Lecture 6. MDSE for

Integrating Times Series and Text Data

in Finance and Economics

I AbouHassan, N Kasabov, V Jagtap, P Kulkarni
"Spiking Neural Networks for Predictive and Explainable Modelling
of Multimodal Streaming Data with a Case Study
on Financial Time Series and Online News,"
SREP, Springer-Nature, Sci Rep 13, 18367 (2023),
https://doi.org/10.1038/s41598-023-42605-0.

MDSE is a new discipline in science and engineering that develops new methods and their engineering implementations for integrating the processing of multiple modalities (e.g., different types) of data into one system for better performance compared with systems that deal with single modalities.

Advantages:

- *MDSE offers a holistic approach to better problem solving, considering multiple related factors.*
- *MDSE can extract novel associations between different modalities of data for new knowledge discovery.*
- *MDSE can offer a better prediction of future events.*

Examples:

- *Integrating multiple medical factors in health predictive modelling.*
- *Integrating multiple sensory information for environment prediction.*
- *Integrating audio and visual information.*
- *Integrating multiple factors for financial and economic predict*The course is by research papers

1- Topic/task/problem specification - Challenges:

- **Can SNNs integrate and model multimodal streaming data, particularly focusing on financial time series and online news data?**
- **Can SNNs integrate time series with online news and text information to effectively predict and understand financial markets?**
- **Can SNNs integrate and explain the real-time dynamic interactions between different data types compared to traditional machine learning models?**

2- Previously published methods for solving the problem:

Existing methods, such as ***traditional machine learning*** and ***deep learning techniques*****,** have made significant advances in improving predictions by leveraging the textual content of news, but they still face limitations in handling online, incremental, and adaptive learning and integrating these with real-time news updates effectively.

A more dynamic and integrative approach, we propose, which uses spiking neural networks (SNNs) for more robust and explainable modelling of multimodal streaming data.

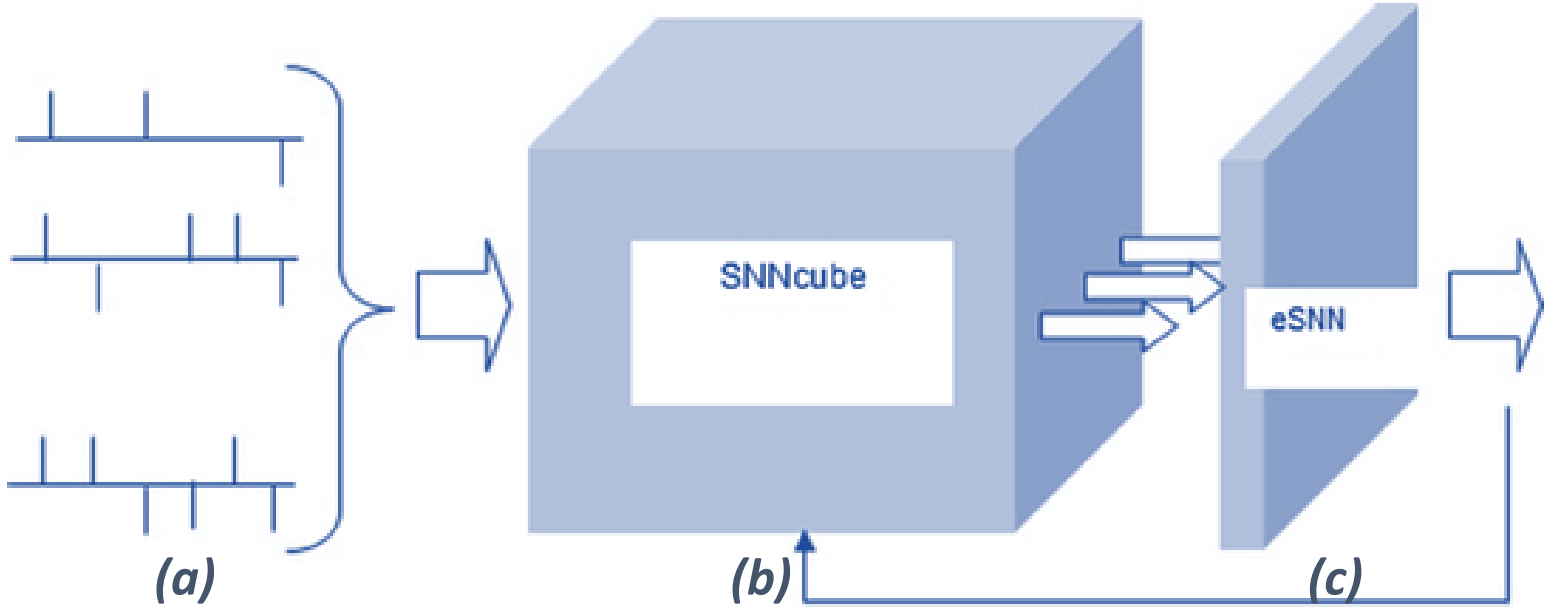
and
we propose

3- The Proposed Method – Unified SNN Framework:

Unified SNN Framework

to improve predictive accuracy and provides interpretative insights into the interactions between stock variables and news information.

