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# Plasma density raw signal prediction to duplicate feedback in tokamak control system to enhance reliability

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Tokamak is a promising device for producing nuclear fusion energy. Due to the high speed of physical processes, tokamak requires automation of control system to provide the most effective use. Researchers already proposed some essential automation such as gas puffing control system [[1]] and disruption mitigation system [[2]]. In turn, performance of those proposed automations highly relies on diagnostic data, especially on plasma density. Therefore, any fault occurred in plasma density data may lead to poor performance of the control system or even may lead to destructive consequences. To overcome the aforementioned challenge, this paper proposes utilization of artificial neural network to predict raw signal of plasma density to organize feedback duplication in tokamak control system. Thus, after detection of any fault in plasma density data (e.g., by threshold method), the tokamak control system could rely on predicted plasma density data and continue operating in normal mode. To prove the concept, a simple multilayer perceptron model [[3]] was used with 12 input neurons, two hidden layers with 100 neurons each, and one output neuron. Training data comprises experimental data from T-11M tokamak. All data went through cleaning, initial signal subtraction, and averaging. Input data contains information of plasma current, toroidal magnetic field, operating parameters of gas puffing system, signals of soft and hard x-ray, neutral lithium light emission from lithium limiter (LI I), vertical and horizontal shifts of plasma column center (Z, R). Operating parameters of the gas puffing system include time of opening valves and gas pressure before valves. Time of opening valves was transformed to an array of 0 and 1: if the valve is open at the moment, value is 1; otherwise, the value is 0. Output data (target) contains information of raw plasma density signal. Final dataset size is 184832 samples. Number of training epochs was 150, while loss (mean squared error) reached 0.0014. Figure 1 and 2 shows measured and predicted plasma density signals of shots number 40472 and 40751. Measured signals include some "noises", which can be a potential reason for malfunctioning of control systems relying on plasma density data. However, predicted plasma density signals are smooth when measured signals are "noised". Also, predicted plasma density signals are very close to the measured signals when the measured signals are smooth. Therefore, the proposed solution can provide duplication of feedback in today's and future tokamak control system, thus, enhance reliability of automation.

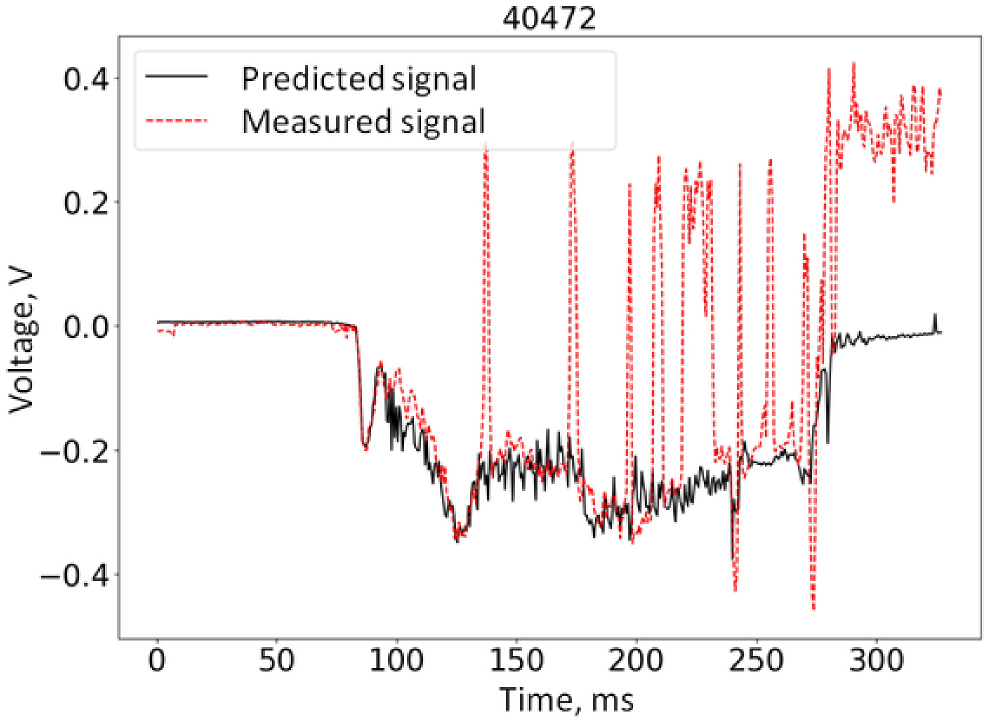


Figure 1: Measured and predicted plasma density raw signals shot 40472

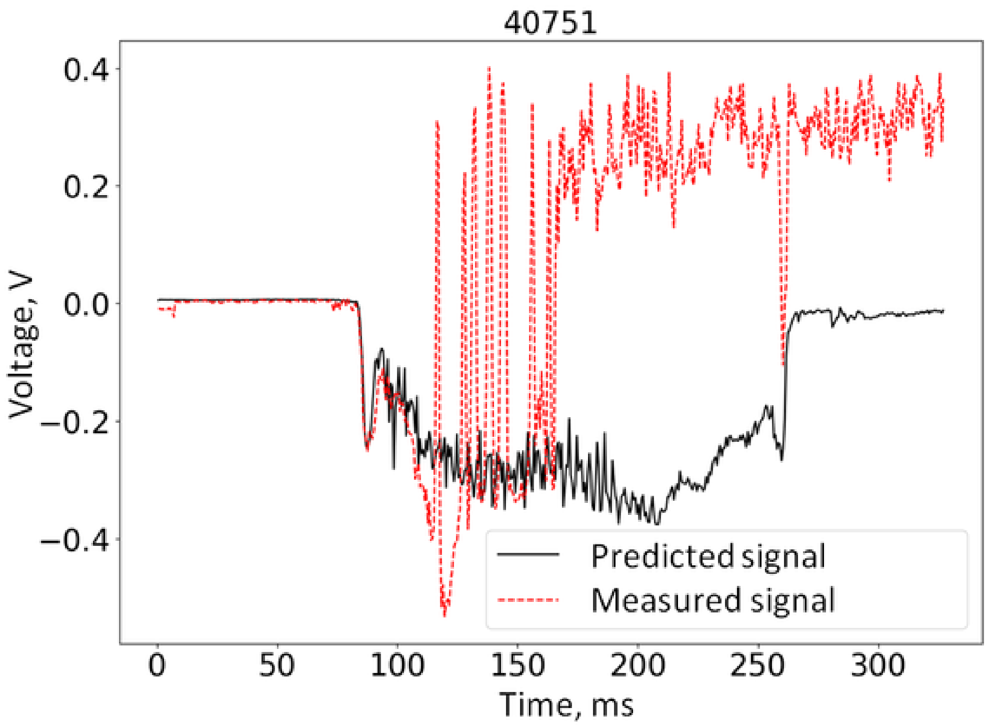


Figure 2: Measured and predicted plasma density raw signals shot 40751

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