GCN-FinBERT-LSTM: A Graph Convolutional Deep Fusion Model for Multimodal Stock Market Prediction

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Abstract

Time series forecasting models play a crucial role as decision support tools in various real-world domains. Among them, stock market represents a notably complex domain, characterized by a rapidly evolving temporal nature and a multitude of factors influencing stock prices. While many machine learning-based approaches for stock trend prediction have been proposed in the literature, they often focus on analyzing a single data source or modality. Additionally, those considering multiple modalities often do not consider correlations between different stocks, which limits their predictive power. In this paper, we introduce a novel multimodal deep fusion model for predicting stock trends. Our approach incorporates diverse data sources, including stock prices, technical indicators, graph-based stock interactions, and sentiment extracted from daily news headlines published by media outlets. Our model architecture consists of a Bidirectional Encoder Representations from Transformers (BERT) model branch fine-tuned on financial news, a Long Short-Term Memory (LSTM) branch, and a Graph Convolutional Network (GCN) branch that captures salient temporal patterns in multi-stock data, encompassing stock prices and technical indicators. Our experiments, conducted on data from 17 comprehensive real-world stocks, reveal that our method is capable of effectively predicting market dynamics, outperforming popular baseline approaches, and yielding capital preservation capabilities in downtrend market conditions. Moreover, we showcase the effective trading performance of our model in portfolio analysis simulations, highlighting the positive impact of multimodal deep learning for stock trend prediction.

Keywords: Sentiment analysis; polarity detection; algorithmic fairness; bias

Appendix

Model accuracy

For Activision Blizzard (ATVI), the best-performing model in uptrend market conditions is Polarity with an F1-Score of 0.63, followed by LSTM (0.58), Proposed (0.49), GBTs (0.49), ARIMA (0.45), Bi-LSTM (0.45), CNN-LSTM (0.42), CNN-Seq2Seq (0.4), Attention-CNN-LSTM (0.39), GRU-CNN (0.39), and Dilated CNN Seq2Seq (0.38). The worst-performing model in uptrend is Dilated CNN Seq2Seq with an F1-Score of 0.38. In downtrend market conditions, the best model is GBTs with an F1-Score of 0.56, followed by Proposed (0.54), ARIMA (0.52), LSTM (0.49), Bi-LSTM (0.49), CNN-LSTM (0.47), Polarity (0.46), Attention-CNN-LSTM (0.46), Dilated CNN Seq2Seq (0.45), CNN-Seq2Seq (0.43), and GRU-CNN (0.28). The worst-performing model in downtrend is GRU-CNN with an F1-Score of 0.28.

Turning our attention to Google (GOOG), the best-performing model in uptrend market conditions is Polarity with an F1-Score of 0.58, followed by GBTs (0.56), GRU-CNN (0.54), Proposed (0.51), LSTM (0.48), ARIMA (0.45), Bi-LSTM (0.44), CNN-Seq2Seq (0.45), CNN-LSTM (0.45), Attention-CNN-LSTM (0.43), and Dilated CNN Seq2Seq (0.43). The worst-performing models in uptrend are Attention-CNN-LSTM and Dilated CNN Seq2Seq with an F1-Score of 0.43. In downtrend market conditions, the best model is GBTs with an F1-Score of 0.4, followed by Polarity (0.52), GRU-CNN (0.5), LSTM (0.48), ARIMA (0.45), Bi-LSTM (0.44), Proposed (0.41), Attention-CNN-LSTM (0.4), Dilated CNN Seq2Seq (0.39), CNN-Seq2Seq (0.38), and CNN-LSTM (0.37). The worst-performing model in downtrend is CNN-LSTM with an F1-Score of 0.37.

Moving on to Netflix (NFLX), the best model for uptrends is GBTs with an F1-Score of 0.54, followed by LSTM (0.51), Polarity (0.51), Proposed (0.45), CNN-Seq2Seq (0.45), GRU-CNN (0.44), ARIMA (0.41), Dilated CNN Seq2Seq (0.4), CNN-LSTM (0.4), Attention-CNN-LSTM (0.39), and Bi-LSTM (0.38). The worst-performing model for uptrends is Bi-LSTM with an F1-Score of 0.38. For downtrend prediction, the best model is Proposed with an F1-Score of 0.51, followed by GBTs (0.5), ARIMA (0.5), Polarity (0.46), Bi-LSTM (0.45), LSTM (0.44), GRU-CNN (0.41), Dilated CNN Seq2Seq (0.4), Attention-CNN-LSTM (0.4), CNN-LSTM (0.39), and CNN-Seq2Seq (0.39). The worst-performing models for downtrends are CNN-LSTM and CNN-Seq2Seq with an F1-Score of 0.39.

For Amazon (AMZN), the best-performing models in uptrend market conditions are GBTs and LSTM with an F1-Score of 0.55, followed by Proposed (0.5), GRU-CNN (0.49), ARIMA (0.47), CNN-Seq2Seq (0.4), CNN-LSTM (0.39), Attention-CNN-LSTM (0.39), Bi-LSTM (0.38), Polarity (0.37), and Dilated CNN Seq2Seq (0.36). The worst-performing model in uptrend is Dilated CNN Seq2Seq with an F1-Score of 0.36. In downtrend market conditions, the best model is CNN-LSTM with an F1-Score of 0.51, followed by Polarity (0.5), GBTs (0.5), CNN-Seq2Seq (0.49), Proposed (0.48), Bi-LSTM (0.47), Dilated CNN Seq2Seq (0.46), ARIMA (0.46), Attention-CNN-LSTM (0.46), LSTM (0.42), and GRU-CNN (0.35). The worst-performing model in downtrend is GRU-CNN with an F1-Score of 0.35.

In eBay (EBAY), the best-performing model in uptrend market conditions is GBTs with an F1-Score of 0.55, followed by Bi-LSTM (0.48), LSTM (0.48), Proposed (0.46), CNN-LSTM (0.45), CNN-Seq2Seq (0.44), Polarity (0.42), Dilated CNN Seq2Seq (0.42), ARIMA (0.4), GRU-CNN (0.4), and Attention-CNN-LSTM (0.36). The worst-performing model in uptrend is Attention-CNN-LSTM with an F1-Score of 0.36. In downtrend market conditions, the best model is GBTs with an F1-Score of 0.53, followed by ARIMA (0.51), Proposed (0.5), Bi-LSTM (0.49), LSTM (0.46), CNN-Seq2Seq (0.46), Dilated CNN Seq2Seq (0.44), Polarity (0.43), Attention-CNN-LSTM (0.4), CNN-LSTM (0.39), and GRU-CNN (0.39). The worst-performing models in downtrend are CNN-LSTM and GRU-CNN with an F1-Score of 0.39.

For Starbucks (SBUX), the best-performing models for uptrend prediction are ARIMA and GBTs with an F1-Score of 0.52, followed by LSTM (0.51), Polarity (0.51), Attention-CNN-LSTM (0.51), Bi-LSTM (0.5), Proposed (0.5), CNN-LSTM (0.43), Dilated CNN Seq2Seq (0.41), CNN-Seq2Seq (0.38), and GRU-CNN (0.37). The worst-performing model for uptrends is GRU-CNN with an F1-Score of 0.37. For downtrend prediction, the best model is Dilated CNN Seq2Seq with an F1-Score of 0.57, followed by Proposed (0.56), Bi-LSTM (0.55), CNN-Seq2Seq (0.53), Attention-CNN-LSTM (0.51), GBTs (0.5), GRU-CNN (0.48), ARIMA (0.47), LSTM (0.46), Polarity (0.45), and CNN-LSTM (0.37). The worst-performing model for downtrends is CNN-LSTM with an F1-Score of 0.37.