3- The Proposed Method – A functional diagram of the NeuCube SNN architecture:

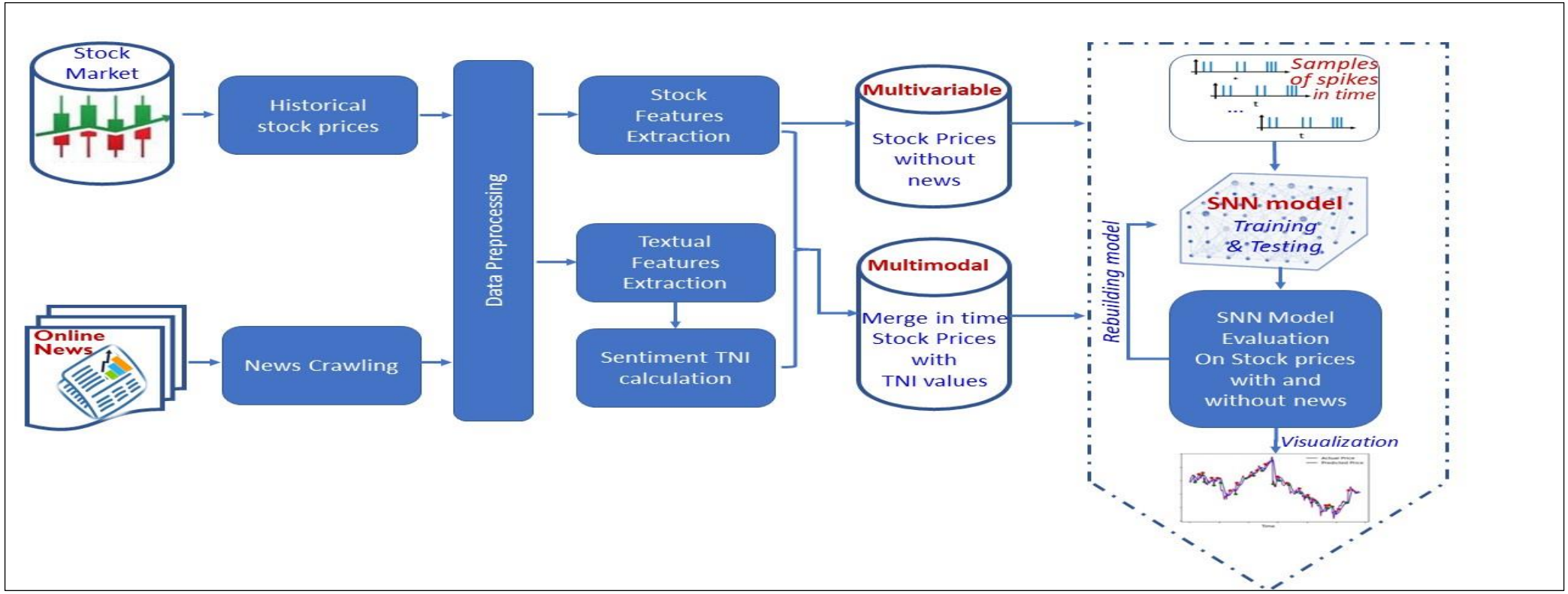


(a) The input data encoding module, which transforms continuous input data into trains of spikes, uses encoding algorithms,

(b) 3D SNN cube module, where spatio-temporal data are mapped into predefined areas, and unsupervised training of STDP is applied, that allows learning spatio-temporal relations from input data;

(c) Output deSNN regression module for supervised learning, where a new output neuron is dynamically allocated and connected to the neurons in the SNNcube using the Rank Order rule and a drift parameter.

3- The Proposed Method – Unified SNN Framework (cont'd):



A functional diagram of the prosed SNN-based methodology illustrated on the case study of financial stock data.

3- The Proposed Method – Unified SNN Framework (cont'd):

A. Unified SNN Framework Implementation:

- Multimodal Integration and combining Time Series and Online News Data.
- Historical financial stock time series prices were combined with real-time online news.
- Using the BI-SNN-based 'NeuCube' architecture.
- 'NeuCube' offers holistic decision support and improved predictive accuracy.

B. Advantages of Multimodal Integration using the BI-SNN-based 'NeuCube':

- Extracting meaningful insights,
- improved predictive accuracy,
- a deeper contextual understanding,
- real-time decision support,
- sentiment analysis,
- anomaly detection,
- the potential to revolutionise decision-making processes in finance and economics.

4- A Unified SNN Framework: Multiple time series data:

- Stock indices (spatial features): Wipro Limited [WIT], Microsoft Corporation [MSFT], Lennar Corporation [LEN], International Business Machines [IBM], Adamis Pharmaceuticals Corporation [ADMP], Alphabet Inc. [GOOG], Reliance Industries Ltd. [RIL], and Tata Consultancy Services [TCS].
- News variable [NWS] quantified to a decimal value.
- Original dataset (temporal features): 129 daily observations for 9 variables.
- Sample generation: 70 Samples, each of which contained 60 timed sequences of daily closing prices.
- New dataset = 37,800 data points (4,200 observations for 9 variables)
- The target values representing the closing price of ***WIT*** on the next day are arranged in a column in the target file.

