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Temperature Prediction on medicines using machine learning through regression.

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Abstract

Temperature control is a mainstay during medicine storage. Drug stores sell some medical items which are kept in fridges. when the frequency of opening and closing the fridge there is a possibility of entering the outside hot air into the fridge. This will increase the inner fridge temperature, and it may go beyond the allowed storage temperature range as well. In this paper, we propose a model that will be used in multiple chamber fridges to keep indicating the time remaining for the inner temperature to go beyond the allowed range, and if the time is short, the system will advise the pharmacist not to open that particular room and instead recommend a room with enough time slots (time to reach the upper limit temperature). We built a multiple linear regression model using training data from a thermo-electric cooler-based fridge to forecast how long it will take for a given space to reach the cut-off temperature if it is opened. This created model is evaluated using the coefficient of determination R^2 and obtained 77% accuracy, and this helps to develop a smart fridge with multiple rooms for storing sensitive medical products efficiently.

***Keywords*—**temperature range, machine learning, thermo-Electric cooler, multiple linear regression, cut-off temperature

I. INTRODUCTION

Among the pharmacist's most critical responsibilities is drug storage.The storage of pharmaceutical items is an important issue in patient care.The manufacturing and storage environment of pharmaceutical items can significantly impact their quality.[1]Medical products are maintained according to the parameters of their storage, which include temperature, light, and humidity. Certain medications are kept at room temperature, in the freezer, or the refrigerator. Vaccines are primarily used to maintain a temperature range of 2 to 8^0 Celsius.[2]The pharmacist whomanages the drug storewill open the refrigerator and retrieve the requested medicine for the customer or patients. When the refrigerator door is opened, cold air rushes out and is replaced by hot air.it will cause the temperature to rise faster.[3]The energy usage of a refrigerator with an open door was found to be significantly higher than that of the same product without an open door. Depending on the number of door openings,energyconsumption is increased by approximately 7-30 % when compared to the closed-door situation.[4]Continuous monitoring of the environment's temperature is vital since medical items cannot be stored at temperatures beyond particularthresholds temperature for an extended period.Based on their efficiency in modeling dynamic systems in a diversity of science and engineering applications, machine learning approaches could be deemed an effective and efficient technique for modeling the temperature forecast system.It learns things from and generates predictions about data.This is frequently referred to as predictive analytics, and it is at the forefront of data-driven decision-making in the present day.[5]Regression analysis is one of the supervised ML Among the different ML algorithms.Multiple linear regression is a technique for estimating the connection between two or more independent variables and a single dependent variable.Based on the number of independent variables, we can predict the output.We used Multiple Linear Regression with the given time series temperature data and predict optimal temperature.[6]The temperaturedepends on many other factors, including air, pressure, and humidity. A single data point is insufficient as a metric for reliable prediction. To achieve high-resolution predictions, a heterogeneous temperature observation method is required. we need to find the relationships between the dependent and independent variables.[7]IoT sensor networks are rapidly being employed in environmental monitoring because they provide accurate real-time measurements. Different research areas based on IoT datasets and ML/DL models demonstrate the applicability of IoT data with promising outcomes. These data enable lightweight ML/DL models to outperform numerical models in terms of forecasting speed. As recent research has discovered, the intelligence of IoTs improves the quality of the prediction model, which leads to faster decision-making and responses.[8-10]

II RELATED WORK

This section covers several smart refrigerators and temperature prediction studies using machine learning algorithms and IoT devices. Many researchers proposed refrigerators that can be remotely monitored using the IoT technologies, refrigerators that can help in monitoring the cut-off temperature for storing sensitive medical items such as vaccines and other drugs, and refrigerators that can help in the management of medical products.

