TUP15

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NEURAL NETWORK TECHNIQUE FOR IMPROVING ACCURACY, RELIABILITY AND ROBUSTNESS OF BEAM POSITION MONITOR SYSTEM

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-Abstract

The beam position monitor (BPM) is a crucial instrumen tation system for the commissioning and operation of the accelerator. Its accuracy and robustness are essential for ensuring the stability of the accelerator. Currently, the beam position is calculated by fitting a polynomial to the four volt age signals obtained from the BPM electrodes in BEPCII and HEPS. To improve the system's robustness, a formula is provided that expresses the relationship between the three voltage signals and the position. The average fitting error is 40 µm, but the error of the three-electrode calculation is not high. Therefore, we propose using neural networks for beam position calculation to improve the system's robust ness while guaranteeing its accuracy. This will ensure that the beam position can be provided stably, even in the case of one single electrode error. In our experiments, we use BPM calibration data from HEPS. The trained neural network's performance on the test set meets the accuracy requirements, with an error of less than 15 µm in both four-electrode and three-electrode predictions, and an average value of fitting error is 1 µm. Furthermore, we validate the neural network's generalization ability by using data measured by BPM on HEPS.

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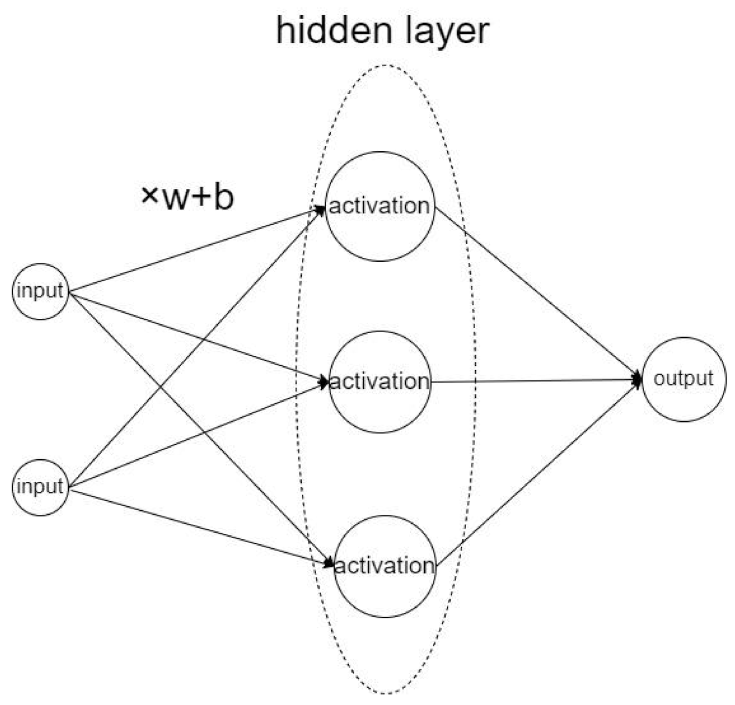