4- A Unified SNN Framework - Encoding Online News:

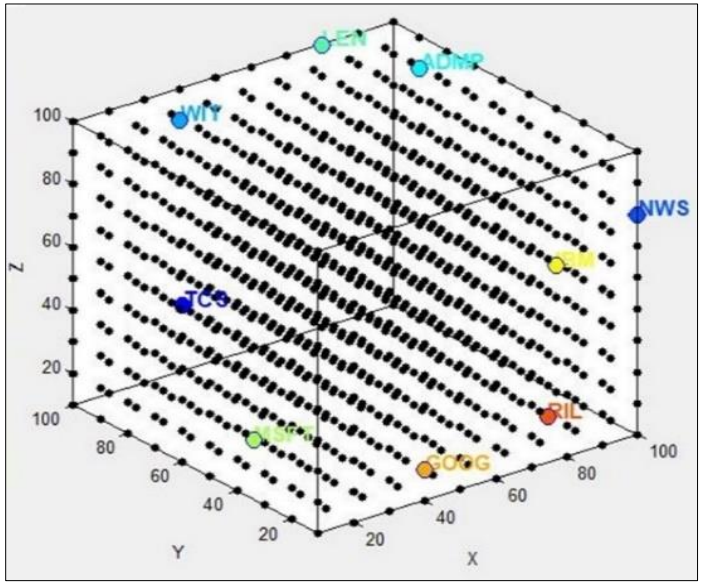
- a Turning News Index (TNI) is used to encode online news texts into a numerical time.
- TNI is linked to stock prices and calculated using the Bag of Words (BoW) method.
- BoW measures the importance of words based on their frequency in the document, ignoring word order.
- News is classified as 'direct' or 'indirect' based on the occurrence of the word and the topic of the news.
- Classified news is quantified using the BoW approach, and the TF-IDF is used to calculate TNI.
- TF is the term frequency, which determines the significance of a term in a document
- IDF is the Inverse Document Frequency, which measures the rarity of a term.
- TF-IDF assigns a numerical weight to words based on how important a word is.
- TNI = TF-IDF. The upward and downward trends are analysed using numerical values from the input text.
- The news can be quantified in the [-1, +1] range to indicate the trend's upward or downward direction and in the [0, 1] range to indicate the probability value of news impact on the stock.

4- A Unified SNN Framework for Multimodal Data Integration (cont'd):

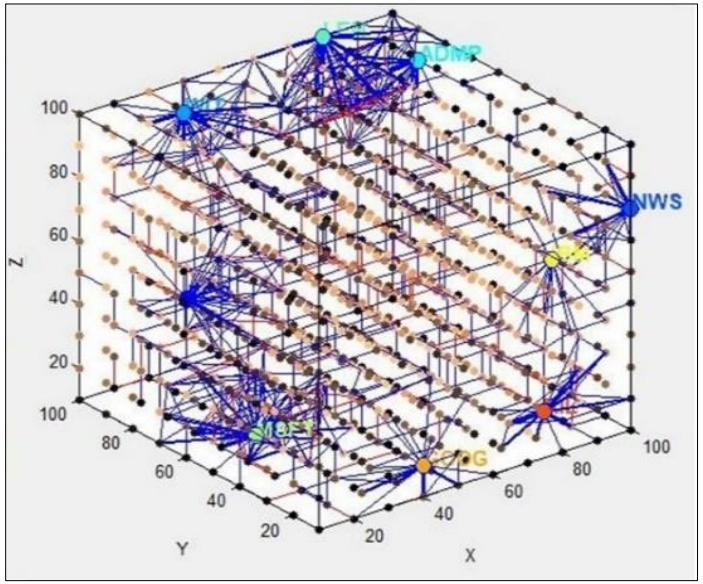
- The generated samples are transformed into trains of spikes (Th = 0.5) with a split of 50/50 for training/validating processes.
- Assign 1000 spiking neurons using a graph-matching algorithm to allocate input neurons based on their time series similarity.
- Regulating the initial connection weights between neighbouring neurons in the reservoir with small-world connectivity of radius 2.5.
- Setting the unsupervised learning parameters: Spike-Time Dependent Plasticity (STDP) = 0.001, leak rate = 0.002, firing threshold = 0.5, refractory period = 6, and 2 training iterations.
- Setting the supervised learning parameters: Modulation factor = 0.8, and drift parameter = 0.005.
- When online news was integrated, the achieved RMSE on 50% of the data selected for testing was enhanced by 25%.

