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Monitoring and Mapping of Machine Learning Supported Sensor Data for Digital Transformation Transfer Laboratory

Gökçe İye*, Merih Palandöken [2]

[1]*Department of Electrical and Electronics Engineering, Faculty of Engineering and Architecture, Izmir Katip Celebi University, Turkey*
[2]*Department of Electrical and Electronics Engineering, Faculty of Engineering and Architecture, Izmir Katip Celebi University, Turkey*

(gokceiye280@gmail.com)

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Abstract – Along with technological innovations, the internet of things, artificial intelligence and big data, as a result of all these, the "digital age" or "digitalization" processes we have discussed have entered our lives. These concepts emerged in the Industry 4.0 period, which represents the fourth stage of the industrial revolution, and continue to exist today. The internet of things (IoT) refers to all systems that can transfer data over a network. In the world of the Internet of Things, the role of human-to-human commands and even human-computer interaction has been minimized. In this context, sensor technology forms the basis of IoT. Sensors detect variables in their environment and transfer this data to other devices or a data storage center. By analyzing large data sets, machine learning algorithms discover patterns and relationships and can thus predict future events. The Python programming language, in particular, offers a wide set of libraries and tools for machine learning applications. Therefore, when IoT, sensor technology, machine learning and Python programming language come together, it becomes possible to effectively measure, analyze and map environmental parameters. This can be used as an important tool for monitoring and managing environmental conditions in various industries. This study combines sensor technology and machine learning methods to measure and map the temperature and humidity values of a specific area, an approach associated with the concept of the Internet of Things (IoT). After different temperature and humidity values are taken from different locations, a mapping is created for the area where the data is taken. In addition to the temperature and humidity values taken from certain locations, the temperature and humidity values of locations where no data is taken are estimated and mapped with the support of machine learning methods.

Keywords – Industry 4.0, Sensor, Python, Machine Learning, IoT

I. INTRODUCTION

The main goal of advances in Industry 4.0 technology is advanced industrial automation and high efficiency. Industrial innovation has enabled the development of smart factories, which emerged with the Internet of Things (IoT) and are now widely used. IoT is evolving around smart industrial components such as cloud computing, cybersecurity, autonomous robots, system integration, big data, data analytics and artificial intelligence. With the Fourth Industrial Revolution, industries began to use new formations in their production processes [1]. In this context, the introduction of digital transformation transfer laboratories and the use of a system with high industrial automation has reduced personnel demand and minimized errors caused by human influence. The main goals of digital transformation transfer laboratories include the creation and use of industrial automation, reducing error rates, reducing personnel demand and commissioning high-tech systems [2]. Machine learning techniques include regression models, classification algorithms, clustering algorithms, deep learning and time series analysis. These techniques enable better understanding and use of data. For example, regression models can be used to predict future temperature and humidity levels in a particular region, while classification algorithms allow data to be sorted into specific categories. Clustering algorithms classify data points with similar characteristics into natural groups, while deep learning enables the analysis and prediction of large and complex data sets. Time series analysis allows predicting future events by examining past data. The aim of this study is to obtain sensor data of a specific area in a digital transformation transfer laboratory with high original value, in accordance with Industry 4.0 criteria, and to create predictions and maps about other data points of this area using machine learning techniques [3]. The purpose of the sensor data is to estimate the temperature and humidity map. To realize this technological transformation, IoT, cloud computing and sensor data categorization were used in the study. Mapping can be expressed as a visual representation of data collected in a particular area, and machine learning plays an important role in this process [4]. Machine learning techniques are used to extract meaningful patterns and predictions from large data sets, such as estimating missing data, finding correlations between data points, and predicting future events. Mapping and machine learning techniques enable better understanding and use of data, allowing more effective and efficient decisions to be made in various fields. This supports goals such as achieving industrial automation, reducing error rates and stimulating industrial innovations, and finds a wide range of applications. In this way, industrial processes can be made more efficient, sustainable and innovative by taking advantage of the advantages brought by technological transformation.