In the case of Tesla (TSLA), the best-performing models in uptrend market conditions are Dilated CNN Seq2Seq, CNN-Seq2Seq, and LSTM with an F1-Score of 0.56, followed by Bi-LSTM (0.54), Attention-CNN-LSTM (0.54), Polarity (0.53), Proposed model (0.5), CNN-LSTM (0.5), GBTs (0.48), ARIMA (0.47), and GRU-CNN (0.27). The worst-performing model in uptrend is GRU-CNN with an F1-Score of 0.27. In downtrend market conditions, the best model is Polarity with an F1-Score of 0.55, followed by ARIMA (0.52), Proposed (0.49), Attention-CNN-LSTM (0.48), Bi-LSTM (0.48), CNN-Seq2Seq (0.48), GBTs (0.48), Dilated CNN Seq2Seq (0.47), LSTM (0.47), GRU-CNN (0.34), and CNN-LSTM (0.31). The worst-performing model in downtrend is CNN-LSTM with an F1-Score of 0.31.

For Adobe (ADBE), the best-performing models in uptrend market conditions are ARIMA and LSTM with an F1-Score of 0.54, followed by GRU-CNN (0.51), Polarity (0.48), Bi-LSTM (0.47), GBTs (0.46), Attention-CNN-LSTM (0.44), Dilated CNN Seq2Seq (0.39), CNN-LSTM (0.39), CNN-Seq2Seq (0.41), and Proposed (0.34). The worst-performing model in uptrend is Proposed with an F1-Score of 0.34. In downtrend market conditions, the best model is CNN-Seq2Seq with an F1-Score of 0.5, followed by GRU-CNN (0.47), GBTs (0.48), ARIMA (0.44), Polarity (0.44), Bi-LSTM (0.43), LSTM (0.42), Dilated CNN Seq2Seq (0.41), Proposed (0.38), CNN-LSTM (0.37), and Attention-CNN-LSTM (0.36). The worst-performing model in downtrend is Attention-CNN-LSTM with an F1-Score of 0.36.

Moving to IBM, the best model is Proposed with an F1-Score of 0.58, followed by GBTs (0.56), LSTM (0.52), Bi-LSTM (0.52), ARIMA (0.51), Attention-CNN-LSTM (0.46), Dilated CNN Seq2Seq (0.46), CNN-Seq2Seq (0.46), Polarity

(0.46), GRU-CNN (0.36), and CNN-LSTM (0.35). The worst-performing model in uptrend is CNN-LSTM with an F1-Score of 0.35. In downtrend market conditions, the best model is GBTs with an F1-Score of 0.57, followed by Proposed (0.55), LSTM (0.55), Attention-CNN-LSTM (0.51), CNN-Seq2Seq (0.49), Bi-LSTM (0.48), Dilated CNN Seq2Seq (0.48), GRU-CNN (0.46), CNN-LSTM (0.44), Polarity (0.42) and ARIMA (0.37). The worst-performing model in downtrend is ARIMA with an F1-Score of 0.37.

In the case of NVIDIA (NVDA), the best-performing model in uptrend market conditions is Proposed with an F1-Score of 0.55, followed by Bi-LSTM (0.50), Polarity (0.48), LSTM (0.45), GBTs (0.45), ARIMA (0.44), Attention-CNN-LSTM (0.44), GRU-CNN (0.44), CNN-Seq2Seq (0.39), Dilated CNN Seq2Seq (0.38), and CNN-LSTM (0.35). The worst-performing model in uptrend is CNN-LSTM with an F1-Score of 0.35. In downtrend market conditions, the best models are Polarity and LSTM with an F1-Score of 0.50, followed by ARIMA (0.49), GBTs (0.49), Bi-LSTM (0.47), Proposed (0.46), GRU-CNN (0.44), CNN-Seq2Seq (0.42), Attention-CNN-LSTM (0.41), Dilated CNN Seq2Seq (0.39), and CNN-LSTM (0.35). The worst-performing model in downtrend is CNN-LSTM with an F1-Score of 0.35.

Analyzing Apple (AAPL), the best-performing model in uptrend market conditions is Polarity with an F1-Score of 0.55, followed by LSTM (0.52), GBTs (0.5), Bi-LSTM (0.43), CNN-Seq2Seq (0.43), Attention-CNN-LSTM (0.43), Dilated CNN Seq2Seq (0.43), GRU-CNN (0.43), CNN-LSTM (0.41), Proposed (0.4) and ARIMA (0.4). The worst-performing models in uptrend are Proposed and ARIMA with an F1-Score of 0.4. In downtrend market conditions, the best model is ARIMA with an F1-Score of 0.55, followed by Bi-LSTM (0.5), CNN-LSTM (0.5), Polarity (0.47), LSTM (0.47), Proposed (0.46), Attention-CNN-LSTM (0.46), Dilated CNN Seq2Seq (0.46), CNN-Seq2Seq (0.45), GBTs (0.45), and GRU-CNN (0.41). The worst-performing model in downtrend is GRU-CNN with an F1-Score of 0.41.

For American Tower Corporation (AMT), the best-performing model in uptrend market conditions is GBTs with an F1-Score of 0.51, followed by ARIMA (0.5), Polarity (0.49), Proposed (0.44), LSTM (0.44), Bi-LSTM (0.4), CNN-Seq2Seq (0.4), Attention-CNN-LSTM (0.4), Dilated CNN Seq2Seq (0.4), CNN-LSTM (0.4), and GRU-CNN (0.4). The worst-performing models in uptrend are Bi-LSTM, CNN-Seq2Seq, Attention-CNN-LSTM, Dilated CNN Seq2Seq, and CNN-LSTM with an F1-Score of 0.4. In downtrend market conditions, the best model is Proposed with an F1-Score of 0.55, followed by GBTs (0.54), Dilated CNN Seq2Seq (0.48), GRU-CNN (0.48), LSTM (0.47), CNN-Seq2Seq (0.46), CNN-LSTM (0.45), Attention-CNN-LSTM (0.43), ARIMA (0.4), Polarity (0.4), and Bi-LSTM (0.4). The worst-performing models in downtrend are ARIMA, Polarity, and Bi-LSTM with an F1-Score of 0.4.

Turning to Prologis Inc. (PLD), the best model for uptrends is Proposed with an F1-Score of 0.6, followed by ARIMA (0.59), Polarity (0.57), GBTs (0.55), GRU-CNN (0.55), LSTM (0.54), Bi-LSTM (0.5), Dilated CNN Seq2Seq (0.49), CNN-Seq2Seq (0.49), CNN-LSTM (0.49), and Attention-CNN-LSTM (0.48). The worst-performing model for uptrends

is Attention-CNN-LSTM with an F1-Score of 0.48. For downtrend prediction, the best model is GRU-CNN with an F1-Score of 0.6, followed by GBTs (0.58), Proposed (0.44), LSTM (0.51), Dilated CNN Seq2Seq (0.47), ARIMA (0.41), CNN-Seq2Seq (0.39), Bi-LSTM (0.39), CNN-LSTM (0.39), Attention-CNN-LSTM (0.38), and Polarity (0.3). The worst-performing model for downtrends is Polarity with an F1-Score of 0.3.

For VICI Properties Inc (VICI), the best-performing model in uptrend market conditions is GRU-CNN with an F1-Score of 0.54, followed by LSTM (0.52), GBTs (0.52), ARIMA (0.5), Bi-LSTM (0.48), Attention-CNN-LSTM (0.48), Proposed (0.47), CNN-Seq2Seq (0.43), Dilated CNN Seq2Seq (0.41), CNN-LSTM (0.38), and Polarity (0.36). The worst-performing model in uptrend is Polarity with an F1-Score of 0.36. In downtrend market conditions, the best model is LSTM with an F1-Score of 0.50, followed by CNN-Seq2Seq (0.49), ARIMA (0.49), Proposed (0.48), Bi-LSTM (0.48), Polarity (0.48), GBTs (0.46), Attention-CNN-LSTM (0.45), Dilated CNN Seq2Seq (0.43), CNN-LSTM (0.37), and GRU-CNN (0.36). The worst-performing model in downtrend is GRU-CNN with an F1-Score of 0.36.