4- A Unified SNN Framework for Multimodal Data Integration (cont'd):

Mapping and neuronal connections in the reservoir



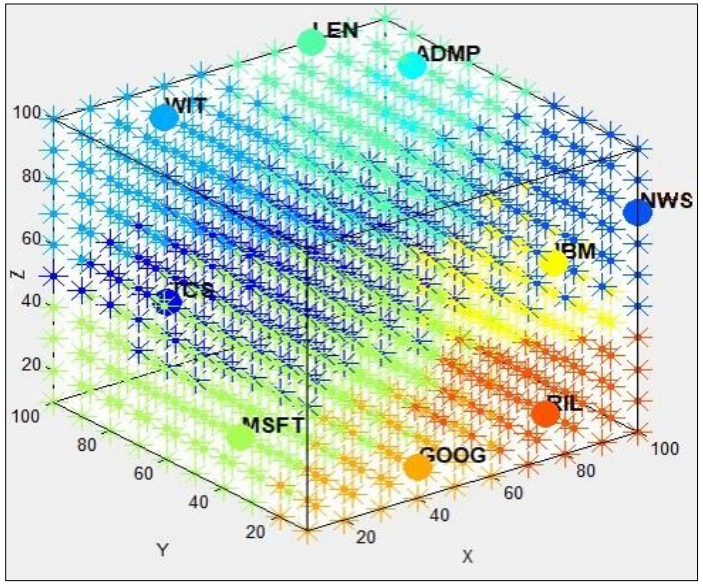
Mapping time series variables including online news variable (NWS) into a 3D SNN.



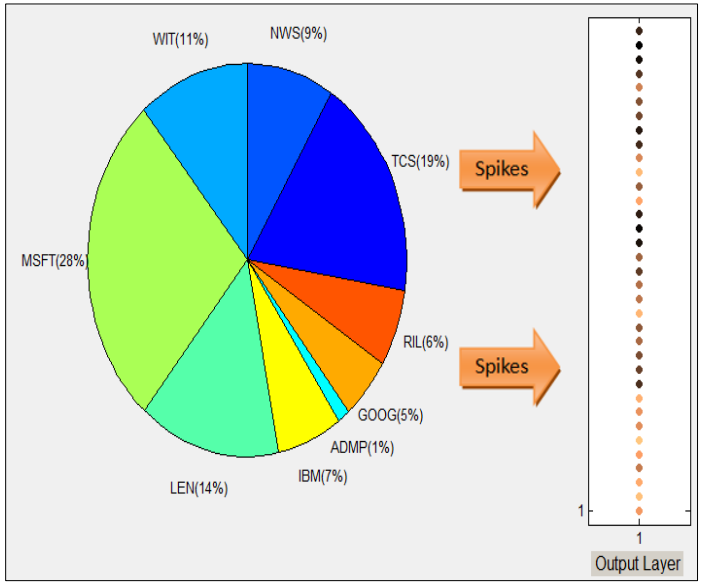
Resulted connectivity of a trained SNN model on the 8 stock time series and on-line news (NWS).

4- A Unified SNN Framework for Multimodal Data Integration (cont'd):

Results of the analysis of the trained model on stock indexes and on-line news



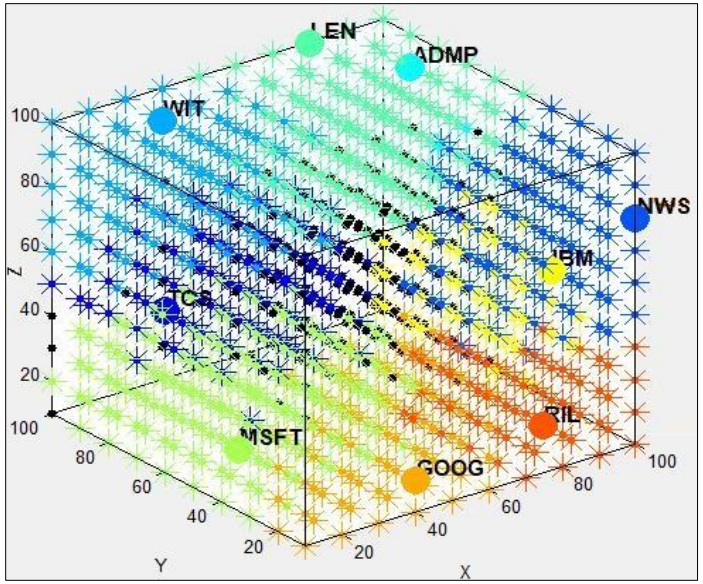
Clustered neurons according to their maximum connection weight with an input neuron (input variables);



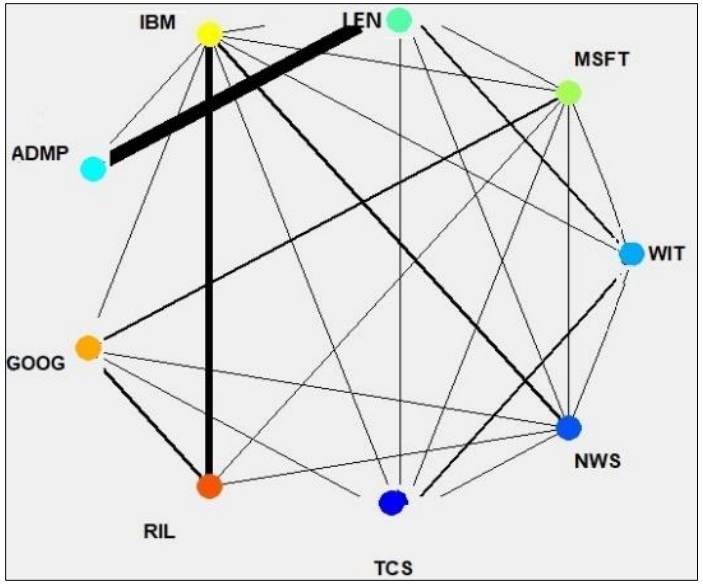
Percentage of neurons with maximum connection weights to each of the input neurons represents the impact of the input variables on the model functionality.

