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Harnessing ICT in Concrete Curing

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Abstract:
Majority of people travel on roads, bridges, and highways daily without ever giving a thought to the safety and reliability of these structures. Despite these shortcomings, the country has a large amount of old and deteriorating transport and other infrastructure that needs to be repaired, and much of it is outdated. For this reason, curing is one of the most important steps in the concrete construction process as it allows the structure to evaluate the strength of the cement mixture and contribute in some way as well as to achieve the desired strength. The moisture, temperature, and humidity levels of the surrounding area will be monitored by the system and accordingly, the system will alert you when the moisture level in the area decreases and pump water when necessary. By utilizing machine learning techniques, this system has been able to determine whether the concrete has reached the specified strength level. It leverages machine learning to accurately measure the strength of the concrete, ensuring the highest quality results.

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I. INTRODUCTION

Concrete hardens through curing under conditions of humidity and temperature, which cause cement components to set. The curing process reduces shrinkage and cracking in concrete and increases its strength. The curing time may vary from days to months that depend on type & age of concrete. This process takes several days and is essential to concrete strength. Curing also helps to reduce cracking and other surface defects. It also increases concrete durability and water resistance. Using an automatic curing mechanism, a smart concrete curing system supplies water to concrete mixture for curing purpose. This system is affected by moisture and temperature present in surrounding. There are two types of curing one is traditional ways and other one is smart curing process. In the traditional curing process, a lot of water is wasted because water is not measured during the procedure and controlled. The traditional curing method is less efficient because it does not measure how much water is used, leading to more water waste than necessary. Moreover, manual checking is more time-consuming and can lead to curing inconsistencies. Smart way: accurate data on temperature and humidity is recorded, which will allow us to achieve the required strength. Also solves water management issues. Accurate data on temperature and humidity can help us better monitor and control the curing process of cement-based materials so that the necessary strength can be achieved. This also helps us to optimize water management, reducing water waste and ensuring that the right amount of water is used for the mix.

II. LITERATURE REVIEW

A study conducted by Shima Taheri[1] graded sensors that are used for administering the structures in the construction industry. This focuses on tracking parameters to ensure they are in order. The study found that sensors can be used to detect problems with a structure before they become serious, providing an excellent early warning system. This can result in cost savings for construction companies, as well as safety improvements for the workers and the general public.

A model-embedded sensor system designed, constructed, and tested by Juan Antonio[2] for monitoring concrete curing was developed and evaluated. It has been tested in the laboratory and on civil works. The results showed that the system could accurately measure the temperature and humidity of the concrete curing process. The sensor system was also accurate and reliable for long-term monitoring. This system provides a cost-effective solution for monitoring concrete curing.

A study and report by Neeraj K.P[3] observed the conception of an automatic curing system that would monitor the moisture & temperature inside the concrete block. This would extend its lifespan and ensure concrete cures properly. The system is an innovative approach to extending the lifespan of concrete blocks as it provides an accurate and reliable way to monitor moisture and temperature levels.

J.Yang[4] exhibited that concrete could reach high strengths under rigidly regulated humidity and temperature. They emphasized the limitations of traditional curing, implying that it is difficult to ensure consistent and predictable curing intervals. This is because of the issue of ensuring consistent curing intervals, and hence this reduces concrete quality. Through their research, they found that curing the concrete with computer-assisted system produces an efficient and stable curing environment which leads to improved concrete quality and strength. This is because the computer-controlled system maintains constant and consistent relative humidity and temperature, which is essential; for proper curing. This will also reduce cracking, making concrete more durable

According to Nrutya N. Gandhi [5], a smart irrigation system provides water automatically in accordance with plant requirements. To maintain an optimum water content level, the threshold value can be set to reduce water consumption. This is beneficial as it eliminates the need for manual watering, and as well ensures that only the necessary amount of water is used. This can help conserve water resources. Additionally, it can also reduce the amount of labour needed to maintain the irrigation system. This technique also helps conserve valuable resources and preserve the environment by preventing pollutants from entering water sources.