In the case of Johnson & Johnson (JNJ), the best-performing model in uptrend market conditions is GBTs with an F1-Score of 0.56, followed by Bi-LSTM (0.52), Polarity (0.52), LSTM (0.51), GRU-CNN (0.51), ARIMA (0.46), Attention-CNN-LSTM (0.5), CNN-Seq2Seq (0.48), CNN-LSTM (0.48), Dilated CNN Seq2Seq (0.46), and Proposed (0.42). The worst-performing model in uptrend is Proposed with an F1-Score of 0.42. In downtrend market conditions, the best model is ARIMA with an F1-Score of 0.54, followed by LSTM (0.48), Bi-LSTM (0.48), Polarity (0.49), Proposed (0.49), GBTs (0.47), Dilated CNN Seq2Seq (0.42), CNN-Seq2Seq (0.42), Attention-CNN-LSTM (0.41), CNN-LSTM (0.4), and GRU-CNN (0.38). The worst-performing model in downtrend is GRU-CNN with an F1-Score of 0.38.

For CVS, the best-performing models in uptrend market conditions are Proposed and GBTs with an F1-Score of 0.58, followed by Polarity (0.48), ARIMA (0.49), LSTM (0.44), Attention-CNN-LSTM (0.43), Dilated CNN Seq2Seq (0.4), CNN-Seq2Seq (0.39), GRU-CNN (0.38), CNN-LSTM (0.31), and Bi-LSTM (0.3). The worst-performing model in uptrend is Bi-LSTM with an F1-Score of 0.3. In downtrend market conditions, the best model is Polarity with an F1-Score of 0.51, followed by Proposed (0.49), Bi-LSTM (0.49), Dilated CNN Seq2Seq (0.49), CNN-Seq2Seq (0.47), Attention-CNN-LSTM (0.47), LSTM (0.45), ARIMA (0.44), GRU-CNN (0.42), GBTs (0.45), and CNN-LSTM (0.35). The worst-performing model in downtrend is CNN-LSTM with an F1-Score of 0.35.

Finally, for Bio-Rad Laboratories, Inc. (BIO), the best-performing model in uptrend market conditions is LSTM with an F1-Score of 0.52, followed by GBTs (0.5), GRU-CNN (0.46), Proposed (0.46), Dilated (0.45), ARIMA (0.44), Bi-LSTM (0.41), CNN-Seq2Seq (0.41), CNN-LSTM (0.41), Attention-CNN-LSTM (0.4), and Polarity (0.4). The worst-performing models in uptrend are Attention-CNN-LSTM and Polarity with an F1-Score of 0.4. In downtrend market conditions, the best model is

GRU-CNN with an F1-Score of 0.56, followed by Bi-LSTM (0.54), LSTM (0.52), ARIMA (0.45), Proposed (0.46), Dilated CNN Seq2Seq (0.42), CNN-Seq2Seq (0.42), CNN-LSTM (0.42), Attention-CNN-LSTM (0.42), GBTs (0.55), and Polarity (0.26). The worst-performing model in downtrend is Polarity with an F1-Score of 0.26.

Confusion matrices

A detailed examination of the confusion matrices for various stocks across different sectors, such as communication services (ATVI - Figure 1 and NFLX - Figure 2), consumer services (AMZN - Figure 3), information technology (NVDA - Figure 4), real estate (VICI - Figure 5), and healthcare (CVS - Figure 6), illustrates the diversity of model predictions regarding uptrends (top) and downtrends (bottom).

For instance, focusing on ATVI (see Figure 1), it is noticeable that correct predictions for days categorized as downtrends and uptrend (as indicated by the true negatives - TN and true positives - TP, respectively) are reasonably balanced for certain models in uptrends, such as ARIMA (24, 30), LSTM (36, 34), GBTs (33, 27), Polarity (42, 34), and imbalanced for others, such as Bi-LSTM (37, 18), CNN-LSTM (34, 16), CNN Seq2Seq (30, 19), GRU-CNN (41, 10), Dilated CNN Seq2Seq (40, 11), and Attention-CNN-LSTM (34, 15). Regarding downtrends, certain models exhibit relatively imbalanced performance, like LSTM (54, 30), GBTs (60, 36), Polarity (29, 55), ARIMA (61, 29), and the proposed multimodal model (81, 17), while others are markedly imbalanced, such as Bi-LSTM (88, 9), CNN-LSTM (92, 5), CNN Seq2Seq (96, 1), GRU-CNN (5, 64), Dilated CNN Seq2Seq (90, 5), and Attention-CNN-LSTM (90, 6).

Shifting the focus to NFLX (see Figure 2) GBTs presents the most balanced performance in terms of correctly predicted days of the uptrend (27 - 38), followed by LSTM (21 - 41) and ARIMA (19 - 31). Results for the other models are otherwise quite imbalanced. In downtrend, in decreasing order of imbalance we can find CNN-Seq2Seq (91, 0), together with Dilated CNN Seq2Seq (95, 0) and attention-CNN-LSTM (93, 0), followed by CNN-LSTM (92, 0), Bi-LSTM (81, 9), GRU-CNN (17, 64), our multimodal approach (53 - 35), LSTM (49 - 27), and Polarity (30 - 53), GBTs (54 - 32), and ARIMA (45 - 42), which presents the most balanced performance.

Furthermore, it is evident that several models manifest imbalance in their predictions across different stocks (see Figures 1–6), as observed with the proposed multimodal approach in uptrend for NFLX, ARIMA in uptrend for VICI, and the Polarity approach for a majority of stocks in both uptrend and downtrend (AMT, PLD, AMZN, NVDA, VICI, and CVS). Additionally, a significant number of stocks analyzed using methodologies like Bi-LSTM, CNN-LSTM, CNN Seq2Seq, GRU-CNN, Dilated CNN Seq2Seq, and Attention-CNN-LSTM exhibit imbalances in both uptrends and downtrends. Specifically, stocks like NFLX, AMZN, NVDA, and CVS display imbalances during uptrends, whereas ATVI, NFLX, and NVDA exhibit imbalances during downtrends.

