigation system. Deepak Sinwar et al. 2019 [3] presented different techniques and applications of Artificial Intelligence for yield prediction and smart irrigation. Sunil Kumar et al. 2019 [4] talk about intelligent IOT based smart irrigation devices and the process of their development. Pravina B. Chikankar et al. 201 [5] discussed automation in the field of agriculture using ZigBee wireless technology.

Many AI based solutions are being investigated for automating agriculture, but very few of them manage to find a way into regular farmer's fields, which is mainly because of the lack of Proper microclimate data that is required to train AI models. In addition, developing a low-cost approach that is specifically designed for Indian farmers, the crops they grow and the Indian climate we have in India is also very important.

An autonomous irrigation system that is unaffected by communication failure or delay is the ideal solution for farming automation. Microcontrollers, which are small computers that operate in farm fields, are used to accomplish this. In this project, several microcontrollers were considered and findings suggest that these tiny computers satisfy the standards for an irrigation system and that they might be used to assess other smarter AI-based systems utilized in large-scale farming. Furthermore, for the benefit of farmers, accurate predictions of irrigation requirements and crop yields are necessary. The foresight contributes greatly to lowering production costs and increasing agricultural yields per unit area. Precision agricultural techniques based on artificial intelligence can notably increase yield. A system based on artificial intelligence delivers sufficient information on crop yields at an early stage, and its linked smart irrigation management system is efficient in the use of important resources such as water and energy in agriculture.

1.1 The major Goals of AIFA system are:

- Help farmers grow more and better crops with reduced per unit of input.
- Completely Automate Irrigation and Fertigation.
- Provide early detection of crop diseases and Provide to point exact suggestions to farmers about the disease and pest control.
- Provide To-point exact suggestions to farmers about fertilizer requirements.

1.2 Accomplishment of major goals will allow for the following outcomes:

- Customized solutions of sensors that record a variety of growth conditions on the farm optimizing the inputs as per crop demand.
- Climate-smart precision production farming options for realizing higher yield and quality with reduced cost of inputs.
- Optimizing farmer's daily tasks by automating processes.
- Getting real-time alerts about crop conditions to make adjustments to reach optimal growth conditions.

II. SYSTEM DESIGN THEORY

The proposed automatic irrigation system is made up of multiple data collection nodes, data processing nodes, decision-making nodes i.e. the brain node, and implementation nodes. In traditional systems, these multiple nodes would be connected to each other using wires or through internet. While physical wiring is a cheap, efficient and reliable option it is hard to maintain because of unpredictable movements of people and animals on a farm. Utilization of the internet presents another set of problems such as added cost of running servers, unavailability of the internet in certain regions and most importantly the cost of the internet itself. So AIFA system is designed to completely work on a wireless LAN or a wireless intranet type of network. While having a stable internet connection would add more functionality but all the necessary functions work with or without the presence of the internet.

In addition, to cope with the shortage of water, there is a critical need for some smart irrigation systems that can irrigate more areas with low consumption of water. A comprehensive review of various techniques of smart irrigation was done. However, there is an availability of various low water consumption-based irrigation techniques, for example, sprinkler systems and drip irrigation systems; but these systems need human intervention up to a great extent. There is a scope to add features to existing systems to develop smart irrigation systems. The system continuously monitors the level of water in a crop, compares the water content available in soil and crop plant with the standard need of water, it then starts automatically.

For smart irrigation, there is a requirement of the gathering of information about the level of moisture present in the soil, the water content in plants, humidity in the atmosphere, temperature, etc. This information can be gathered using soil moisture sensors, temperature sensors, humidity monitoring sensors, etc. These sensors are connected to low price ESP32-based systems for storage of gathered information and executing analysis algorithms for predicting the water requirement of the crop at a particular time.
With the help of an array of sensors like temperature, humidity, soil moisture mounted on a rover, or installed at various spots in the farm, real-time data collection nodes can be designed, these will provide microclimate information, which is useful for making irrigation decisions.

