Temperature Prediction at FAST using LSTMs

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FERMILAB POSTER-22-127-STUDENT

Background

The temperature of the water entering the electron gun at FAST needs to be regulated to within ± 0.02 °C for adequate phase stability. The controllable variables are the flow control valve setting and the heater power setting.

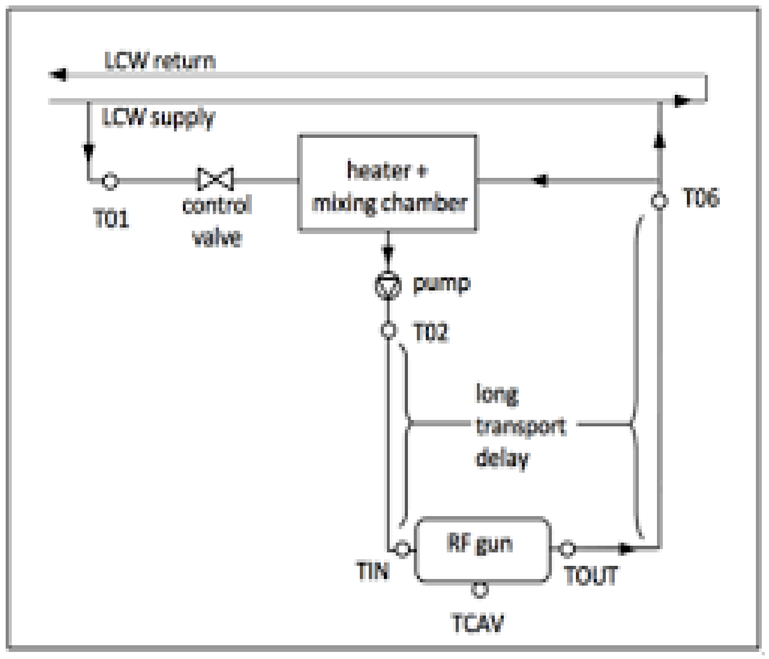

Figure 1: Layout of the gun water system. T01, T02, TIN, TCAV, TOUT, and T06 are temperature sensors.

A model was developed to predict the temperature of the cavity of the RF gun (TCAV) by getting the flow control valve setting, the power setting and the water flow rate as inputs.

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.

Modeling with LSTMs: Training

The model was trained using a Long Short-Term Memory network (LSTM), a type of recurrent neural network. In this NN, vectors with the sets of data are processed and the hidden state is passed to the next step of sequence. The input is combined with the previous hidden state to form a new vector with the new hidden state.

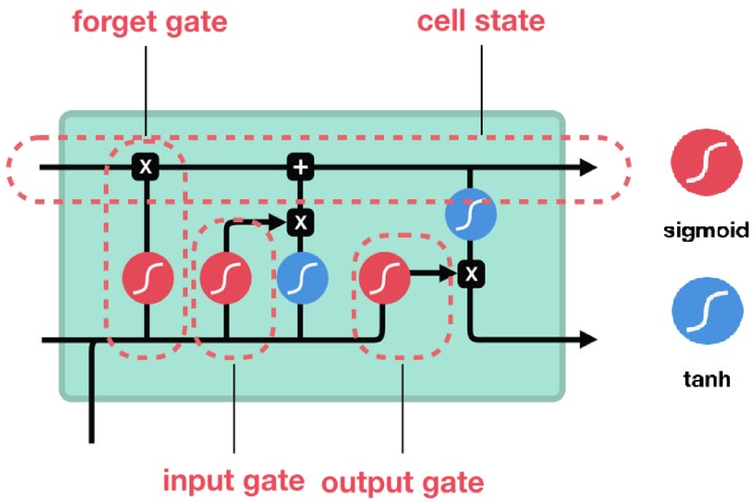

Figure 2: Module in a LSTM.

The LSTM removes or adds information to the cell state, regulated by the gates.

The forget gate decides what information should be thrown away from the cell state after passing the information from the previous hidden state and from input through a sigmoid function.

The input gate decides what values will be updated with a sigmoid function and a tanh function.

The output cell decides the next hidden state. The previous hidden state and input are passed through a sigmoid. Then, the new cell state is passed through a tanh function and multiplied by sigmoid output to decide the data the hidden state should carry.

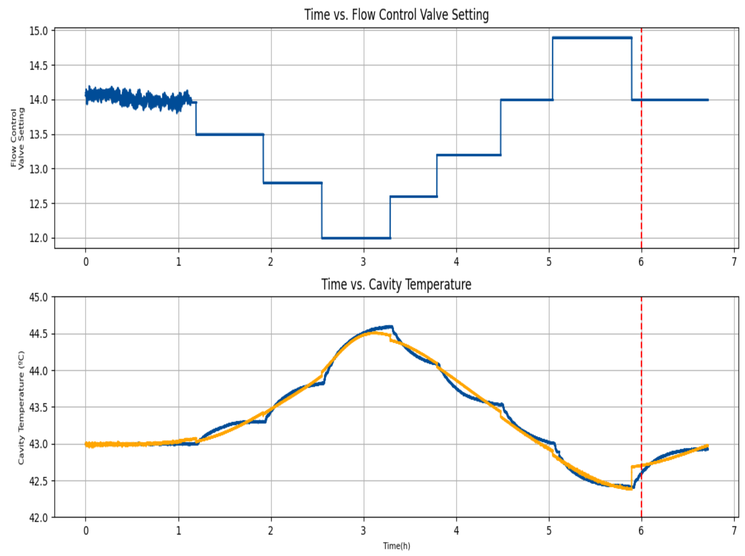

Figure 3: Comparison of change in temperature of the cavity with the predicted change in said temperature, along with the change in the flow control valve setting.

Conclusion

The next step would be to use the model to predict what adjustments at the inputs should be made to get the temperature to settle to a value faster.

This model was developed without making changes in the power setting and without TOUT or T06 readings. In the future, implementing these inputs in the model while training it to account for more changes could lead to more accurate predictions.

References

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[2] Zarzycki, K., & Ławryńczuk, M. (2021). LSTM and GRU neural networks as models of dynamical processes used in predictive control: A comparison of models developed for two chemical reactors. *Sensors*, *21*(16), 5625. https://doi.org/10.3390/s21165625