Figure 1: Neural network structure

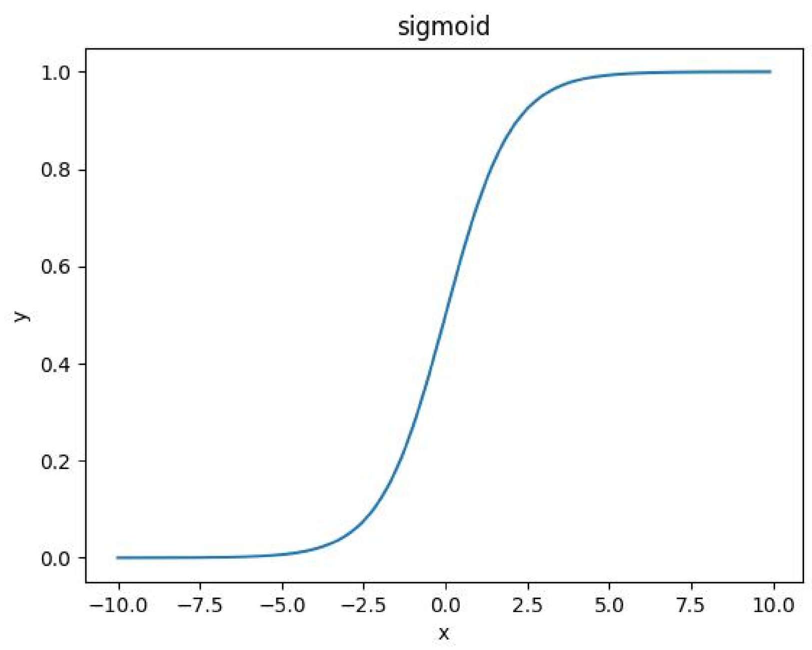

Figure 2: Sigmoid function

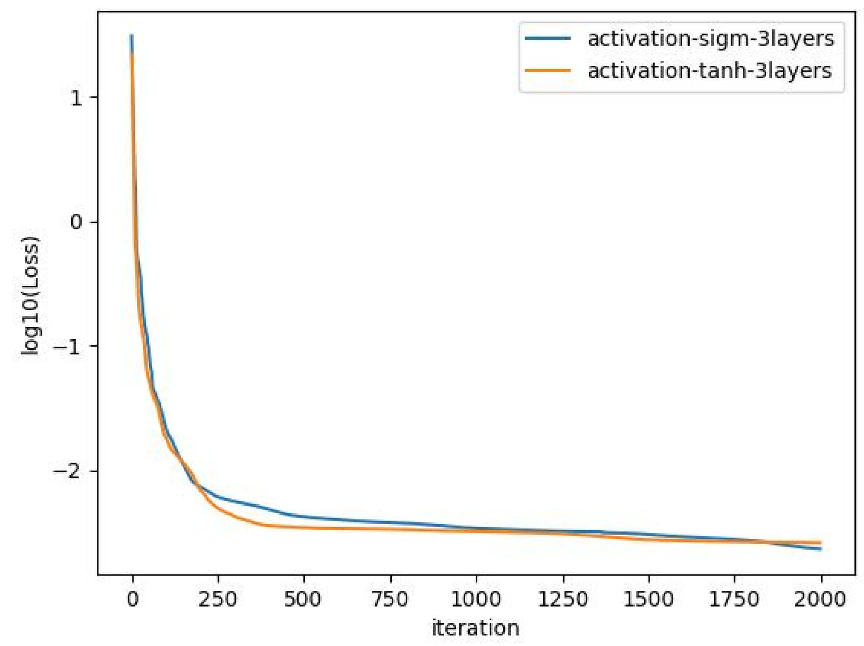

Figure 3: loss curves for different activation functions indicate that the choice of the nonlinear activation function does not significantly impact the training efficiency and accuracy of the results.

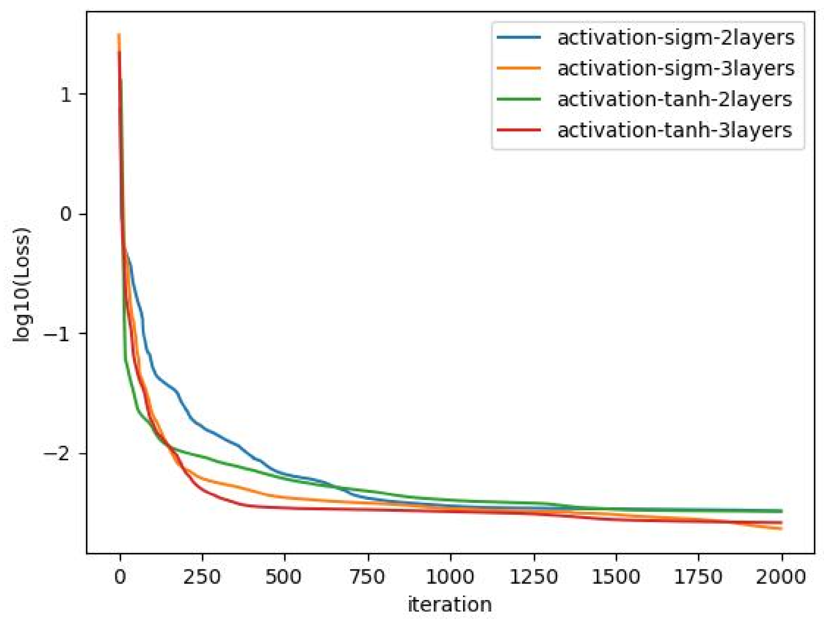

Figure 4: the experimental results demonstrate that the impact of three and two hidden layers on the precision of the results is not significant when the four voltages input is employed to determine the beam position.