4- A Unified SNN Framework for Multimodal Data Integration (cont'd):

Results of the analysis of the trained model on stock indexes and on-line news



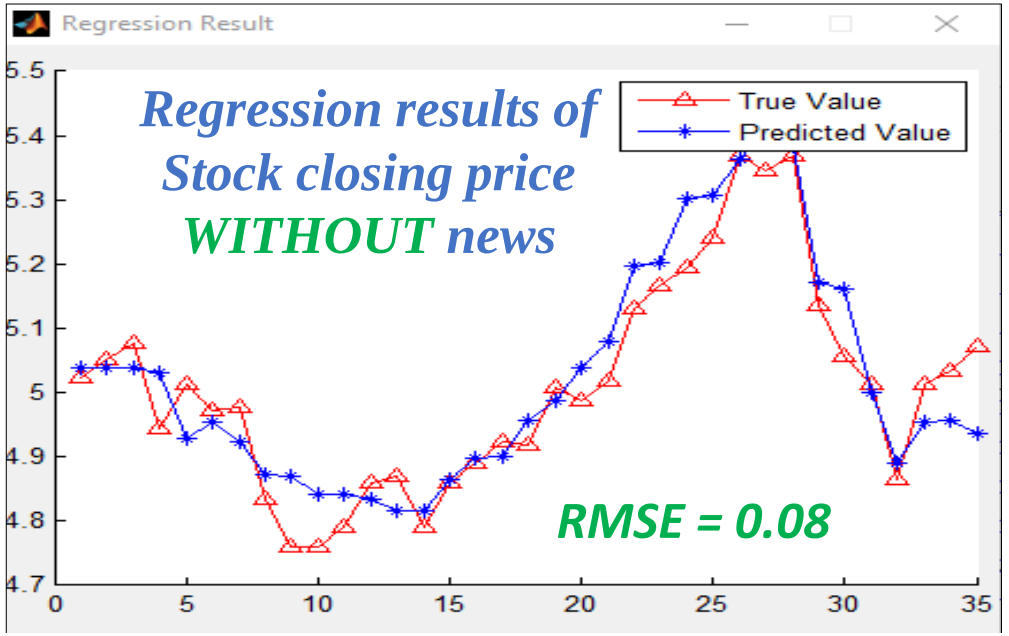
Clustering of neurons in SNN model according to max number of spikes received from an input neuron, shows dynamics of neurons' interactions.

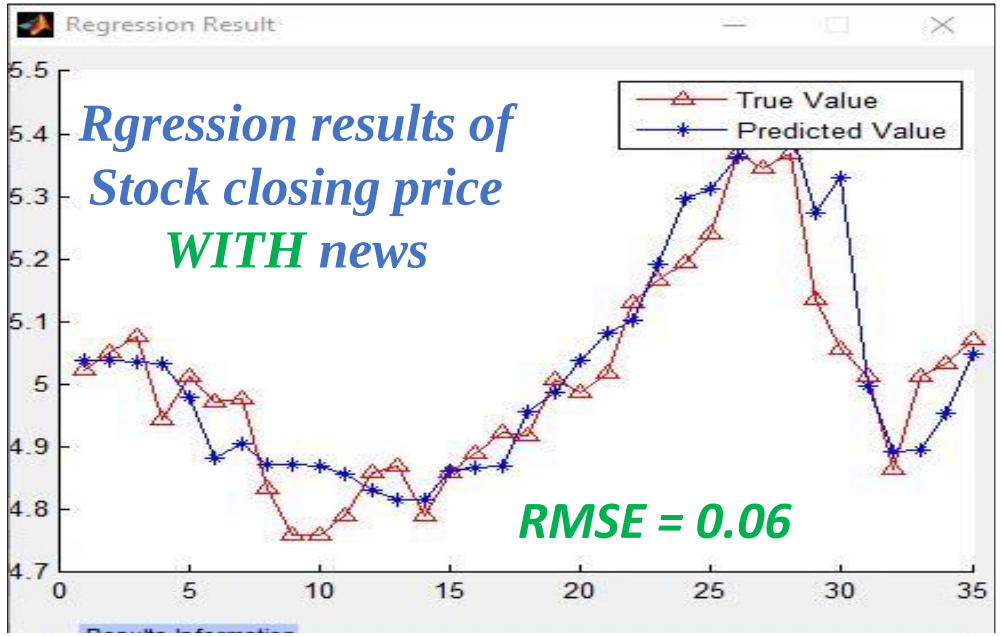


Feature Interaction Network - dynamic graph, where the thickness of the arcs shows the intensity of spike exchange between corresponding input neurons.