II. MATERIALS AND METHOD

Information about the hardware products used for mapping in the digital transformation transfer laboratory is provided in this section. Raspberry Pi enables exploration of the Internet of Things. It is a low-cost, credit card-sized computer that plugs into a computer monitor. It is a capable little device that allows learning to program in languages such as Python [5]. Sensor nodes collect various physical information; temperature, pressure, motion of an object, etc. ensures his capture. It can also allow the physical properties of the environment to be matched with quantitative measurements [6]. BME680 sensor used transmit data instantly. Data collected in the monitoring environment is generally processed at 3 levels. Events in the environment to be monitored are detected by sensor nodes. Each sensor node processes the data it obtains separately. At the second level, each node detects the processed data and sends it to its neighbors. In sensor network communication, the upper layer sends the processed data to the center called the base.

Raw sensor data for humidity and temperature values were systematically collected from the BME680 sensor and stored over time. Raw data are cleaned, normalized, and features extracted before modelling. This phase ensures that the data have to be high qualitative and consistent enough to train an appropriate model. KNN and Linear Regression were used as modeling techniques [7]. The model was trained using the training dataset to understand the interactions between humidity, temperature, and location data. Predictions were made by applying modeling techniques according to the temperature and humidity values measured in the location data. As a result of the predictions, the heat map, where the points are clear and the prediction can be shown, was created separately for both humidity and temperature values. Different performance criteria have been applied. The most frequently used model performance criteria include Mean Absolute Error (MAE) and Mean Squared Error. (MSE), Root Mean Square Error (RMSE), Coefficient of Determination (R^2) and Median Absolute Error (MedAE). These performance criteria are used to determine the accuracy and reliability of the model and provide important information about how the model will perform in different conditions.

III. RESULTS

Sensor data was collected at various points and at different time periods in Katip Çelebi University Digital Transformation Transfer Laboratory and campus garden. The data was collected by the self-propelled robot mechanism and recorded in the Google Firebase Real-Time Database. In total, 1450 different data points were collected, and the data was stored in JSON format. This data was converted to Excel format for machine learning applications, streamlining the data analysis and model training processes. Details and statistics of the data are presented in Table 1.

Table 1. Some of the data collected from temperature, humidity and pressure values

Humidity	Pressure	Temperature
23.744	1014.37	35.52
23.775	1014.37	35.52
23.792	1014.37	35.52
23.802	1014.37	35.52
23.823	1014.37	35.52
23.834	1014.37	35.52
23.845	1014.36	35.52
23.845	1014.36	35.52
23.872	1014.37	35.52
23.877	1014.37	35.52
23.888	1014.38	35.52
23.885	1014.36	35.51
23.906	1014.37	35.51

In light of the criteria in Table 2 below, it can be concluded that the KNN algorithm performs better than Polynomial Regression in temperature prediction. KNN explains the data better, reduces the average error and makes predictions more accurate. Therefore, it can be said that the KNN algorithm is a more suitable model for temperature prediction. The 2D KNN regression graph for temperature prediction is shown in Figure 1.

Table 2. Results of Two Different Regression Models for Temperature Prediction

	Polynomial Regression	**KNN**
R^2	0.9270	0.9377
MAE	0.3078	0.2239
RMSE	0.4642	0.4287
MSE	0.2155	0.1838
MedAE	0.1846	0.0430