The author proposed the model for the prediction of smart building indoor temperature by combining machine learning and IoT mechanisms. IoT devices like Energy consumption devices monitor the amount of energy consumed by the people and automatically control the energy consumption over thenetwork, and this IoT architecture is designed based on safe andsecure Edge computing technology.[11] Livingston et al [12] proposed a smart home fridge (that stores vaccines) that is set to monitor the patient's actions of opening and closing the door to see if they taking medicine at regularly scheduled intervals. If the refrigerator is not opened at the appropriate time, it will send a message to the doctor or a family member. Raspberry Pi Works in [13] RFID technology, a smart fridge was proposed, from which information on products left within and the status of its door could be obtained.[14] the author proposed the content awareness fried based on an RFID mechanism that will merge food item information and the user's health state. Refrigerator with RFID technology With the mobile app, the user sets a food stock threshold in the fridge. The household server will send a reminder message to the user when particular food products are going to run out. Refrigerator with RFID technology With the mobile app, the user sets a food stock threshold in the fridge. The household server will send a reminder message to the user when particular food products are going to run out.T Kwon et al.[15]Based on a built-in sensor within the refrigerator, inventors developed the smart refrigerator that employs artificial intelligence algorithms to classify different products and alert the user when fruits or vegetables are missing. It's an algorithm-based study that measures humidity and temperature utilizing sensors and an Arduino mega board. It also checks the products' expiration dates and notifies the consumer via an Android app. In addition to material images, this system is directly connected to a server to save and preserve data. The research work[16]proposedusing a QR code reader system, and suggests a medical fridge to improve the healthcare system. to keep track of the expiration date, the system scans the barcode for each drug. It also contains a camera that can be used to keep an eye on the contents of the fridge from afar. A low-cost smart refrigerator was discussed in this paper[17], which combines Smart Home principles with the Internet of Things (loT) technologies to reduce food waste. Users may quickly enter new food information by snapping photos of the food or verify the images obtained from within the refrigerator using the Raspberry Pi system. Data collected by the Raspberry Pi may be easily synchronized and accessible across numerous devices via a cloud-based service. Masudet al.[18], presented security concerns that may be examined in the context of the Internet of Medical Things (IoMT); this could also be applied to our medical fridge. This study[19] describes a low-cost IoT method for monitoring the temperature in refrigerated retail cabinets that are built on free hardware and software. It is proposed that the ESP-8266-Wi-Fi microcontroller be used in conjunction with DS18B20 temperature sensors. Data is stored and processed in the cloud using the Thing Speak IoT platform. With the use of two servers, one Cloud server, and one Edge Server, the study in [20] presented the concept of a Cache Distributed System. This highlights the need of using 6G in scenarios involving large amounts of data. On the refrigerator's side, some authentication can be implemented so that it can only be accessible by specific people for better and safer handling.

To our knowledge, this is the only research that proposes a machine learning model to be embedded in a medical multi chambers fridge to assist pharmacists in achieving an effective way of storing medical products by estimating the remaining time for a particular chamber to exceed the acceptable storage temperature.

III. MATERIALS

To manage the storage of pharmaceuticals, particularly temperature-sensitive items such as vaccinations, in an effective manner. We present a multi-chamber refrigerator with an embedded controller capable of running a predictive machine learning model. Figure 1 represents the multi-chamber fridge; in our proposed model we are considering the four-chamber fridge to generate the data. Each of the four rooms of the fridge has inside temperature sensors and a magnetic door switch to indicate whether the fridge is opened or closed. The fridge has LCD which indicates the current room temperature, and the remaining time for each champers to obtain a cut-off temperature. besides that, the data can be transmitted to the remote database through the GSM modem for monitoring and storing the data for further usage. The cut-off temperature depends on the initial temperature of the room, The present time of day, and the temperature of the atmosphere.

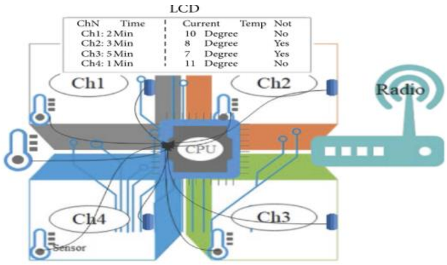


Fig 1:Four Chamber Fridge

3.1 Elements of the fridge:

The sensor presented in the smart fridge will indicate the cut-off temperature. Figure 2 depicts the elements of the fridge that describes a generation of the data.

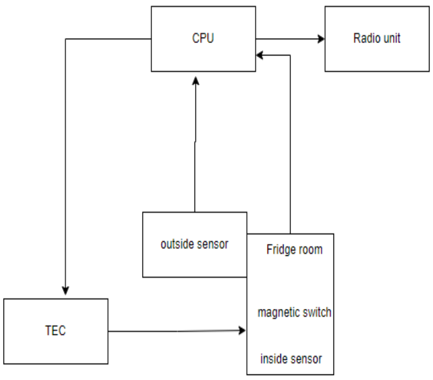


Fig 2:Data generation system diagram.