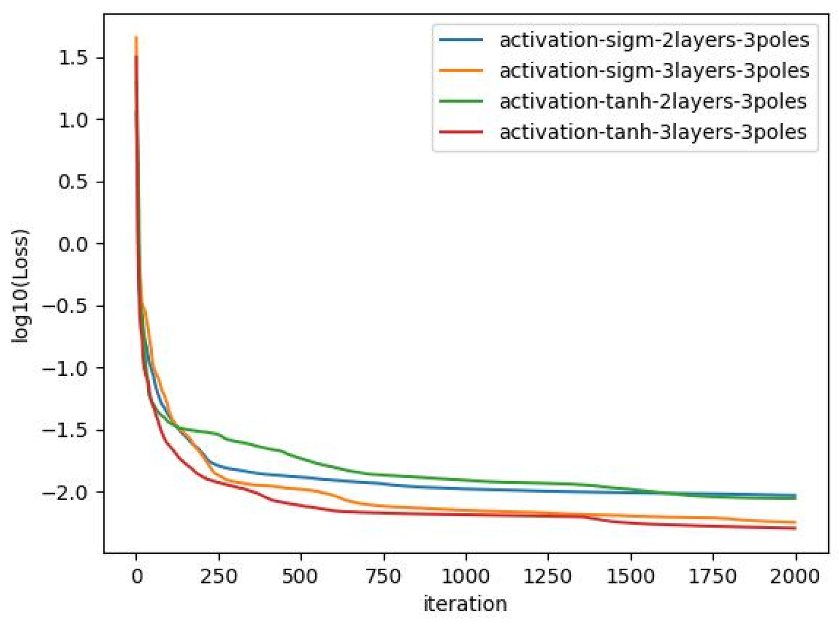

Figure5 : for the three voltages input, the three hidden layers yielded superior results compared to the two hidden layers for the same number of iterations.

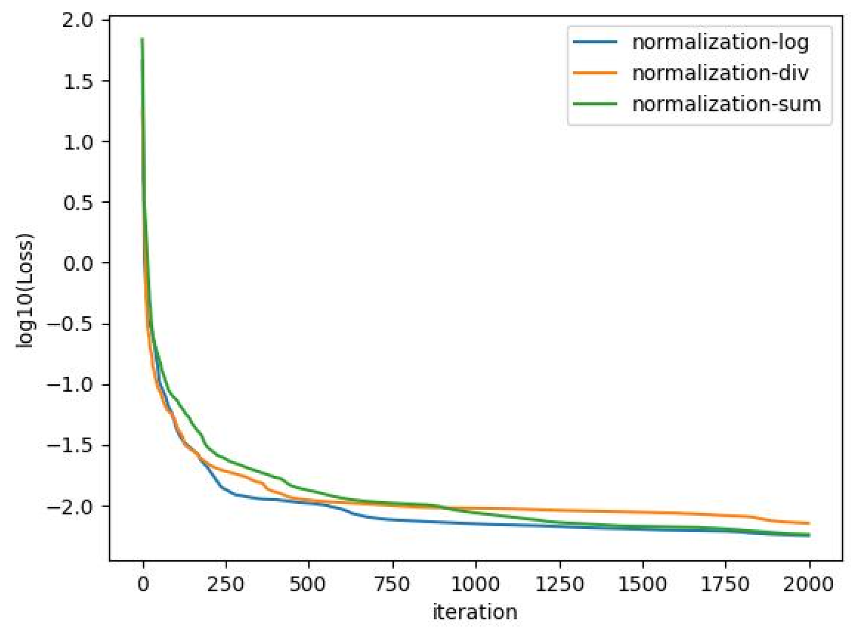

Figure 6: loss plots for different normalization methods.

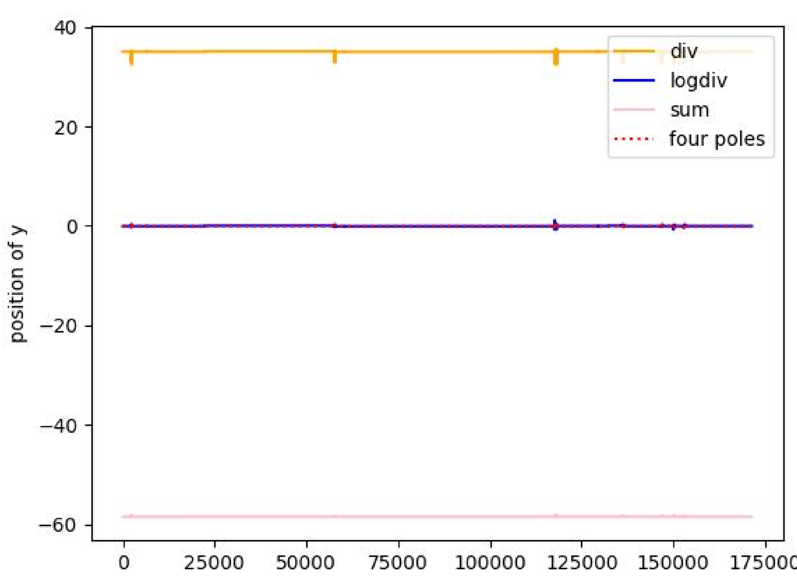

Figure 7: the results are excellent on the learning set, as shown in Fig. 6, but poor on the validation set.