III. SYSTEM ARCHITECTURE

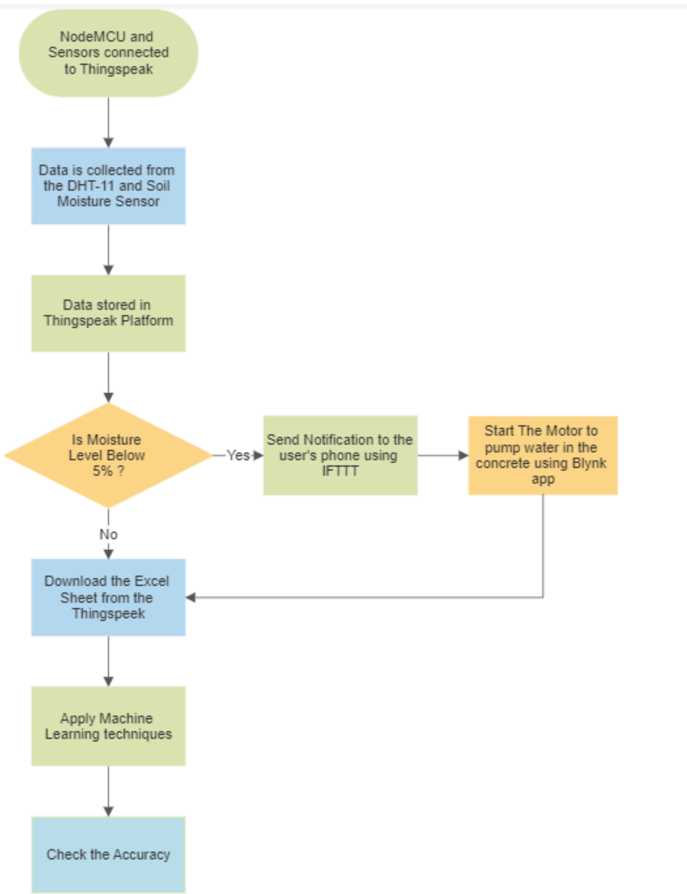

Fig 1: Flowchart of the Concrete Curing System

IV. PROPOSED SYSTEM

The first step is to mix cement, gravel, and sand in a 1:2:4 ratio to create concrete. During the setting process, IOT device will use 3 different parameters like temperature, humidity and moisture from the moisture sensor and DHT-11 to measure the moisture, humidity, and temperature respectively of the mixture. As a result of the IoT system, the temperature, humidity, and moisture of the environment will be collected in real-time from the sensors, and that information will be stored as part of the Thinkspeak platform on the cloud. This method uses a spray of water that is applied to the concrete surface after certain intervals to maintain the moisture level required by the concrete. By monitoring the moisture level, temperature, and humidity levels of the surrounding area, the IFTTT system will alert you when the moisture level in the area decreases, and when moisture drop to 5%, it will pump water into the system as necessary. After moisture is detected, the pump will stop the water. Using machine learning techniques, our excel sheet is applied to determine whether the achieved concrete is strong and suitable for use by applying machine learning techniques on the excel sheet that we have created. With the data from our excel sheet, we can further analyze if the concrete is strong and suitable for use, thus confirming the accuracy of the machine learning techniques employed. This data can then be used to adjust the water to concrete ratio for future applications, ensuring that the concrete produced is always of the highest quality. Additionally, this data can be used to develop more efficient and accurate machine learning models.

V. RESULT ANALYSIS

In our research work we have utilised various ML algorithms like decision tree, random forest & linear regression to get accuracy for the real-time entries from the sensors in the period of two and half days. Linear Regression is giving train score with 0.788 and test score with 0.77, the r2 score is 4.08. Decision Tree with max_depth of 3, RMSE value of 1.43 and R2 value of 0.97 gives the accuracy of 95.6% Lastly, Random Forest with n_estimators equal to 100 and RMSE value of 0.38 and R2 value 1.00 resulting the highest accuracy of 97.2%. The device is also cost-effective, making it an attractive choice for those looking to save money while still achieving efficient results. Water loss is reduced providing substantial strength for commercial use and managing the cost of laborers.