3.1.1Thermoelectric Cooler System(TEC):

It works based on the Peltier effect that creates the temperature variance between the junctions, this requires DC voltage .when the power passes through this junction, heat is removed in one place and cooling occurs.

3.1.2 Controller and Radio unit:

Temperature and door magnetic sensors

regulate the cooling system (TEC Systems) which are controlled by Arduino Mega.The radio device is a SIM800L (SimCom, Shangai, China) that transmits data through GPRS protocol to a remote database, from which data is manually downloaded in CSV format for model training. The controller was programmed to read sensors (temperature and door magnetic switch), count the amount of time that had passed since a specific door had been opened, and then communicate this information to the GSM modem.

3.1.3 Temperature Sensor:

DHT11 and FSR are the two sensors that help to measure the fridge parameters like temperature, humidity, and weight of the product. Fig 3describes about the architecture diagram of the working of the sensor in the smart fridge system

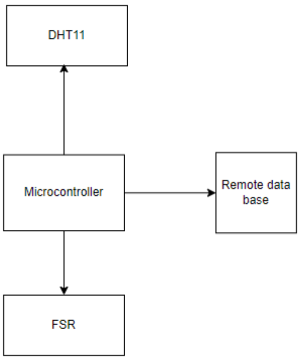


Fig 3:Architecure diagram of the sensor connected with the smart system.

DHT11and FSR are connected with the microcontroller of the smart fridge and gather the data such as temperature, and humidity and send that to the remote database for creating the analytic model to predict the cut-off temperature. The DHT11 is a temperature and humidity sensor that is widely used. The sensor includes a dedicated NTC for temperature measurement and an 8-bit microprocessor for serial data output of temperature and humidity values. The sensor is factory calibrated, making it simple to connect to other microcontrollers. With an accuracy of 1°C and 1 percent, the sensor can measure temperature from 0°C to 50°C and humidity from 20% to 90%. Force sensing Register (FSR) When a force or pressure is applied to it, it changes its resistance. We can detect physical pressure, squeezing, and weight with it.

IV. METHODOLOGY

4.1Data Generation:

Our aim is to measure the effects of opening and closing the fridge while picking up certain medications. The data collected from this fridge was transferred to a remote database for storage, this can be downloaded as a CSV file for analyzing the model using the ML algorithm. figure 4 gives the details about the generation of data.

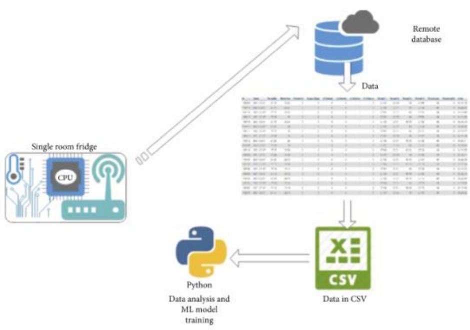


Fig 4 Data generation process

Yet this cooling system could not help becausewe can store the vaccine's temperature range about 2ºC-8ºC. Here the data is generated by simulating the process of opening and closing the fridge by the pharmacist while taking the drugs. To accomplish the simulation by considering the temperate range from 10ºC-18ºC and using it to arbitrarily open and wait for the chamber temperature to reach the upper permitted range (18ºC degrees); if the buzzer rung when the upper acceptable temperature was reached. We used to shut the door and wait a random amount of time before repeating the action. Figure 5 specifies the manner in which we gathered data.