0.1 Portfolio analysis: Impact of Max Shares

Another interesting perspective is provided by analyzing the impact of the

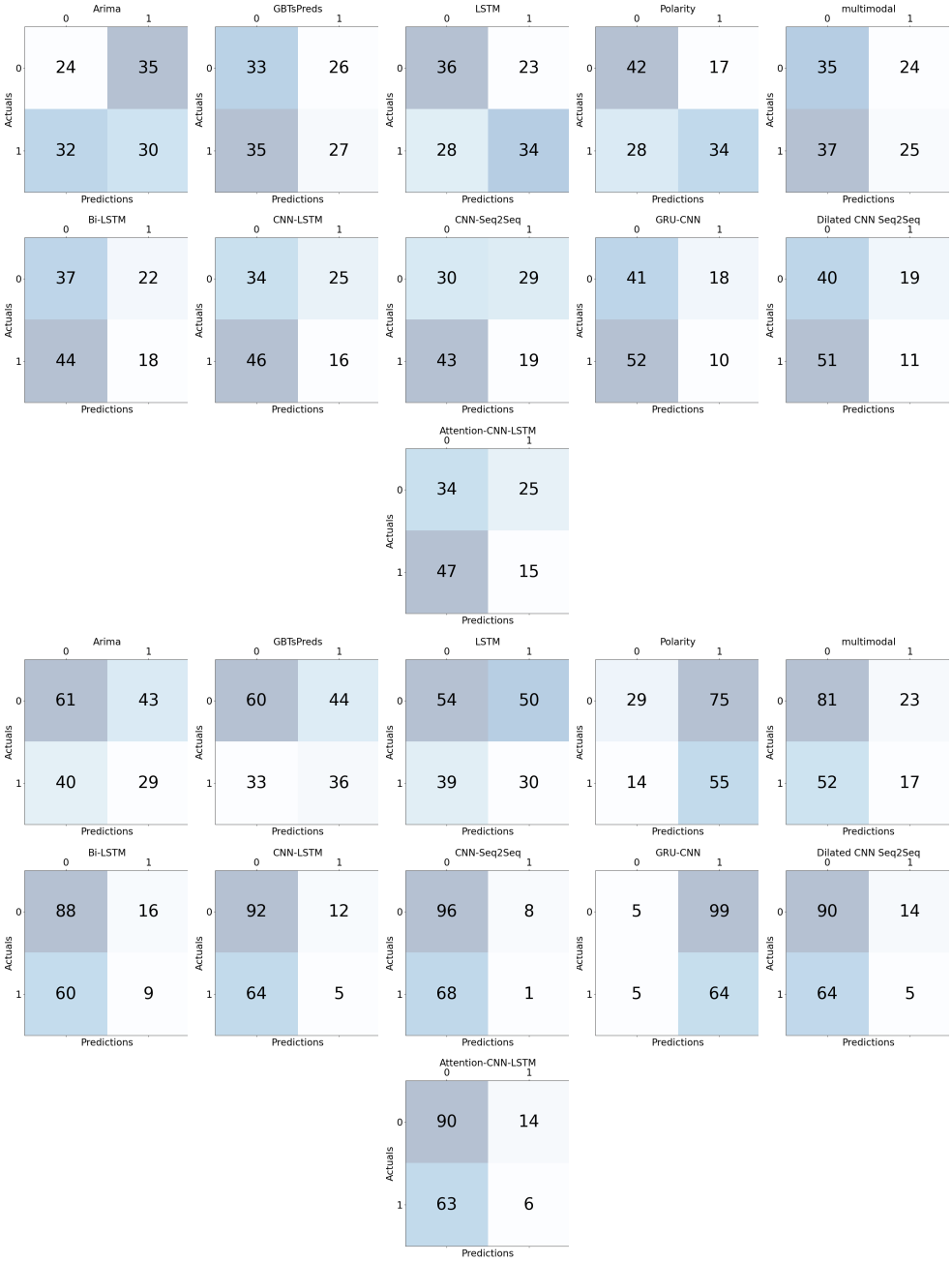

Fig. 1: Confusion matrices obtained by all methods on the next day trend prediction task in the evaluation period from July 1, 2021 to Dec 31, 2021 (Uptrend) and Jan 1, 2022 to Sep 20, 2022 (downtrend) (ATVI stock).

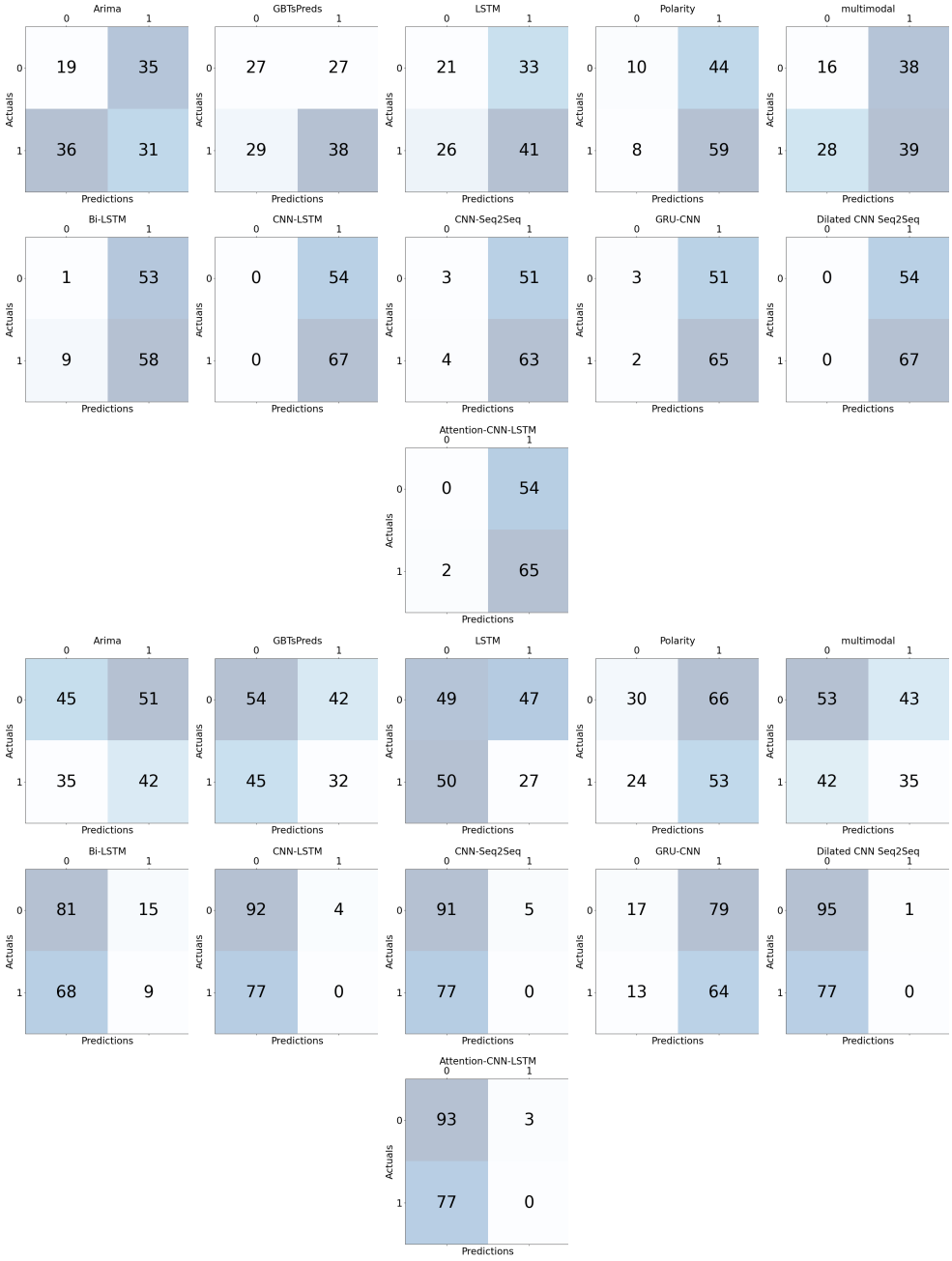

Fig. 2: Confusion matrices obtained by all methods on the next day trend prediction task in the evaluation period from July 1, 2021 to Dec 31, 2021 (Uptrend) and Jan 1, 2022 to Sep 20, 2022 (downtrend) (NFLX stock).

