Machine Learning and Deep learning Approach to Detect Dynamical States from Recurrence Plots and Recurrence Measures

Poster

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We combine machine learning and deep learning techniques with nonlinear time series analysis, focusing on recurrence plots, recurrence measures, and network measures, to classify various dynamical states arising from time series data. For this study, we employ three machine learning algorithms Logistic Regression, Random Forest, and Support Vector Machine alongside a deep learning CNN model. The CNN processes recurrence plot images as input, while the machine learning models utilize features extracted from recurrence quantification analysis (RQA) of nonlinear time series and measures derived from their corresponding recurrence networks. Synthetic data generated from standard nonlinear dynamical systems are used for training and testing, allowing us to assess the efficiency and performance of these algorithms in categorizing time series into periodic, chaotic, hyperchaotic, and noise categories. Additionally, we present a Python software tool designed to compute RQA and network measures and automate time-series classification. Furthermore, we demonstrate the application of the trained algorithms in predicting the dynamical states of two variable stars, SX Her and AC Her, using their light curve data. We also evaluate the model's performance on X-ray data from the black hole GRS 1915+105.

References

[1] Thakur, D., Mohan, A., Ambika, G., & Meena, C. (2024). Machine learning approach to detect dynamical states from recurrence measures. Chaos: An Interdisciplinary Journal of Nonlinear Science, 34(4). https://doi.org/10.1063/5.0196382

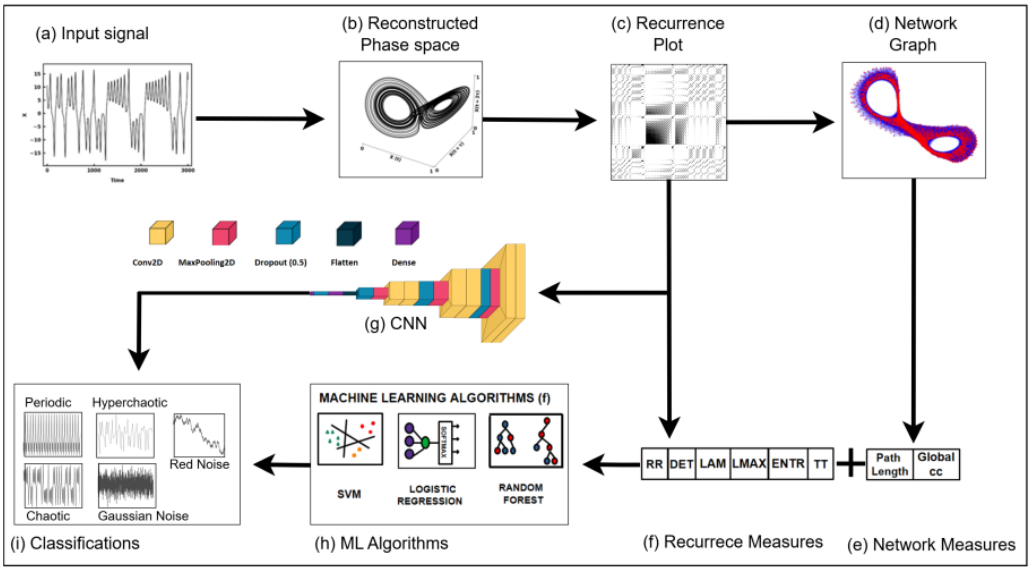

Figure 21: Schematic of the methodology developed for the classification of the time series data using machine learning and deep learning algorithms. From the given (a) nonlinear time series, we reconstruct the attractor (b) using time delay embedding. Following this, we generate (c) recurrence plots and (d) recurrence networks (nodes are shown in red and edges in blue). Then, we extract (f) and (e) six recurrence measures from the recurrence plots and two measures from the recurrence networks. These measures serve as features for the machine learning algorithms. (g)Recurrence plots are fed directly into the Convolutional Neural Network (CNN). (h) Logistic Regression, Random Forest, and Support Vector Machine. The final step (i) classifies the time series into four classes: periodic, chaotic, hyperchaotic, red noise, or noise.