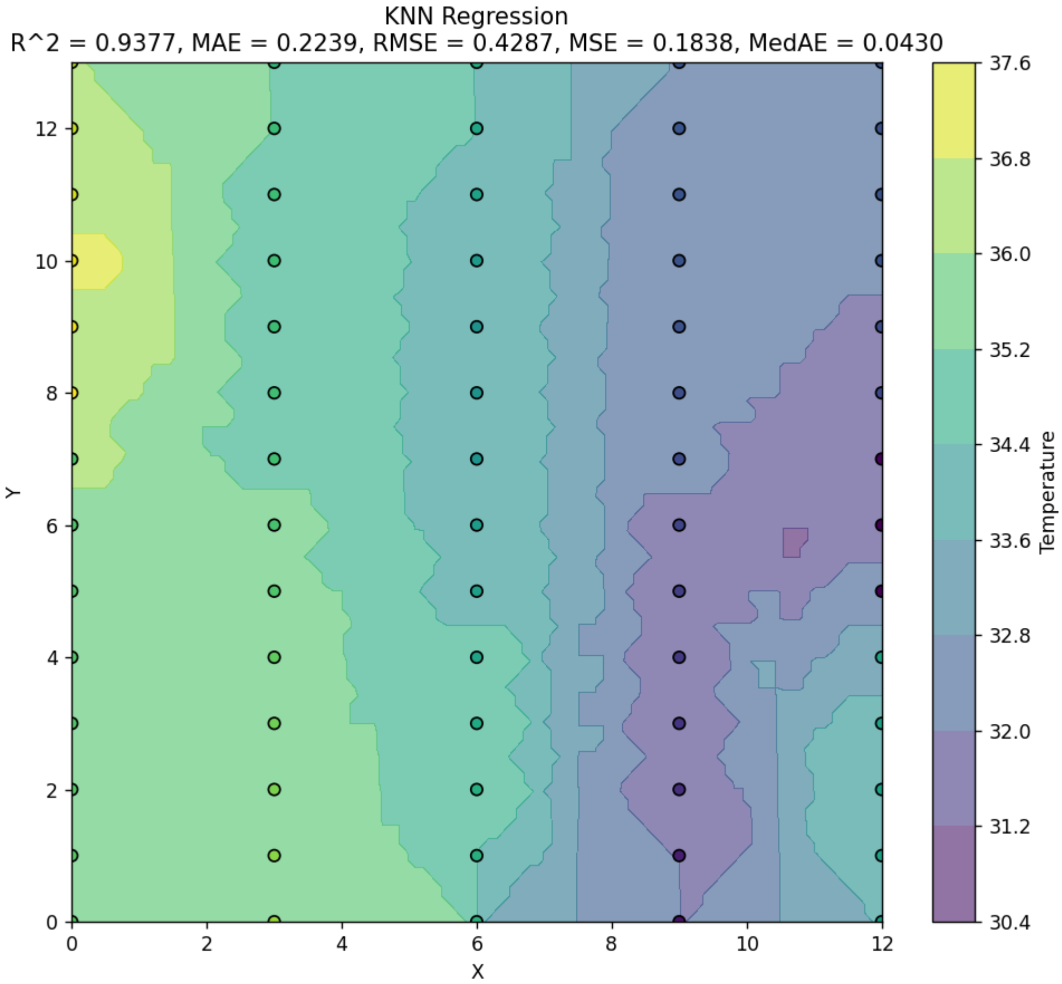

Figure 1. 2D KNN Regression Graph for Temperature Prediction

In light of the criteria in Table 3 below, the R^2 value of the KNN model is 0.7021, which is higher than the Polynomial Regression model's value of 0.6637, which shows that the KNN model explains the moisture variability better. Additionally, the Mean Absolute Error (MAE), Root Mean Squared Error (RMSE), Mean Squared Error (MSE) and Median Absolute Error (MedAE) values of the KNN model are lower, indicating that the KNN model makes fewer errors in moisture prediction and provides more accurate predictions. indicates that it exists. As a result, the KNN model stands out as a more suitable and effective model for moisture estimation and mapping in terms of both accuracy and error metrics.

Therefore, it is recommended to use the KNN model for moisture estimation and mapping. The 2D KNN regression graph for humidity prediction is shown in Figure 2.

Table 3. Results of Two Different Regression Models for Humidity Prediction

	Polynomial Regression	KNN
R^2	0.6637	0.7021
MAE	0.3549	0.2867
RMSE	0.4865	0.4410
MSE	0.2195	0.1945
MedAE	0.2761	0.1992