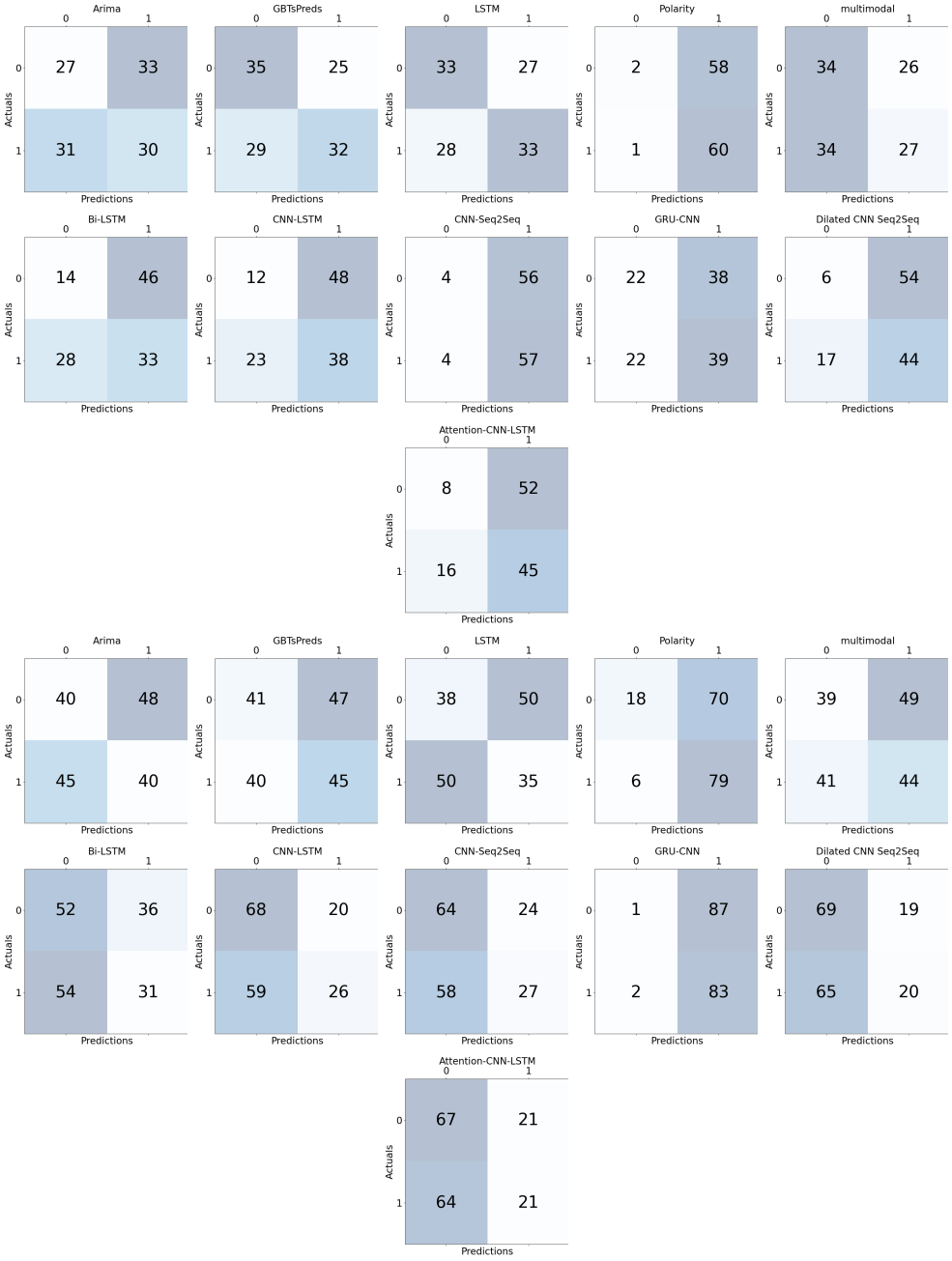

Fig. 3: Confusion matrices obtained by all methods on the next day trend prediction task in the evaluation period from July 1, 2021 to Dec 31, 2021 (Uptrend) and Jan 1, 2022 to Sep 20, 2022 (downtrend) (AMZN stock).

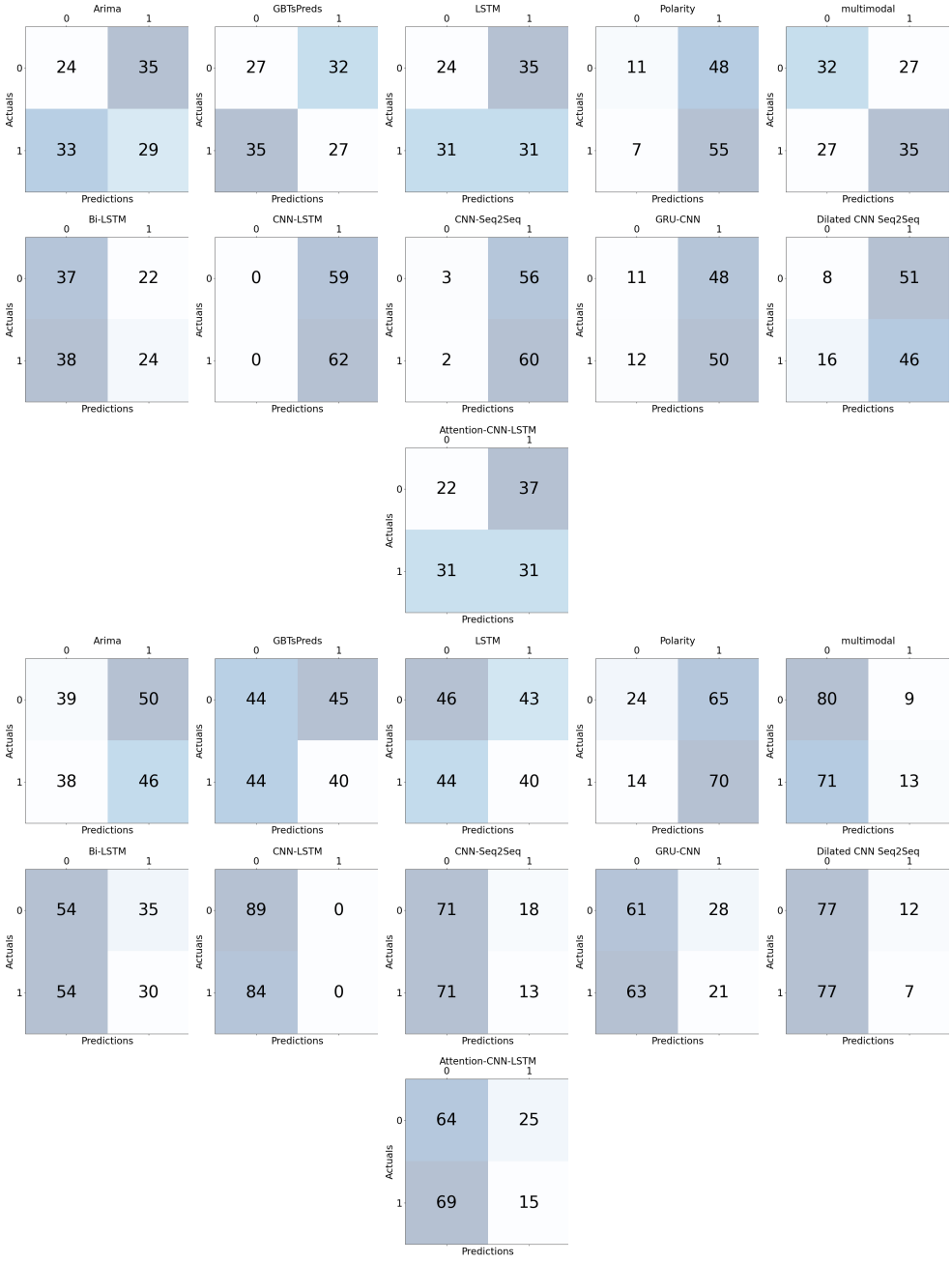

Fig. 4: Confusion matrices obtained by all methods on the next day trend prediction task in the evaluation period from July 1, 2021 to Dec 31, 2021 (Uptrend) and Jan 1, 2022 to Sep 20, 2022 (downtrend) (NVDA stock).