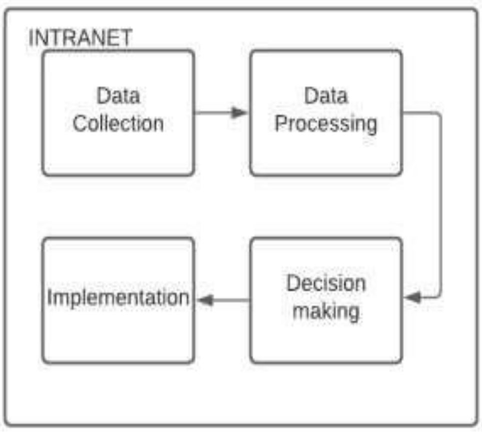


Fig.1: Basic block diagram of AIFA system

Traditional methods of monitoring crop health are time-consuming and inefficient especially for larger areas of thousands of acres. Many have developed AI based architectures to overcome the challenges identified in the arena of traditional agriculture, with the help of simple cameras mounted on rovers, the disease can be caught in plants during very early stages with the help of CNN models. CNN's extract useful features from fed images and make predictions about the disease(s) in crops. The system is effective in continuous monitoring of the health of plants and hence gives better solutions for calculating the amount of pesticides to be used and time to use a pesticide.

III. THE BRAIN

To design and develop the brain of the AIFA system is the most difficult and tedious task. The efficiency of the AI Brain will directly determine whether a farmer in his field can utilize the AIFA system. The brain of the AIFA system is what differentiates it from everything else available in terms of how it will be able to achieve its goals. The brain should be ably capable of automatically adjusting to unpredictable harsher climatic conditions in an appropriate way. The main design methodology behind the brain was similar to any other supervised learning problem. Firstly, to collect a proper dataset that the brain can learn from, and then train the brain to mimic the learnings in a meaningful and intelligent way.

3.1 DATA COLLECTION

Data collection is an important step when talking about providing automation in the field of agriculture. The data will not only be needed during the project and development period but real-time data of microclimatic conditions will be needed in the final system too, which will be deployed on real fields. Therefore, a need for a proper dataset is there. Data collection for the dataset comes with its own set of challenges that needed to be overcome such as, collect too much data and all the operations performed on the dataset will become space and time expensive. On the other hand if you collect too little data then the dataset will not provide an accurate picture of real-world conditions. A balance was needed which is further discussed in the data processing and modelling section.

To solve the data collection problem, custom data loggers can be designed and developed, that collect data of different scenarios and test environments. One set of data loggers collect data such as soil moisture, temperature, the humidity of uncontrolled farmland environment, which can be defined as a patch of land that is totally at the mercy of the environment for the growth of crops. Another set of data loggers are also deployed that collect the same data points for a highly controlled and maintained farmland in which all the parameters are manually maintained very specifically according to the already very well projected microclimatic conditions required for the growth of a specific crop. A note is taken for the number of resources that were spent to convert the said uncontrolled farmland to controlled farmland.

With this approach for data collection, a baseline of the climate can be established from the unsuitable uncontrolled environment, then collect what kind of resources are needed to be spent to convert an unsuitable uncontrolled environment to a suitably controlled environment.

This approach can be considered similar to how a young farmer learns how to grow crops by observing his more experienced father. With this approach, a very large dataset can be developed. The data set can be used for automation of crop growth for a wide variety of crops that can keep improving with an increase in experience. Once growth cycle data is collected properly, the brain can then maintain the desired climate parameters throughout the growth cycle automatically.

3.2 DATA MODELLING

For effective modelling of the data, firstly there was a need for standardization of change of the value of microclimatic factors. There was a need for defining delta quantities such as what is considered as a singular unit of soil moisture change at a specific temperature.

The most important delta value was soil moisture change, as the whole idea of automatic irrigation is changing the soil moisture to the desired value from an undesired value automatically. 1 unit of soil moisture is defined as increment when 1 liter of water is added to a 2 cubic foot (1 L * 1 B * 2 H) of soil. And similarly defined 1 unit of soil moisture decrement. However, it was noted that the amount of water required was dependent on the type of soil, its absorption capabilities and the temperature of the day. Delta values for different soil based on the crop can be easily obtained, but the temperature of the environment was a variable factor to be considered.

A dry value (0 % hydration) of moisture is defined as when the soil gave the reading that is equal to when the sensor was in dry air. In addition, a wet value (100 % hydration) is defined as when the soil gave the reading equal to when the sensor was placed in a vessel of water. All the sensor data was mapped between the dry value and the wet value.

1 unit of Irrigation is defined as that is the amount of water required in 1 unit of a time period to cause 1 unit of soil moisture increment at a particular temperature and humidity. The final system is to just to think in terms of how many units of irrigation are to be done to the farmland, based on all the climate data.
For example, consider a simple data set, which was collected from 2 cubic feet of soil, assume the temperature and humidity to be unit constants:

Dry Soil	Wet Soil	ΔS	Time required	Water Required
0	1	1	1 Sec	1 L

In this case, 1 unit of Irrigation is required to convert a dry patch of land to a wet patch of land.
Therefore, from this, 1 unit of irrigation is said to be done that means addition of 1 Liter of water 1 in Second to 2 cubic feet of land.
The sensor data obtained can be grouped into 1 irrigation cycle which is defined as the total irrigation activity done during a time period.
The irrigation cycle can then be grouped into a single growth cycle which would represent how a crop should be grown in that climate data. This growth cycle data is essentially what needs to be mimicked efficiently by the brain.