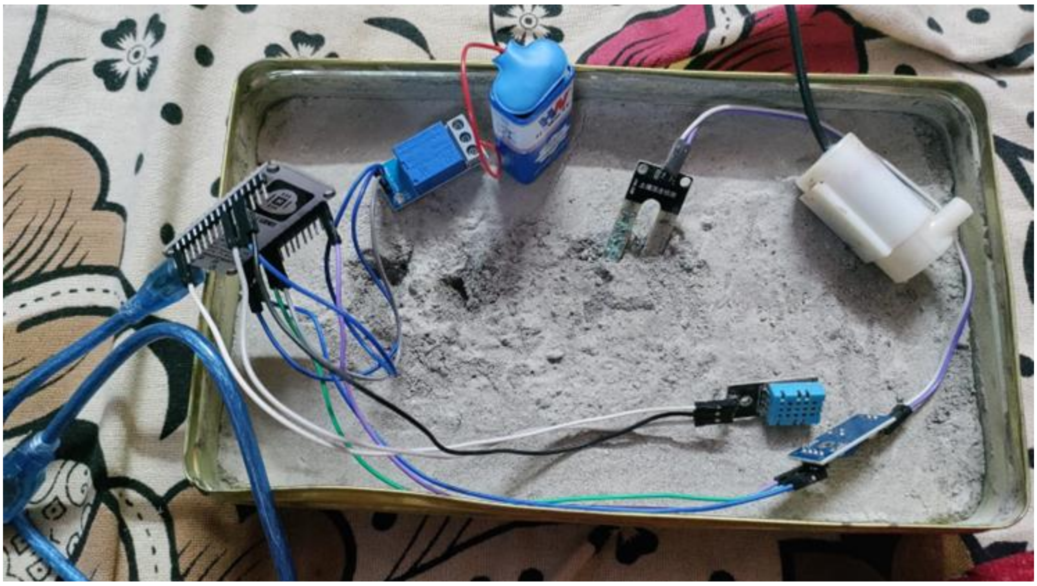

Fig 2: IOT system

Fig 3: Readings from Serial monitor on Arduino IDE

Push Notification:
With this platform (IFTTT) user can be alerted with notification when the moisture level drops to 5%