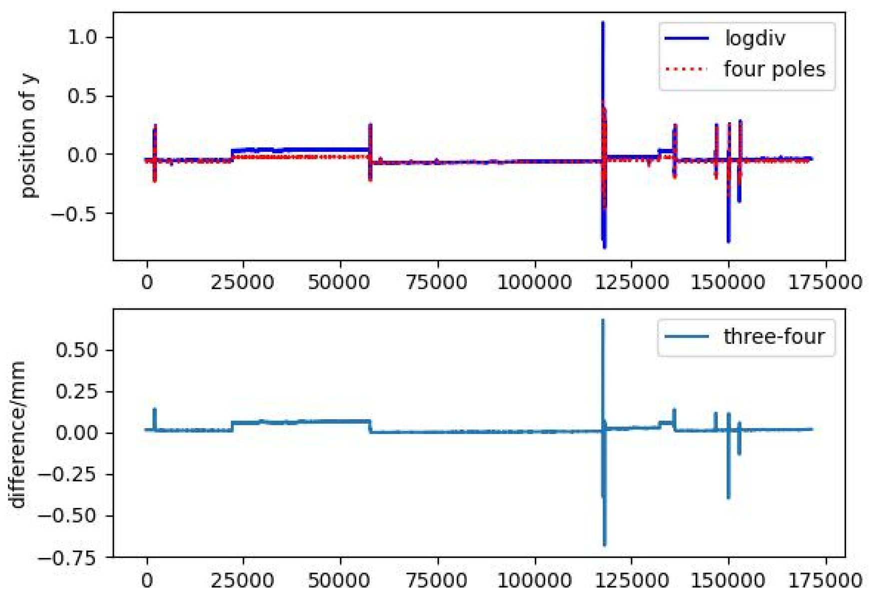

Figure 8: when using $V_i = -\ln\frac{V_i}{V_0} + 1$ as a normalization method on the validation set, the performance of both the four electrodes and the three electrodes tends to be similar.

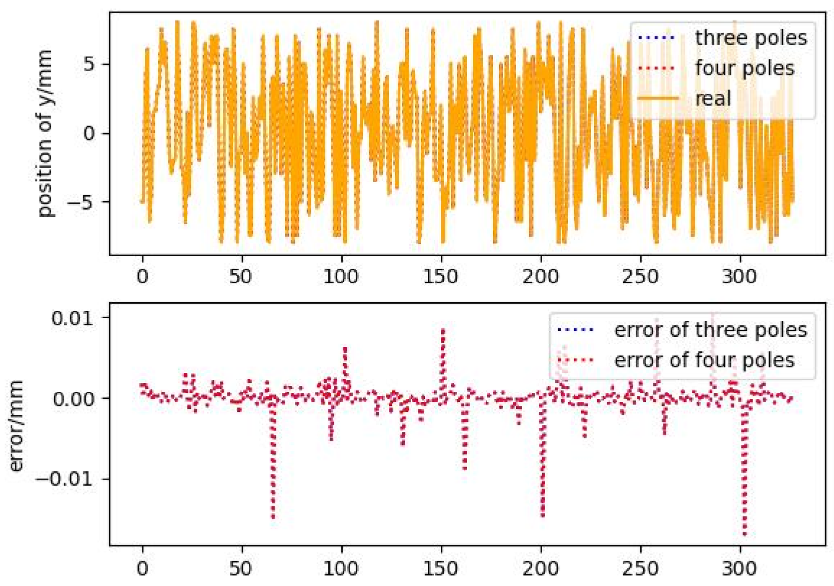

Figure 9: Based on the experimental findings, it is evident that the errors for three and four voltages are mostly below 5 µm on test set, with a few exceeding 5 µm but still within 10 µm, and only a small number falling within the 15 µm range.

Conclusion

It has been demonstrated that neural networks are capable of fitting any bounded continuous function. In our experiments, we have selected the appropriate normalization method, activation function and optimizer with the objective of reducing the average error in the calculation of the beam position to 1µm. Furthermore, we have conducted experiments which have shown that three electrodes can be used to calculate the beam position, thus improving the robustness of the system.