3.3. THE INTELLIGENCE

Thus from these definitions, the collected sensor data can be fed to a modified neural network algorithm. In the initial prototype testing, the data was taken from a fixed soil type and the data was meant to represent how the brain should grow a fixed crop in the local climate. It slowly learned to mimic the same growth cycle, which was performed manually.

Even with the limited data collected, the brain was able to maintain soil moisture values reliably in different climatic conditions consistently. The most desirable feature of the brain is that it can smartly react to unpredictable harsher climatic conditions in a very calculative manner. For example for a summer crop, if the sun is particularly very harsh for a few days, the temperature will rise considerably, but as the system is equipped to deal with this kind of problem it can adjust its irrigation units required properly

IV. RESULTS

Many data loggers were prepared and lot of data was collected a lot of baseline data of soil. Data for soil that had no crops planted on it was collected just to get an idea of how the soil interacts with the environment. The data was collected for several weeks. Data points or features like temperature, soil moisture, and light levels were collected. Multiple sensors of same type were placed to assure data integrity.

The sensors were placed in the evening and allowed to collect the data until next day. Water was added after mid-day. The soil was potted and had no crops planted on it. So, the water will majorly be lost due to the heat of the sun in form of evaporation.

4.1 Moisture vs. Time of day

Collection of soil moisture data was one of the primary goal of the data collection. All the soil moisture sensors were redundant to ensure correct data was collected. While there was some deviation from the data collected from same spots across different sensors which can be seen on the graph below the data seems to follow the same trend. This soil moisture data was collected from potted soil with no crop present. This was done to observe the trends in change in soil moisture when interacting with the climate throughout the day.

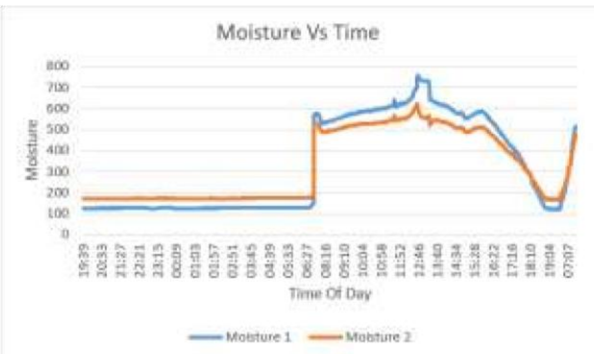


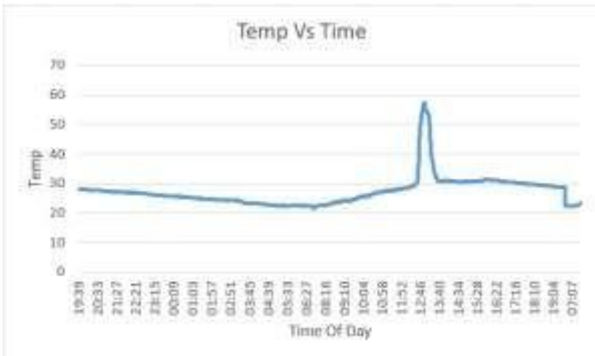
Fig. 2: Moisture vs. time

Fig 2 gives us data about soil moisture throughout the day, the moisture values are inverted i.e. higher value denotes a lower moisture value and vice versa. From this, easy identification the driest parts of the day and then can decide if irrigation is necessary or not.

Soil moisture is the primary feature. This is the feature that is most important to maintain to ensure proper growth of the crops. Just doing irrigation to an arbitrary value of soil moisture works, but if proper optimization and standardization can be done them the resources spent can be greatly reduced. Proper optimization will result in standardization of crop quality as well as quantity.

4.2 Temperature vs. Time of Day

From the data of Fig.3, the hottest and the coolest period of the day can be easily derived; this information when combined with soil moisture value during that time, a relation between soil moisture and temperature can be derived very easily. It was observed that if water was added during hotter parts of the day less water was absorbed due to higher amount of water lost to evaporation due to heat as compared to when irrigation was done during the colder part of the day.



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This is an important feature to be considered because water lost to evaporation is not just wastage of water which itself is a very valuable resource in farming. But, this also has negative impact on the growth of the crops because if more water is lost to evaporation then the amount of water absorbed by the soil will be less than intended which would directly result into degradation of not just quality of the crops but in terms of quantity too.