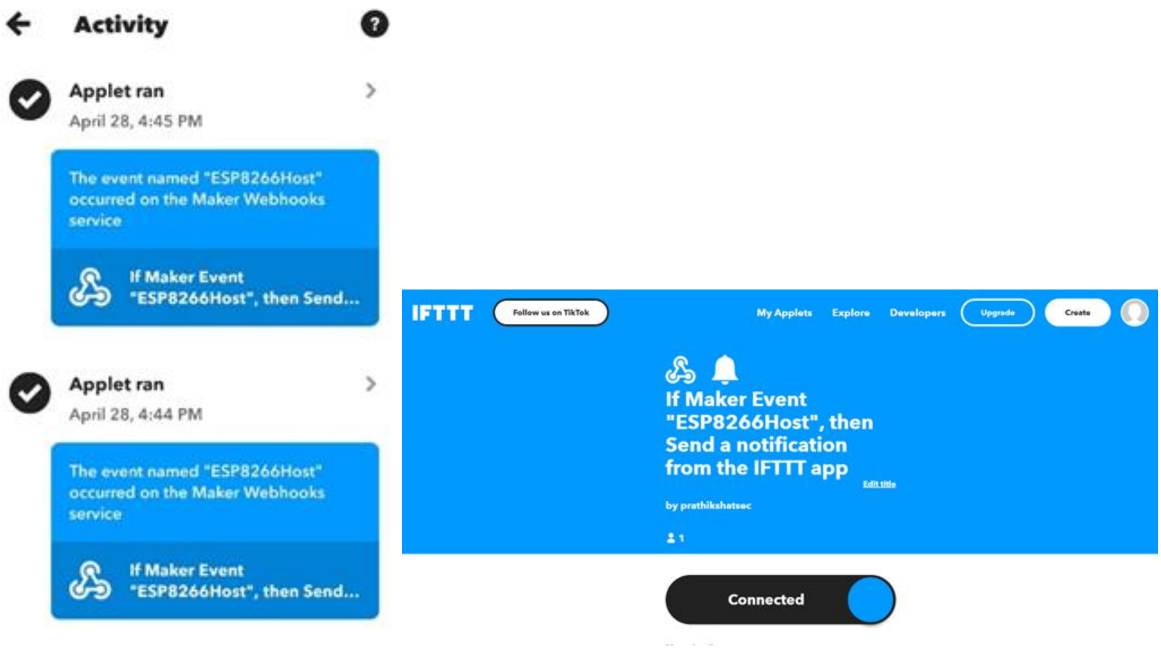

Fig 4: Notification pop up and message on IFTTT

Thinkspeak Cloud:
Real time entries from the sensors for Humidity, Temperature and Moisture.

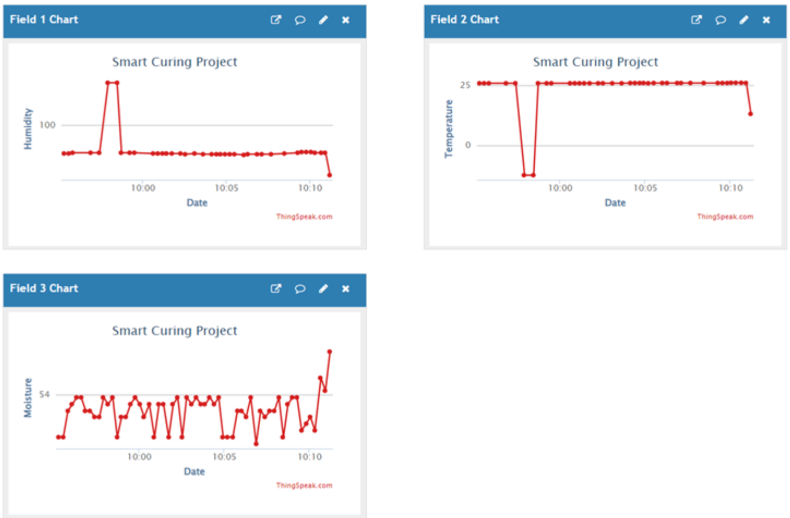

Fig 5: Graphs generated on the Thingspeak from the sensors

Excel:

4712	2023-01-27T13:20:35	4711	58	25.8	40.47
4713	2023-01-27T13:20:51	4712	58	25.8	40.37
4714	2023-01-27T13:21:12	4713	58	25.9	40.37
4715	2023-01-27T13:21:29	4714	58	25.9	40.47
4716	2023-01-27T13:21:45	4715	57	26	40.37
4717	2023-01-27T13:22:01	4716	56	26.1	40.37
4718	2023-01-27T13:22:16	4717	56	26.2	40.37
4719	2023-01-27T13:22:33	4718	57	26.2	40.37
4720	2023-01-27T13:22:54	4719	58	26.2	39.78
4721	2023-01-27T13:23:10	4720	59	26.2	39.98
4722	2023-01-27T13:23:26	4721	60	26.2	40.37
4723	2023-01-27T13:23:45	4722	61	26.2	47.02
4724	2023-01-27T13:24:03	4723	61	26.2	46.73
4725	2023-01-27T13:24:19	4724	61	26.2	46.73
4726	2023-01-27T13:24:35	4725	61	26.2	46.92
4727	2023-01-27T13:24:51	4726	60	26.1	46.33
4728	2023-01-27T13:25:07	4727	61	26.1	46.04
4729	2023-01-27T13:25:23	4728	61	26.1	46.63
4730	2023-01-27T13:25:39	4729 nan		nan	46.53
4731	2023-01-27T13:25:55	4730	60	26.1	45.85
4732	2023-01-27T13:26:11	4731	60	26.1	46.24
4733	2023-01-27T13:26:28	4732	59	26.1	45.75
4734	2023-01-27T13:26:46	4733	59	26	45.55
4735	2023-01-27T13:27:02	4734	59	26	45.94
4736	2023-01-27T13:27:20	4735	58	26	45.94
4737	2023-01-27T13:27:36	4736	59	25.9	45.55
4738	2023-01-27T13:27:52	4737	58	25.9	45.45

