Application of Machine Learning to model the behaviour of PT-100 sensor

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Outline

Aim

- In this experiment we will see how to use regression techniques to identify the temperature based on the voltage across the PT-100 sensor.
- We will also see how the PT-100 resistance changes with changes in temperature, and an appropriate circuit to detect the changes in resistance

PT-100 Sensors

- PT-100 is a temperature dependent resistor with a positive temperature coefficient(it resistance increases with temperature).
- It is called PT-100 because the resistance is made of platinum and at 0^o C it resistance is 100Ω.

Circuit Diagram

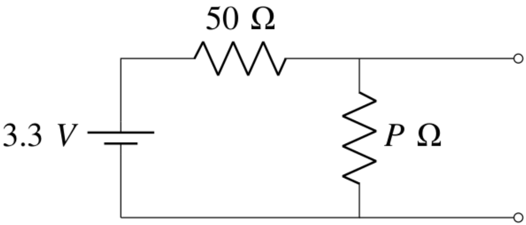

Figure: Circuit Diagram

Data Acquisition

- From the above circuit we can see that the voltage across PT-100 sensor is given by,

$$V_P = 3.3\left(\frac{P}{P+50}\right)V \tag{1}$$

- As the temperature increases, resistance of the PT-100 sensor increases and hence the voltage across PT-100 sensor V_P increases.
- We use an arduino board to read the voltage V_P and a thermomenter to measure the corresponding temperature.

Regression Model

We model the relation between Voltage V_P and the temperature T as,

$$V_P(T) = C + BT + AT^2 \tag{2}$$

Say we collect N data points $(V_{P_1}, T_1), (V_{P_2}, T_2), \ldots (V_{P_N}, T_N)$. Then we can write these N equations as,

$$\mathrm{v} = \mathrm{Xn} \tag{3}$$

$$\begin{pmatrix} V_{P_1} \\ V_{P_2} \\ \vdots \\ V_{P_N} \end{pmatrix} = \begin{pmatrix} 1 & T_1 & T_1^2 \\ 1 & T_2 & T_2^2 \\ \vdots & \vdots & \vdots \\ 1 & T_N & T_N^2 \end{pmatrix} \begin{pmatrix} C \\ B \\ A \end{pmatrix} \tag{4}$$

Training Data

The following table shows the data that is used to train the regression model

Temperature(in Celcius)	**Voltage(in Volts)**
24	2.40
38	2.44
45	2.45
52	2.48
63	2.49
93	2.55
100	2.57

Table: Training data

Regression Model

In regression we find the n that minimizes the euclidean norm of the error between actual voltage and predicted voltage.

$$\mathrm{n}_{\boldsymbol{LS}} = \arg\min_{\mathrm{n}} \|\mathrm{v} - \mathrm{Xn}\|^2 \tag{5}$$

The Least Squares estimate of n is given by

$$\mathrm{n}_{\boldsymbol{LS}} = (X^\top X)^{-1} X^\top \mathrm{v} \tag{6}$$

For the above training data, the least squares estimate that we get is,

$$\mathrm{n} = \begin{pmatrix} 2.33483 \\ 2.93939 \times 10^{-3} \\ -6.24626^{-6} \end{pmatrix} \tag{7}$$

Plot of Predicted voltage and Training Data

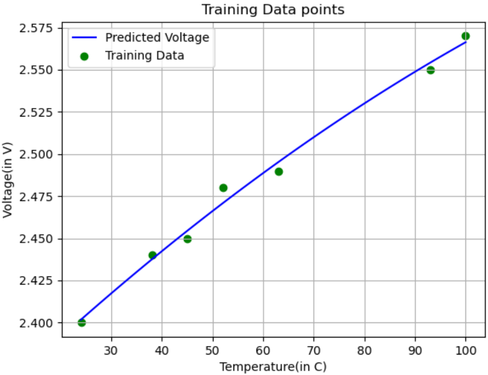

Figure: Training Data

Validation Data

Temperature(in Celcius)	Voltage(in Volts)
29	2.41
32	2.43
74	2.52
85	2.54

Table: Validation data

Plot of Predicted voltage and Validation Data

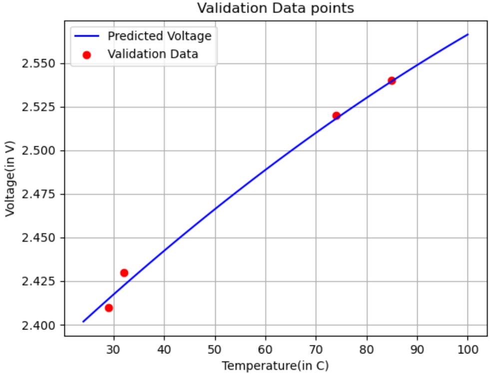

Figure: Validation Data

Conclusion

From above plots we can see that Regression is effective in mapping the relation between the voltage across the PT-100 sensor and it's temperature.