Temperature is one of the more weighted features other than soil moisture as it has a direct effect on the crops. Performing smart irrigation with temperature in mind has a potential to save a lot of wasted water which would otherwise be lost to evaporation. Other than preventing wastage of water in form of evaporation, temperature also directly affects the crop itself, too much heat then the crop burns; too much cold the crop freezes. While control of temperature in larger open fields might be out of the scope of this project. For smaller greenhouses this is possible.

By associating soil moisture with the microclimate data such as temperature the intelligence is greatly increased. The system can look at weather forecasts and help prepare not only the crops for the future but can also alert the farmers.

4.3 Light Level vs. Time of Day

Fig 4 is a representation of light levels throughout the day. From this data, the sunrise, the sunset, and midday can be identified. This also verifies that midday, the brightest part of the day is also the hottest part of the day; this data point was recorded to validate temperature values.

Light levels though not an important feature directly but the temperature of the day greatly depends on it. Since it cannot be realistically controlled this data was only collected to cross verify the temperature data.

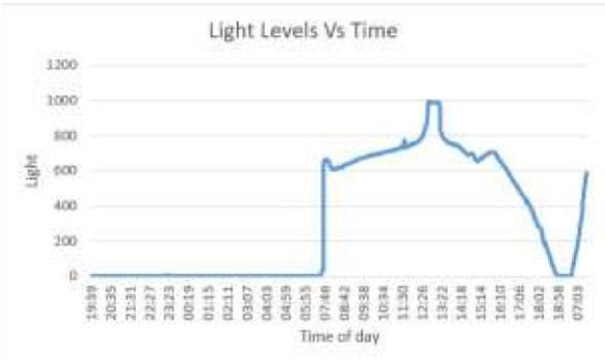

Fig.4 Light vs. Time of day

4.4 All features vs. Time of Day

Fig.5 all features vs. Time of day

Figure 5, shows all the features recorded (Soil moisture, temperature, light level) vs. Time of day. Each value is normalized between 0 to 1, maximum values and minimum values were considered feature wise.

This graph is the visual representation of how all the parameters are not individual entities that can be taken separately but are closely related to each other, change in one automatically translates into a change in another. This kind of data will not only also allow the neural network brain to understand the natural relation between these features and then in turn learn how to regulate them efficiently.

It can be very clearly observed that at the start of data points after sunset on day 1, the temperature drops linearly as the night gets colder; starts to increase linearly with the sunset; then there is a sharp spike during midday, which is then followed by a sharp drop of temperature. After this, the temperature is more or less stable until sunset of day 2 when it would start decreasing linearly again. The temperature feature is closely also followed by the light levels, until sunrise, the value of light is near to zero, after sunrise, it is more or less maintained till midday then it slowly reduces till next sunset. The soil moisture follows the same trends; the sensor reports low value i.e. the soil is hydrated until sunrise. After which the sensor value is increasing linearly implying that the soil is drying up due to the heat of the sun. The soil continues to dry until midday after which water was added to the soil. Then it starts to slowly report lower and lower sensor data implying more moisture being present in the soil. This chart (Fig 5) is a clear visual representation of the kind of data that needs to be collected for the dataset. All this data is baseline values i.e. no crop was planted on the soil, separate data needs to be collected for soil samples with crops that should be manually maintained, then after which the data can be modelled as discussed earlier.

V.CONCLUSION

Smart Irrigation based on artificial intelligence is the future of automation in field of farming. A system to monitor moisture levels in the soil was designed. The system would take into account microclimate data and is designed to act intelligently. Developing this project provided an opportunity to study the existing system and their drawbacks. Which was aimed to overcome. The proposed system is designed to be cost effective as well as intelligent can be used to grow crops autonomously. This automates the irrigation process which is one of the most time consuming and tedious activities in farming. Since Agriculture is one of the most water-consuming activities reduction in wastage of water can have huge impact. The system not only uses information from soil moisture sensors to irrigate soil but also takes into account multiple other factors which are often overlooked in other solution. This in turn helps to provide a higher degree of automation. Higher degree of automation can also avoid crop failure which is one of the biggest fears of a common farmer according to surveys.

The farm owner can monitor his whole crop continuously through his smartphone without the need of internet access. This feature not only allows proper manual supervision but also allows automated crop monitoring. It may be concluded from the results that the application of IOT and automation in farming can lead to significant improvement. As an outcome, the technology could be a potential solution to the challenges associated with the current manual and inefficient farming method by allowing for more efficient use of natural resources & labor.

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