Fig 6: Excel sheet- entries from the sensors (humidity, temperature and moisture)

Machine Learning:
Researching machine learning requires collecting datasets, which is a crucial part of the process. Thus, in order to increase the accuracy and efficiency of the algorithms, it is important to collect accurate data. The dataset in this system is the real time data obtained from the sensors in the time period of two and half days. The collected data has 13000 entries of moisture, temperature and humidity. This dataset is pre-processed to get accurate results.

Accuracy:
Linear Regression:

```
] from sklearn.linear_model import LinearRegression
  lr1 = LinearRegression()
  lr1.fit(X1_train,y1_train)
  lr1.score(X1_test,y1_test)

  0.7730602662450736
```

Fig 7: Accuracy of Linear Regression

Decision Tree:

```
#Decision Tree Regressor
from sklearn.tree import DecisionTreeRegressor
dtr1 = DecisionTreeRegressor(max_depth=2)
dtr1.fit(X1_train,y1_train)
dtr1.score(X1_test,y1_test)

0.9566405453946438
```

Fig 8: Accuracy of Decision Tree Regressor

Radom Forest:

```
#Random Forest Regressor
from sklearn.ensemble import RandomForestRegressor
from sklearn.datasets import make_regression
rfr1 = RandomForestRegressor(max_depth=3 )
rfr1.fit(X1_train,y1_train)
rfr1.score(X1_test,y1_test)

0.9723727420268726
```

Fig 9: Accuracy of Random Forest Regressor

Random Forest has the best accuracy with 97%

VI. CONCLUSION

It suggests that IoT devices can improve concrete curing efficiency and accuracy. Real-time monitoring of environmental conditions is achieved by the IoT system, which measures temperature, humidity & wastage of water from curing process. In order to facilitate better intercommunication, data will be fetched to a central computing device. This allows users to assemble data from the same computer platform. This in turn allows users to modify curing conditions in real-time, making concrete curing more efficient and precise. A user is notified only if a change or anomaly in the curing concrete's call for water emerges, i.e., when the moisture level drops. Traditional manual curing methods require large quantities of water and manpower. The IoT device is also cost-effective, as it does not require the purchase of expensive equipment or the hiring of extra staff to monitor the curing process. It is also much more reliable than manual monitoring, as it can detect changes quickly and accurately. Furthermore, it is easy to use and maintain, which allows for quick implementation in the construction industry. The data collected from plethora of sensors is then applied ML algorithms e.g. decision tree, linear regression & random forest. The Random Forest algorithm gives the highest degree of accuracy, confirming the accuracy of the machine learning techniques used. This data can then be used to adjust the water-to-concrete ratio for future applications, ensuring that the concrete produced is always of the highest quality.

VII. FUTURE ENHANCEMENT:

We aim to integrate a front end for showing the accuracy of the resulting data received from the sensors. This front end will be used to visualize and analyze the data, enabling us to identify trends and anomalies. It will also allow us to easily modify the sensor configuration so that it can be adapted to changing conditions. Furthermore, we can add buzzers which will be an effective way to ensure the user is alerted to any changes or anomalies in the data(moisture), ensuring that they can take the necessary action quickly.

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