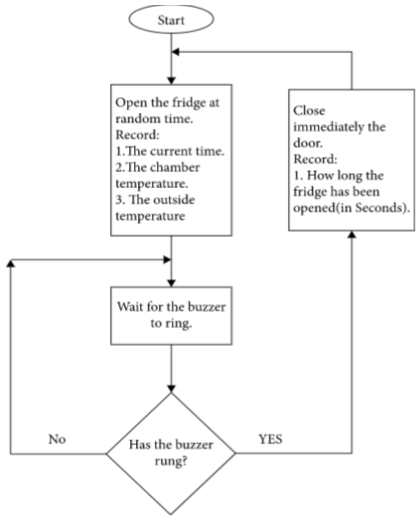


Fig 5:Data generation flow diagram

4.2 Model Training:

The model will be trained using the ML algorithm namely Multivariate regression, which helps to find the relationships between different parameters that we are using in our model. Here thedifferent parameter values areinside temperature(inTemp),outside temperature(ouTemp) ,the time day, and the time when the temperature reaches the cut-off temperatures(Time_Opened_Min). The independent variables are considered as inside temperature,outside temperature, and the time of day. The dependent variable is taken as the time needed for the room temperature to reach the cut-off temperature.The linear regression with multiples features equation can be written as follows:

$T_{cut\text{-}off} = m_1 * OuTemp + m_2 * InTemp + m_3 * daytime + \beta$ (1)

Where$T_{cut\text{-}off}$is the time required for the room temperature to hit the upper-temperature range, OuTemp is the outside temperature, InTemp is the inside temperature, DayTime is the daytime, m_n is the coefficient, β is the intercept.Table 1 gives the statistical values of the variables

Variables	Description	Units
OuTemp	The outside temperature at opening time	°C
InTemp	The inside room temperature at opening time	°C
DayTime	The day time at the time of fridge opening	Hours

Table 1:Explanatory variables considered in the regression model to predict the time to cut-off temperature.

4.3 Data Pre-processing:

While transmitting data to a remote server, the server provided a timestamp in the format HH:MM:SS. The XM format denotes a 12-hour system. To make it easier to incorporate a timestamp into our model, we transformed it to HH:MM:SS: SS denotes a 24 hour system. Our objective was to count a day from the first to the twenty-fourth hour, taking into account the fact that different hours of the day have a distinct effect on the model. The third and fourth tables include only ten items from our dataset. Apart from the timestamp, the time duration during which the refrigerator was opened was calculated in minutes. Table 2 and 3 gives the row and column values of the dataset

OuTemp (°C)	InTemp (°C)	Time_open (sec)	Time_stamp
22.25	14.75	136	8:39:10
22.31	13.69	168	8:54:45
22.31	15.56	95	9:03:33
22.37	14.81	144	9:14:32
22.37	17.37	71	9:19:08
22.44	17.81	22	9:21:19
22.44	15.88	95	9:27:00
22.44	17.19	54	9:31:28
22.44	17.37	38	9:35:16
23.19	15.44	95	1:41:38

Table 2:Data before pre-processing

OuTemp [°C]	InTemp (°C)	Time_open (sec)	Time_open (min)	Time (12 H)	Time (24 H)	Day_hour
22.25	14.75	136	2.3	8:39:10	8:39:10	8.7
22.31	13.69	168	2.8	8:54:45	8:54:45	8.9
22.31	15.56	95	1.6	9:03:33	9:03:33	9.1
22.37	14.81	144	2.4	9:14:32	9:14:32	9.2
22.37	17.37	71	1.2	9:19:08	9:19:08	9.3
22.44	17.81	22	0.4	9:21:19	9:21:19	9.4
22.44	15.88	95	1.6	9:27:00	9:27:00	9.5
22.44	17.19	54	0.9	9:31:28	9:31:28	9.5
22.44	17.37	38	0.6	9:35:16	9:35:16	9.6
23.19	15.44	95	1.6	1:41:38	13:41:38	13.7