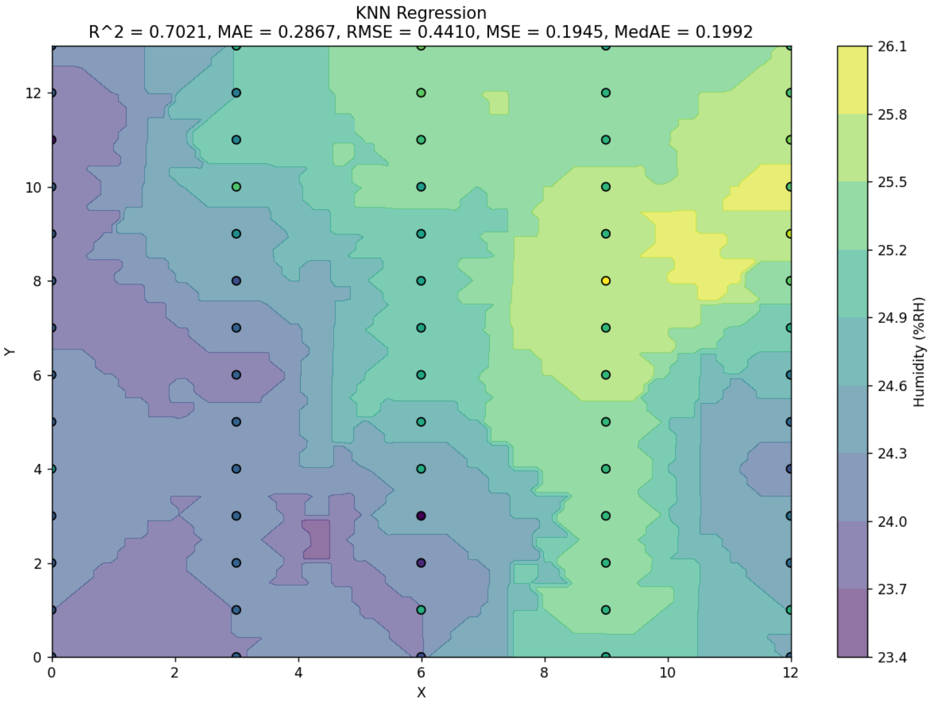

Figure 2. 2D KNN Regression Graph for Humidity Prediction

The results of this study show that humidity and temperature distribution can be predicted and mapped using sensor data. The resulting models can be used to understand the humidity and temperature status of an environment and to predict values at uncertain points. However, suitability and performance in model selection should be taken into account and preference should be made according to specific application requirements. In the future, it may be aimed to increase the prediction performance by using more complex models or different feature engineering techniques.

IV. DISCUSSION

The findings of this study reveal that the integration of sensor technologies, the Internet of Things (IoT) and machine learning holds great potential for measuring, analysing and mapping environmental features. Sensors form the cornerstone of IoT by transferring the data they receive from the environment over networks and provide real-time data collection and communication capabilities [8]. Machine learning algorithms, on the other hand, demonstrate superior performance in analysing large data sets, identifying patterns and predicting future events. In our research, the extensive libraries and tools of the Python programming language played a critical role in data analysis and model development. This integration of IoT, sensor technologies and machine learning has enabled accurate measurement and mapping of temperature and humidity values, especially in fields such as agriculture, urban planning and environmental protection. The results confirm that this approach is effective and appropriate for monitoring and managing environmental factors. In the future, this methodology is expected to be applied in new areas and more complex scenarios, becoming even more scalable and adaptable as technology develops. The integrated approach offered by this study will make significant contributions to various sectors by providing an innovative, efficient and scalable solution for environmental surveillance and control.

V. CONCLUSION

This paper investigates the effective measurement, analysis, and mapping of environmental characteristics through the combined use of sensor technologies and machine learning. Initially, the term "internet of things" (IoT) was defined as any technology that has the ability to transmit data across a network. It is shown here that sensor technology is the cornerstone of the Internet of Things [9]. It has been described that sensors take the information from their surroundings and transmit it to other devices or data center. Machine learning algorithms are able to predict future occurrences, identify patterns and relationships, and evaluate massive data sets. It has been said that a large collection of libraries and tools for machine learning applications are available, especially for Python programming language. It is therefore stressed that measuring, analysing, and mapping environmental factors becomes feasible when IoT, sensor technologies, machine learning, and the Python programming language join together [10]. The project that this paper focuses on measures and maps the temperature and humidity values of a certain area by combining sensor technology with machine learning techniques. Consequently, the approaches' efficacy and suitability have been established, making them a valuable instrument for overseeing and controlling environmental conditions across diverse sectors. This work combines IoT, sensor technologies, machine learning, and Python programming language to propose a novel method for measuring and evaluating environmental factors. It is anticipated that this strategy will be crucial in controlling and keeping an eye on environmental conditions across a range of businesses.

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