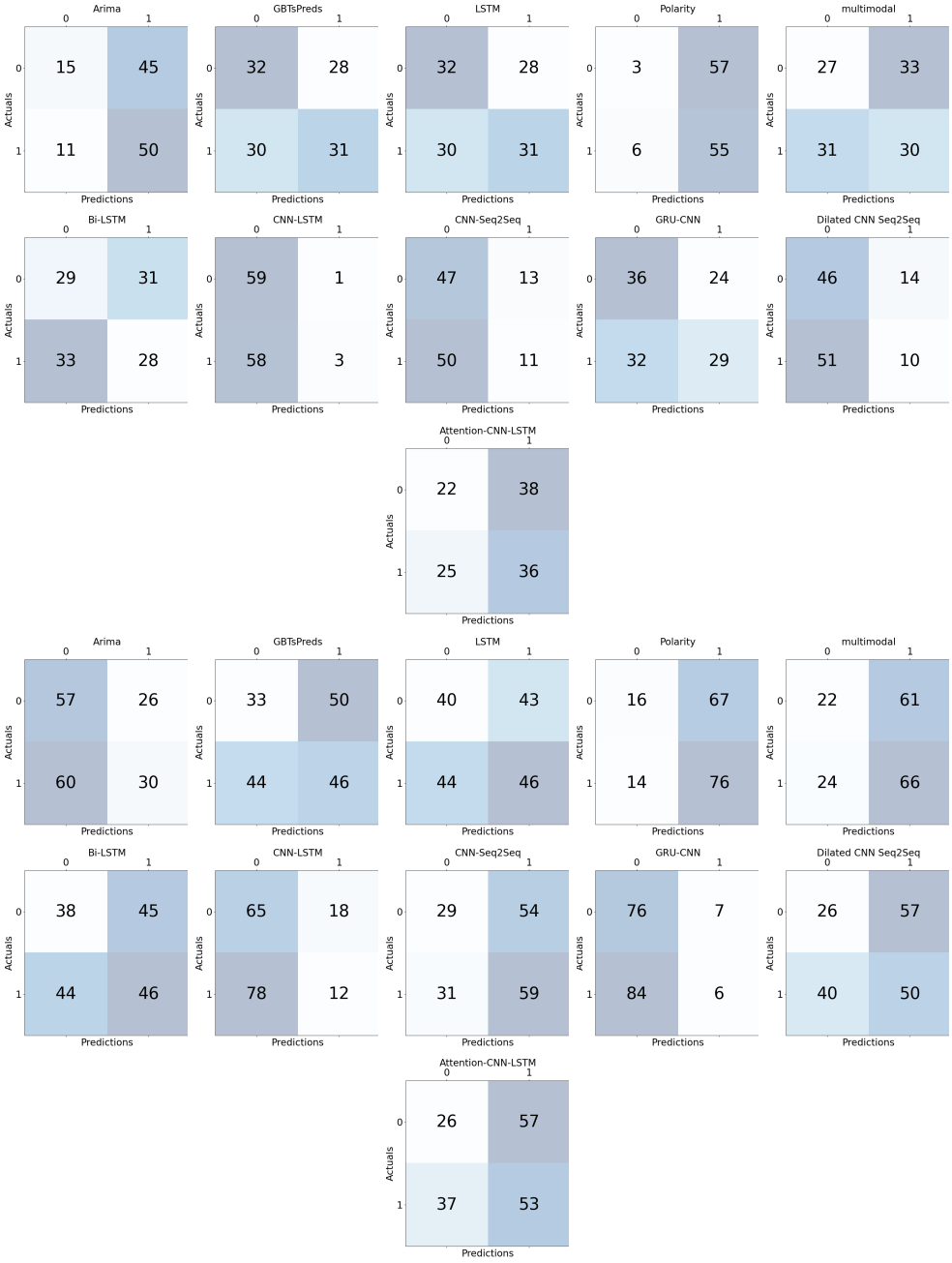

Fig. 5: Confusion matrices obtained by all methods on the next day trend prediction task in the evaluation period from July 1, 2021 to Dec 31, 2021 (Uptrend) and Jan 1, 2022 to Sep 20, 2022 (downtrend) (VICI stock).

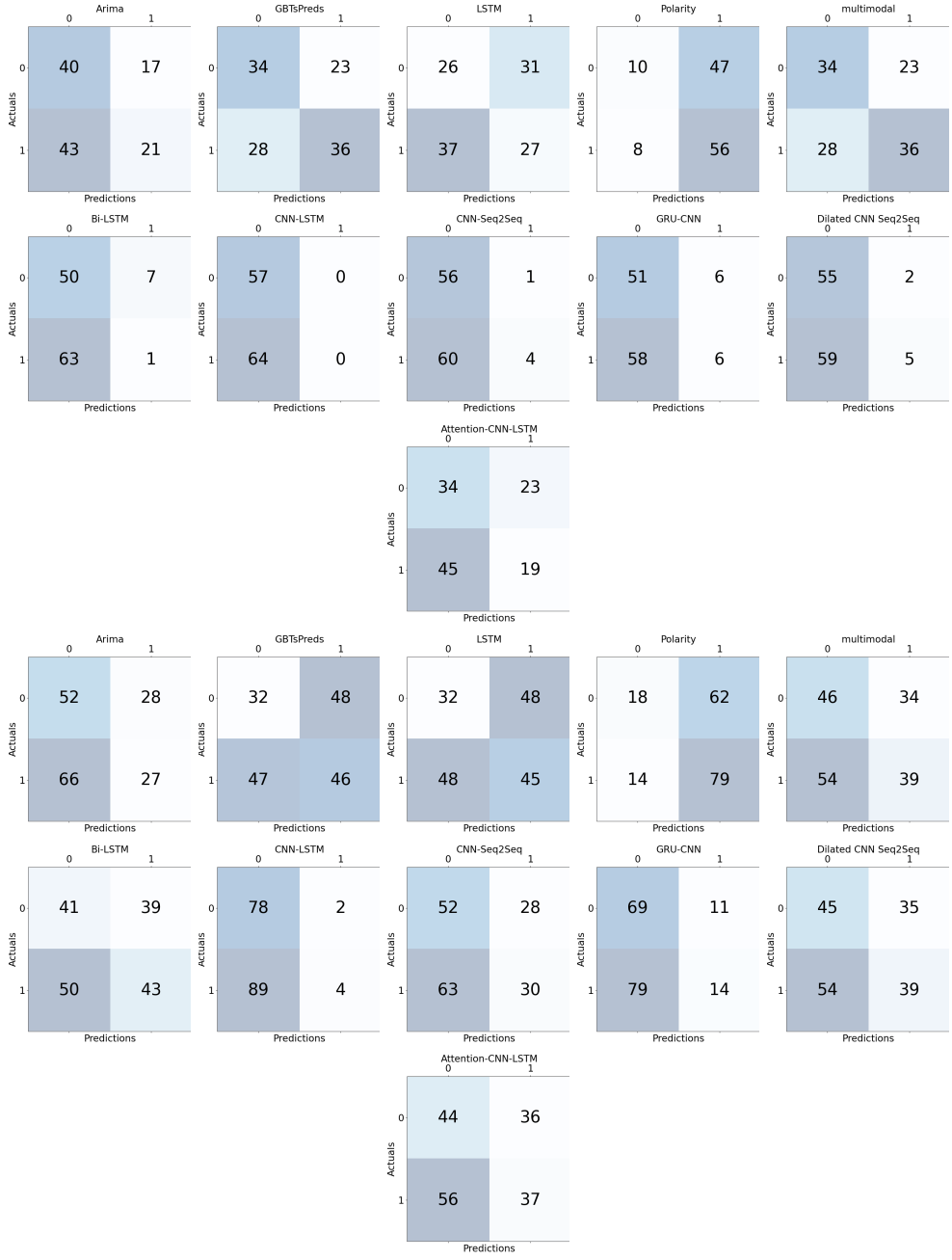

Fig. 6: Confusion matrices obtained by all methods on the next day trend prediction task in the evaluation period from July 1, 2021 to Dec 31, 2021 (Uptrend) and Jan 1, 2022 to Sep 20, 2022 (downtrend) (CVS stock).

