

Interpretable Fuzzy-Embedded Deep Neural Network with its application in stock trading

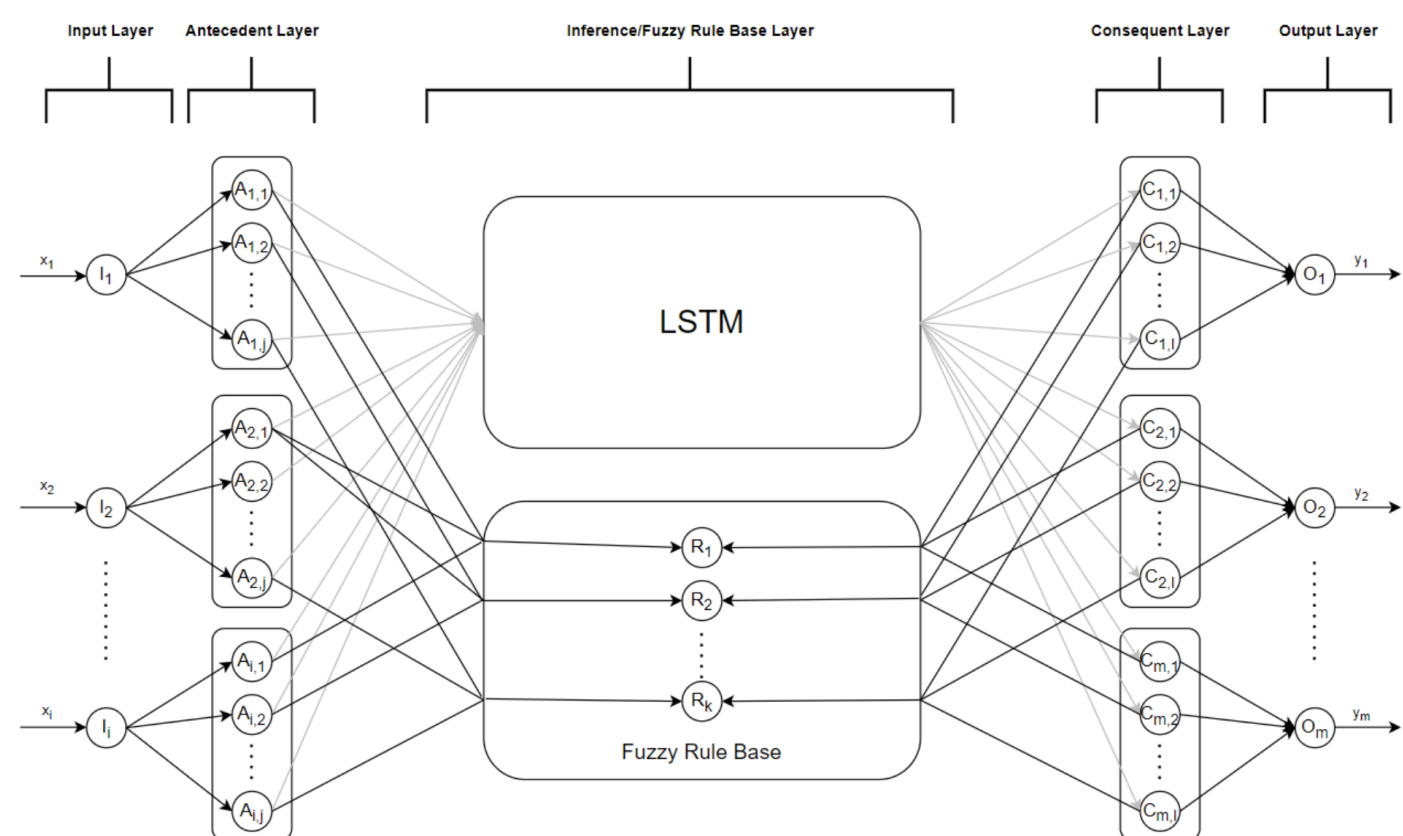
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Abstract

An interpretable **Fuzzy-Embedded Long Short-Term Memory (FE-LSTM)** architecture is proposed to introduce interpretability to the black-box nature of deep learning networks using fuzzy logic, which involves linguistic terms in Fuzzy IF-THEN rules that are more intuitively understood by humans. The FE-LSTM combines a Mamdani Fuzzy Inference System with a LSTM, thus achieving high accuracy and improved interpretability.

Design and Implementation

- The crisp inputs are fuzzified at the Antecedent layer
- The fuzzy membership functions are generated based on the clusters formed using the DBSTREAM incremental clustering algorithm
- The fuzzified inputs are fed into the LSTM and Fuzzy Rule Base, which both share the same input/output vocabulary
- LSTM maps the fuzzified inputs to fuzzified output values which are then defuzzified using the center-of-area defuzzification technique
- Fuzzy rule tagging is performed to tag the fuzzy IF-THEN rules to specific LSTM neurons



Application and Results

FE-LSTM is used to forecast future stock prices from $t+1$ to $t+12$ timesteps. The optimal feature set was determined by the MCES feature selection algorithm, and genetic algorithm was used to tune the LSTM hyperparameters. The FE-LSTM was able to achieve a high Pearson Correlation Coefficient (r) as well as a low RMSE.



Pearson's r	S&P500	FTSE100	CAC40
t+1	0.9950	0.9455	0.9747
t+6	0.9898	0.9013	0.9597
t+12	0.9844	0.8677	0.9380

The forecasted future prices are incorporated into the moving average calculations used in the MACD technical indicator to reduce time lag. The Advantage Actor-Critic (A2C) Reinforcement Learning algorithm is used to generate buy and sell signals of each individual stock using the MACD values as part of the state space.

The Deep Deterministic Policy Gradient (DDPG) RL algorithm is then used to trade and rebalance the portfolio of stocks. The trading strategy for the portfolio was able to outperform the conventional buy-and-hold strategy.

Multiplicative Profits	Buy-and-hold	RL Model
S&P500	94.8331%	102.5244%
FTSE100	21.3220%	17.5434%
CAC40	46.9562%	50.9639%
Portfolio	54.3738%	64.5430%