5- A Unified SNN Framework for Multimodal Data Integration (Single stock):

The resulted accuracy of incremental learning and prediction

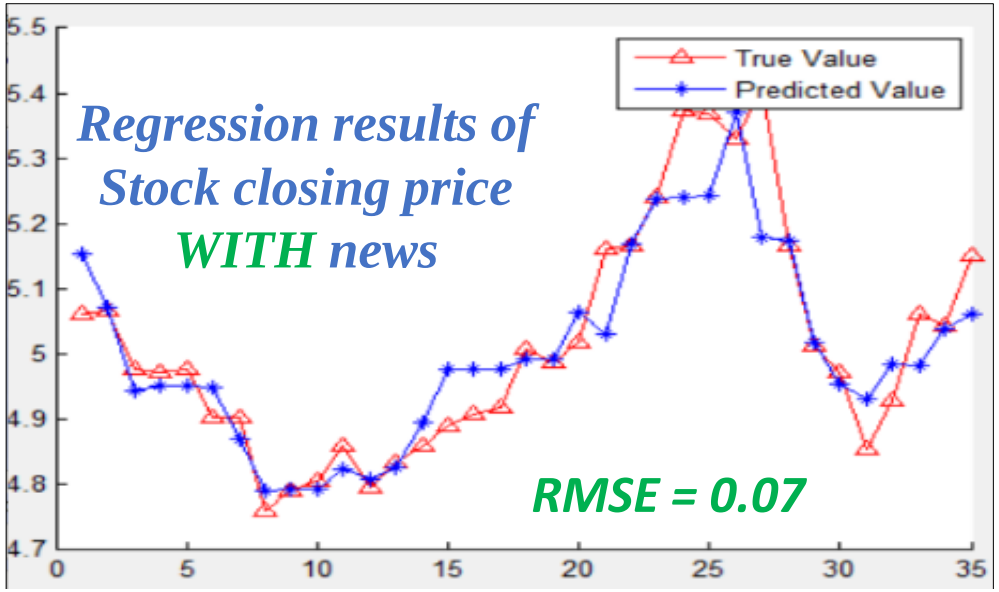




Predicting the WIT stock value one day ahead by using the previous 60 days' values of the 8 stock variables and online news leads to a reduced predictive error compared to forecasting the WIT stock without integrating the online news.

5- A Unified SNN Framework for Multimodal Data Integration (Single stock):

Results on predictive modelling of a single time series using its OHLC variables



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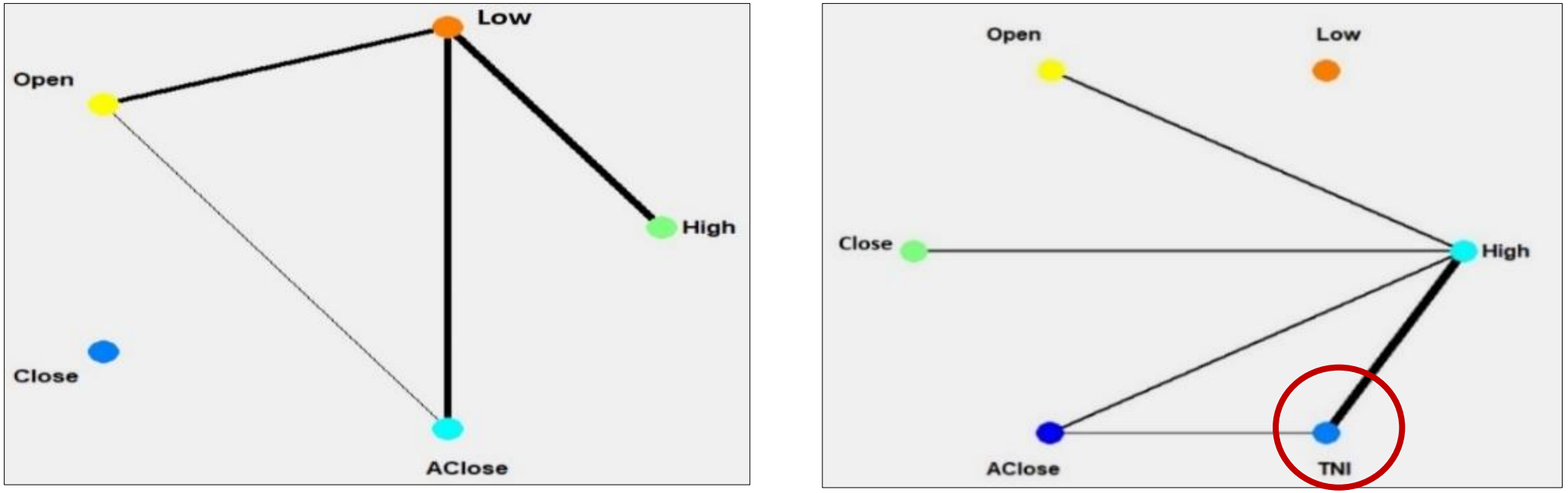


The variable interaction network graph between the features without news indicator (left) and with news indicator (right).