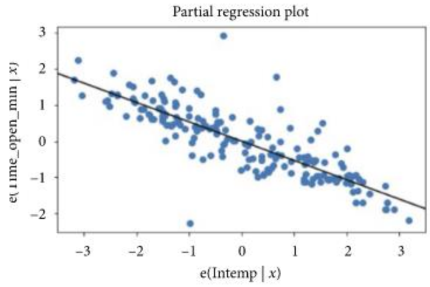
Table 3:Data after pre-processing

V. EXPERIMENTAL RESULTS AND DISCUSSION

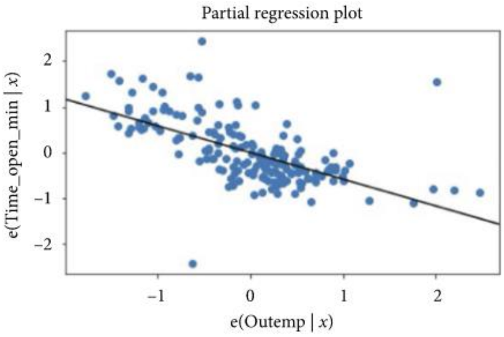
We kept track of the data for three months during our trial. So we need to recreate the selling process of the medicine for a period of 12 days. We can observe that the selling process took place exclusively during the daytime and that the temperature (both inside and outside) climbs during the day, while the temperature drops at night. This explains why the temperature is affected by the time of day. Even when the door is closed throughout the day, we can see a slight increase in internal temperature due to heat exchange between the outside and inside mediums. The temperature of the fridge depends on how often it is opened, the time of day, and the outside temperature, as can be seen. The time it takes for the inside temperature to reach the upper limit is determined by the initial temperature at the moment of opening, the time of day, and the outside temperature.

5.1 <u>Model Performance and Prediction Accuracy</u>

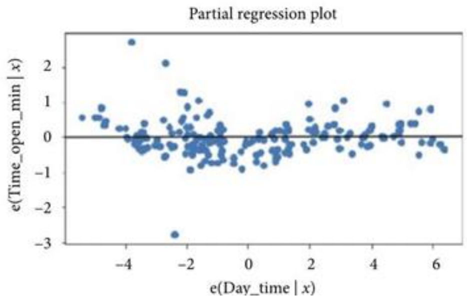
In this section, we have a range of responses that demonstrate the accuracy of our model. Figure 6 depicts the relationship between each predictor variable and the target variable



(a)The relationship between the dependent variable and the chamber temperature.



(b)The relationship between the dependent variable and the outside temperature.



(c)The relationship between the dependent variable and the daytime.

Table 2 presents some numerical results for determining the model's accuracy, and table 3 depicts the other related values of the regression model. The coefficient of determination R^2 is0.767, as shown in this table 3. As a result, the model remains effective and efficient.

	Coefficient	Std error	T	P>|t|
Intercept	23.409	1.989	16.530	0.00
InTemp	-.5330	0.026	-20.19	0.000
OuTemp	-0.5838	0.056	-10.56	0.000
Day_hour	0.0016	0.014	0.121	0.906

Table 2:Regression model results.

Parameter	Value
R^2	0.767
Adjust R^2	0.764
F-Statistic	196.2
Prob(F-Statistic)	4.90e-56
Log-likelihood	−142.47

Table 3:More about Regression model results.

From table 2 we can obtain m_1,m_2,m_3 and β values.m_1=−0.58;m_2=−0.53;m_3=0.0016;β=23. 4.so the eq 1 can be rewritten as follows:

T cut-off = -0.58 * outemp + -0.53*intemp + 0.116*daytime + 23.4(2)

based on the coefficient values on Table 1, the model result can be concluded as

i. When the outside temperature rises, the internal temperature will approach the cut-off point in a short time.

ii. This is also applicable for the internal temperature (at the opening time). It will take a short time to achieve the cut-off temperature if it is higher.

iii. When the values of dependent variables are taken into account, the inside and outside temperatures contribute more to the prediction than the daytime.

Also this work is compared with the a deep Neural Network method, but in the end, we discovered that the regression model works better than the Neural Network. The results of the two methods are summarized in Table 4.

True value [Min]	Predicted linear reg	Predicted DNN
2.3	2.5	2.6
2.8	3.1	3.1
1.6	2.1	2.0
2.4	2.4	2.4
1.2	1.1	2.0

Table 4: comparison between two methods

V. CONCLUSION

We have created a technique that combines IoT and machine learning-based prediction of the remaining time till the temperature inside a refrigerator exceeds the permitted range. The created model should be integrated into a refrigerator equipped with a controller capable of running a machine learning model. The proposed model will continuously monitor the impact of the opening and closing of the smart fridge.Two parameters (inside and outside temperature) have been the considerable contributions to the prediction of the time required for the chamber temperature to reach the upper acceptable range.Results from our analysis show that the model was accuracy is 77%.our proposed system is useful for pharmacies, that sell medicines.Additionally, the Internet of Things can be integrated into the suggested solution for the purpose of remote monitoring and control.

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