Seminar

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Institute for Plasma Research

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Title: Development of Machine Learning Based Technique for Disruption Control and Prediction in ADITYA-U

Speaker: Mr. Ramesh Joshi
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Date: 13th March 2025 (Thursday)

Time: 2.00 PM

Venue: Seminar Hall, IPR

Abstract

The principal objective of ADITYA-U is to conduct focused experiments that encompass various activities including disruption prediction and exploration of mitigation strategies. This research focused on plasma disruption, highlighting the necessity of employing deep learning techniques for disruption prediction. The goal was to develop deep learning models that can predict plasma disruptions (where plasma particles and energy suddenly lose confinement) with sufficient warning time to enable mitigation strategies. The capacity of deep learning techniques to learn from complex data-driven approaches positions them as ideal tools for forecasting disruptions. We finalized an auto-encoder multivariate LSTM model analysing 9 diagnostic signals after assessment of various time series neural network techniques [1]. The model was trained on data from approximately 8,000 valuable plasma shots out of 30,000 available [2] and aimed to forecast disruptions at least 10 milliseconds before they occur [3]. We converted the Keras model in to c convertible code using keras2c for optimization (achieving 1200× speed improvement) [4]. The process of reading inputs and generating predictions within a frequency rate of 1 kHz has been validated, and the results have been benchmarked with prototype development. The prototype was validated using a univariate model to establish the scanning ADC input with various embedded hardware and infer the prediction output using different methodologies. The solution was integrated with high-speed embedded data acquisition hardware and deployed for real-time predictions at a 1 kHz frequency rate. Transfer learning techniques were used to avoid retraining the model to update the model with new plasma discharge data [5].

The system has successfully forecast the prediction over 600 plasma discharges in real-time operations, providing warning times between 3-25 milliseconds for disruption control. The average time of successful prediction is ~18ms to precursor the disruption event. It achieved an 84% successful prediction rate with 16% false alarms. Future plans include reducing classification errors and improving prediction performance by optimizing the neural network and adjusting dynamic threshold conditions.

References:

[1] R Joshi et al. Assessment of stacked LSTM, Bidirectional LSTM, ConvLSTM2D, and Auto encoders LSTM time series regression analysis at ADITYA-U tokamak [IEEE Transactions on Plasma Science, issue: January-2024, Volume-3, Pages 1-7, DOI: https://doi.org/10.1109/TPS.2024.3355283]
[2] R Joshi et al. Conceptual design and preliminary data analysis for classification of plasma disruption event at Aditya-U tokamak [PCCDS 2022 pp. 725-737 DOI: https://doi.org/10.52458/978-81-955020-5-9-69]
[3] R Joshi et al. DISRUPTION PREDICTION ON ADITYA/ADITYA-U USING FUTURE SEQUENCE BASED TIME SERIES NEURAL NETWORK [29TH IAEA FEC 16-21 Oct. 2023 London, U.K. https://conferences.iaea.org/event/316/papers/28423/]
[4] R Joshi et al. Analysis of different inference implementations for deep learning model on ADITYA-U tokamak [SocProS 23, Lecture Notes in Networks and Systems, vol 995. Springer, Singapore. https://doi.org/10.1007/978-981-97-3292-0_9]
[5] R Joshi et al. On-the-fly training architecture for time series neural network on ADITYA/ADITYA-U data [Radiation Effects and Defects in Solids, Pages 1–8., DOI: https://doi.org/10.1080/10420150.2024.2352847, May-2024]