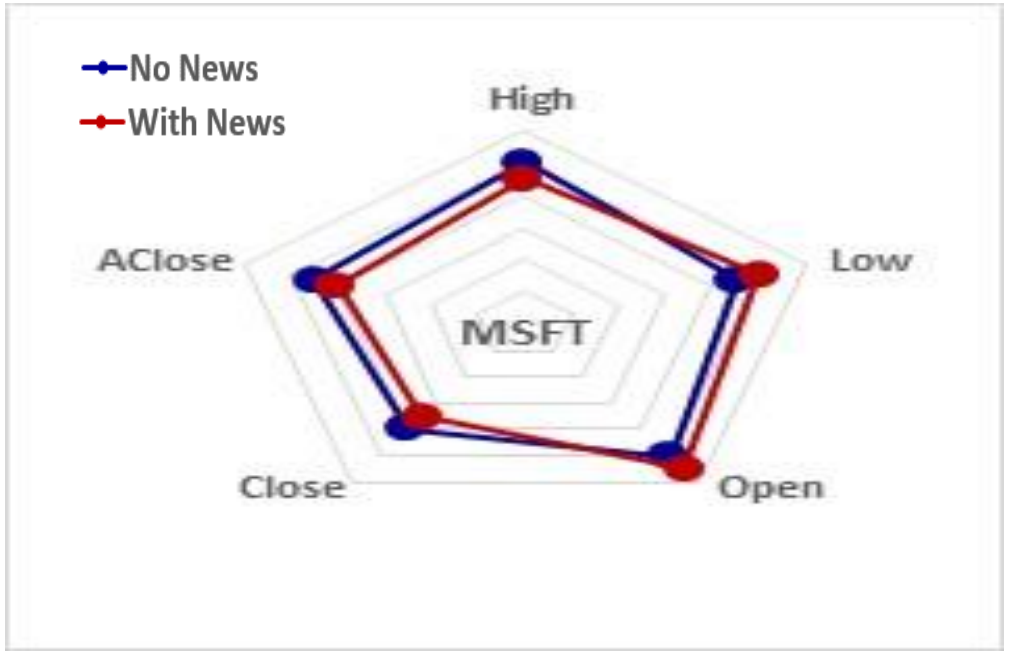
5- A Unified SNN Framework for Multimodal Data Integration (Single stock):

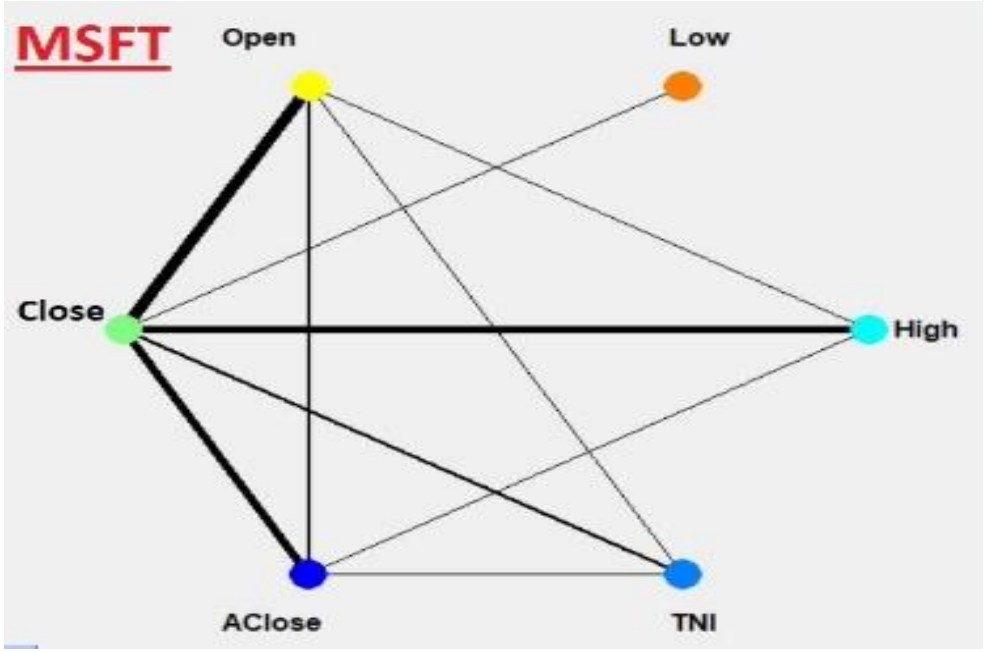
Comparative analysis of the effect of news on the predictive accuracy of other stock TS

Analysis and interpretation of the results of the 64 experimental models (4 x 8 x 2) on the predictive modelling of each of the 4 OHLC features of each of the 8 stock indexes with- and without using the same TNI news indicator. For each stock index, the following explanatory information is derived to evaluate the impact of adding News information on the RMSE of the adjusted close price prediction: a radar chart, showing how close the RMSE is to zero (the center of the chart); a feature interaction network; text, explaining the impact of the encoded News as TNI index on the predictive accuracy. .