"Max Shares" parameter in our experiments. In the following, we analyze the results obtained by stock sectors.

Communication services: In the context of an upward trend in the stock price of ATVI, it is observed that all models exhibit superior performance when "Max Shares" is set to 1. In contrast, during a downward trend in ATVI, the models ARIMA, CNN-LSTM, GRU-CNN, LSTM, Polarity, Attention-CNN-LSTM, and the proposed model demonstrate enhanced performance when "Max Shares" is set to 10, while Dilated CNN Seq2Seq, GBTs, Bi-LSTM, and CNN-Seq2Seq perform best at a "Max Shares" value of 1 (see Table 1). In the case of GOOG during an uptrend, only the ARIMA model performs better with a "Max Shares" value of 5, while the other models perform optimally when "Max Shares" is set to 10. In a downtrend for GOOG, only the Proposed model achieves the best performance with "Max Shares" value of 10, while the rest models perform best at a "Max Shares" value of 1 (see Table 2). For the stock price of NFLX in uptrend only the model ARIMA, and Proposed are found to perform better when the "Max Shares" value is set to 10, while others yield superior results at a "Max Shares" value of 1. For downtrend, only the model ARIMA is found to perform better when the "Max Shares" value is set to 10, while others yield superior results at a "Max Shares" value of 1 (see Table 3).

Consumer discretional: For the AMZN stock in an uptrend, most of the models are found to perform better when the "Max Shares" value is set to 1, while ARIMA and GRU-CNN yield superior results at a "Max Shares" value of 5. During an AMZN downtrend, the models CNN-LSTM, GBTs, Bi-LSTM, Attention-CNN-LSTM, and CNN-Seq2Seq excel with a "Max Shares" value of 10. The proposed model demonstrates enhanced performance when "Max Shares" is set to 5, while other models perform best with a "Max Shares" value of 1. (see Table 4). In EBAY stock in an uptrend, the model ARIMA, CNN-LSTM, Dilated CNN Seq2Seq, GBTs, LSTM, Bi-LSTM, and Attention-CNN-LSTM are found to perform better when the "Max Shares" value is set to 1, while GRU-CNN, Polarity, CNN-Seq2Seq, and the Proposed model yield superior results when "Max Shares" is set to 10. During an EBAY downtrend, all the models excel with a "Max Shares" value of 1 (see Table 5). In the case of SBUX during an uptrend, the models ARIMA, GRU-CNN, Bi-LSTM, Attention-CNN-LSTM, and the Proposed model exhibit a better performance with a "Max Shares" value of 10, while others perform optimally with a "Max Shares" value of 1. In a downtrend for SBUX, the Dilated CNN Seq2Seq, GBTs, LSTM, and CNN-Seq2Seq models provide the best performance with a "Max Shares" value of 10, whereas Attention-CNN-LSTM and the Proposed model achieve superior results when "Max Shares" is set to 5. Finally, ARIMA, CNN-LSTM, GRU-CNN, Bi-LSTM, and Polarity models yield better results with a "Max Shares" value of 1. (see Table 6). For the TSLA stock in an uptrend, Dilated CNN Seq2Seq, LSTM, Bi-LSTM, Polarity, Attention-CNN-LSTM, and the Proposed models are found to perform better when the "Max Shares" value is set to 5, while ARIMA, CNN-LSTM, GBTs, GRU-CNN, and CNN-Seq2Seq model yield superior results at a "Max Shares" value of 10. During a TSLA downtrend,

the ARIMA, CNN-LSTM, Dilated CNN Seq2Seq, GRU-CNN, LSTM, Attention-CNN-LSTM, and CNN-Seq2Seq excel with a "Max Shares" value of 1, while Bi-LSTM, Polarity, the Proposed model perform best when "Max Shares" is set to 10, and GBTs performs optimally at a "Max Shares" value of 5 (see Table 7).

Information technology: For the ADBE stock in an uptrend, the CNN-LSTM, LSTM, Bi-LSTM, Polarity, Attention-CNN-LSTM, and CNN-Seq2Seq models excel with a "Max Shares" value of 10, while ARIMA, Dilated CNN Seq2Seq, GBTs, and GRU-CNN perform best with a "Max Shares" value of 1, and the Proposed model performs optimally when "Max Shares" is set to 5. During an ADBE downtrend, the ARIMA, GRU-CNN, Polarity, and CNN-Seq2Seq excel with a "Max Shares" value of 10, while CNN-LSTM, GBTs, LSTM, Bi-LSTM, Attention-CNN-LSTM, and the Proposed model perform best with a "Max Shares" value of 1. The Dilated CNN Seq2Seq model instead, performs optimally at a "Max Shares" value of 5. (see Table 8). In the case of IBM during an uptrend, only the ARIMA model performs better with a "Max Shares" value of 10, while the other models perform optimally at a "Max Shares" value of 1. In a downtrend for IBM, the models ARIMA, CNN-LSTM, GRU-CNN, and Attention-CNN-LSTM are found to perform better when the "Max Shares" value is set to 1, while the Proposed model performs best when "Max Shares" is set to 5. All other models perform optimally at a "Max Shares" value of 10. (see Table 9). In the context of an uptrend for NVDA, the ARIMA, GBTs, LSTM, Bi-LSTM, and Attention-CNN-LSTM models exhibit superior performance when the "Max Shares" value is set to 10, whereas CNN-LSTM, GRU-CNN, Polarity, CNN-Seq2Seq, and the proposed model yield optimal results at a "Max Shares" value of 5 and Dilated CNN Seq2Seq is found to perform better when the "Max Shares" value is set to 1. During a downtrend in NVDA, only the Attention-CNN-LSTM model exhibits a superior performance when the "Max Shares" value is set to 10, while all other models perform best with a "Max Shares" value of 1 (see Table 10). In the case of AAPL during an uptrend, only the GBTs model performs better with a "Max Shares" value of 5, while the other models perform optimally at a "Max Shares" value of 10. In a downtrend for AAPL, the models CNN-LSTM, Dilated CNN Seq2Seq, LSTM, Attention-CNN-LSTM, and CNN-Seq2Seq exhibit superior performance at a "Max Shares" value of 10, while Bi-LSTM and the Proposed model perform best with a "Max Shares" value of 5. The rest of the models perform best with a "Max Shares" value of 1 (see Table 11).

Real estate: For AMT in an uptrend, the LSTM, ARIMA, Bi-LSTM, and Proposed models perform better with a "Max Shares" value of 1, while CNN-LSTM, Dilated CNN Seq2Seq, GBTs, GRU-CNN, Polarity, Attention-CNN-LSTM, and CNN-Seq2Seq excel with a "Max Shares" value of 10. In a downtrend for AMT, all models perform best at a "Max Shares" value of 1 (see Table 12). During an uptrend in PLD, the GRU-CNN, LSTM, Bi-LSTM models exhibit superior performance with a "Max Shares" value of 5, while the rest perform optimally at a "Max Shares" value of 10. In a PLD downtrend, only the Proposed model yields the best performance with a "Max Shares" configuration of 10, while all other models perform optimally when

"Max Shares" is set to 1 (see Table 13). During an uptrend in VICI, Bi-LSTM, Attention-CNN-LSTM, and the Proposed model exhibit superior performance with a "Max Shares" value of 5 and the rest perform optimally at a "Max Shares" value of 1. In a VICI downtrend, only CNN-LSTM and GRU-CNN yield the best performance with a "Max Shares" value of 1, while all other models perform optimally with 10 (see Table 14).