5- A Unified SNN Framework for Multimodal Data Integration (Single stock):

Comparative analysis of the effect of news on the predictive accuracy of other stock TS

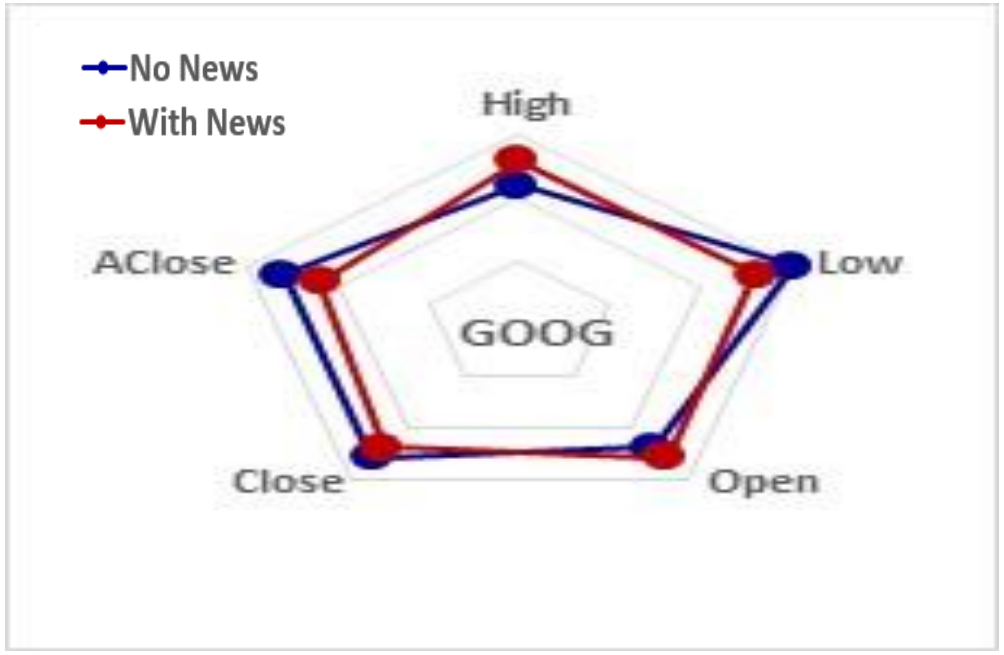


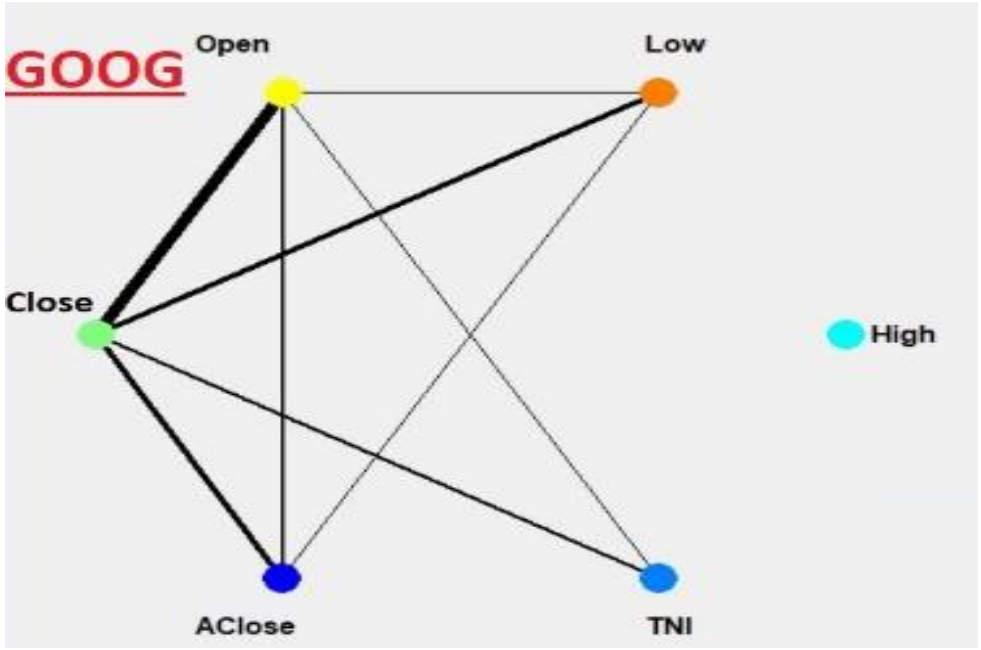


MSFT adj. close price is directly affected by TNI & the improvement of its Close & High which outpace the negative influence of its Open price.

5- A Unified SNN Framework for Multimodal Data Integration (Single stock):

Comparative analysis of the effect of news on the predictive accuracy of other stock TS





GOOG adj. close price improves due to strong activity with its Close price (influenced positively by TNI) versus its Open price (influenced negatively by TNI).

6- Conclusion:

Comparative analysis of the effect of news on the predictive accuracy of other stock TS

- *The proposed SNN approach for integrating times series and online news in predictive models is inspired by the human brain's ability to incrementally incorporate different temporal sources of information.*
- *SNN models capture the direction of influence between input features, allowing for causal associations to be identified.*
- *The method numerically estimates the impact of news on the predictive accuracy of time series variables and offers interpretation and explanation. However, further studies are needed to address questions such as news source choice, relevance over time, parameter optimisation, and better integration of human knowledge and machine intelligence.*
- *The challenge for machine intelligence is to develop efficient and explainable computational models suitable for hardware and low-energy neuromorphic and quantum hardware platforms.*
- *The proposed methodology can be extended to specific domain areas, such as cognitive studies, seismic studies, personalised wearable devices, and global warming prediction.*

Thank you for your attention!