Healthcare: In the case of an uptrend in JNJ, the models LSTM and Polarity, as well as the Proposed model, perform better with a "Max Shares" value of 1, whereas CNN-LSTM, Dilated CNN Seq2Seq, and CNN-Seq2Seq exhibit superior performance with a "Max Shares" value of 5. Conversely, ARIMA, GBTs, GRU-CNN, Bi-LSTM, and Attention-CNN-LSTM yield optimal results with a "Max Shares" value of 10. In a JNJ downtrend, only Polarity exhibits superior performance at a "Max Shares" value of 5, while other models perform optimally with a "Max Shares" value of 1 (see Table 15). During an uptrend in CVS, all the models exhibit superior performance with a "Max Shares" value of 10 and Attention-CNN-LSTM performs optimally at a "Max Shares" value of 5. For CVS downtrend, the ARIMA, CNN-LSTM, Dilated CNN Seq2Seq, LSTM, Bi-LSTM, Attention-CNN-LSTM, CNN-Seq2Seq, and the proposed model excel with a "Max Shares" value of 10, while GRU-CNN and Polarity and the proposed model perform best with a "Max Shares" value of 1, and GBTs performs optimally at a "Max Shares" value of 5 (see Table 16). In the case of BIO during an uptrend, the ARIMA, LSTM, Bi-LSTM, and Attention-CNN-LSTM models perform better with a "Max Shares" value of 1, and GBTs perform optimally at a "Max Shares" value of 5, while CNN-LSTM, Dilated CNN Seq2Seq, GRU-CNN, Polarity, CNN-Seq2Seq, and the Proposed model yield optimal results with a "Max Shares" configuration of 10. In a BIO downtrend, only GBTs and GRU-CNN demonstrate superior performance with a "Max Shares" value of 10, while the other models perform optimally when "Max Shares" is set to 1 (see Table 17).

In conclusion, the impact of the "Max Shares" parameter on the performance of various models varies across different stocks and market trends. The observed patterns reveal that there is no universal optimal value for "Max Shares" across all stocks and market conditions. Instead, the effectiveness of different values depends on the specific stock, its trend (uptrend or downtrend), and the model employed.

In the examination of diverse stocks during uptrend, distinct trends become apparent, although these patterns do not consistently apply to all cases. In certain stocks such as ATVI, NFLX, AMZN, EBAY, SBUX, IBM, and VICI, models tend to exhibit superior performance when the "Max Shares" parameter is set to 1, whereas in GOOG, TSLA, ADBE, AAPL, AMT, PLD, CVS, and BIO, models tend to fare better with a "Max Shares" value of 10.

In a downtrend phase, the optimal choice for the "Max Shares" parameter also varies significantly among different stocks. In some stocks, models demonstrate improved performance with a "Max Shares" setting of 10 (e.g., ATVI, AMZN, AAPL, VICI, CVS), while for other stocks better results are obtained with a setting of 1 (e.g., GOOG, NFLX, AMZN, EBAY, TSLA, ADBE, IBM,

NVDA, AMT, PLD, JNJ, BIO). The effectiveness of specific predictive models, such as CNN-LSTM, GRU-LSTM, LSTM, Polarity, ARIMA, and GBTs, displays inconsistency, indicating their varying efficacy depending on the particular stock and prevailing market conditions. These observations suggest that the relationship between the "Max Shares" parameter and model performance is stock-specific, underscoring the necessity for individualized analysis and customized strategies for each stock.

Declarations

Conflict of interest/Competing interests – The authors declare that there are no financial or non-financial interests directly or indirectly related to the work submitted for publication.

References

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	-2.07	-10.34	-14.75	-9.06	1.36	6.82	9.17	5.78
CNN-LSTM	-2.78	-13.52	-17.48	-11.26	1.36	6.81	13.49	7.22
Dilated CNN Seq2Seq	-1.54	-7.70	-20.08	-9.77	-0.59	-2.95	-4.27	-2.60
GBTs	-1.25	-6.24	-12.47	-6.65	-0.30	-1.49	-0.37	-0.72
GRU-CNN	-2.04	-10.18	-12.28	-8.17	-1.93	1.90	8.31	2.76
LSTM	-1.56	-7.81	-15.61	-8.33	0.86	4.30	8.60	4.58
Bi-LSTM	-3.45	-17.26	-29.15	-16.62	-0.23	-1.15	-1.98	-1.12
Polarity	-0.82	-4.10	-8.72	-4.55	-1.62	0.41	5.64	1.48
Attention-CNN-LSTM	-3.55	-17.75	-29.86	-17.05	0.31	1.56	2.97	1.62
CNN-Seq2Seq	-1.92	-9.62	-25.17	-12.24	-0.01	-0.07	-0.14	-0.07
Proposed	-1.90	-9.48	-11.89	-7.76	0.91	5.03	12.69	6.21
Buy and hold	NA			-27.99	NA			12.61

Table 1: Simulated portfolio gains (ATVI stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	0.75	2.81	1.35	1.64	-1.90	-2.04	-5.59	-3.18
CNN-LSTM	5.61	10.01	12.15	9.26	-0.01	-0.03	-0.07	-0.04
Dilated CNN Seq2Seq	5.18	8.89	10.41	8.16	-1.26	-6.30	-9.17	-5.58
GBTs	0.53	2.98	4.01	2.51	-3.90	-17.93	-22.13	-14.65
GRU-CNN	5.93	13.20	16.45	11.86	-3.58	-11.69	-12.38	-9.22
LSTM	1.25	4.89	6.22	4.12	-1.59	-7.95	-14.27	-7.93
Bi-LSTM	5.34	9.43	11.83	8.86	-2.07	-10.11	-12.83	-8.34
Polarity	4.09	9.84	12.03	8.65	-9.05	-21.18	-31.59	-20.61
Attention-CNN-LSTM	5.18	8.89	10.41	8.16	-3.99	-18.51	-17.77	-13.42
CNN-Seq2Seq	5.52	9.61	11.91	9.01	-2.05	-9.21	-9.03	-6.76
Proposed	4.80	11.36	14.72	10.30	0.75	3.77	7.32	3.95
Buy and hold	NA			15.51	NA			-28.03

Table 2: Simulated portfolio gains (GOOG stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	1.48	6.06	10.90	6.15	-44.54	-43.04	-40.48	-42.69
CNN-LSTM	14.39	13.36	13.82	13.86	-1.50	-7.04	-8.71	-5.75
Dilated CNN Seq2Seq	14.39	13.36	13.82	13.86	-0.06	-0.31	-0.62	-0.33
GBTs	12.25	11.81	7.98	10.68	3.55	-0.79	-12.09	-3.11
GRU-CNN	14.18	12.29	11.91	12.79	-43.93	-53.62	-51.49	-49.68
LSTM	11.48	6.65	4.33	7.49	-5.70	-30.31	-31.95	-22.65
Bi-LSTM	10.67	6.15	7.30	8.04	2.93	-10.28	-13.48	-6.95
Polarity	16.09	12.98	13.57	14.22	-48.35	-55.46	-52.04	-51.95
Attention-CNN-LSTM	14.04	11.63	10.55	12.08	-1.22	-6.09	-7.41	-4.91
CNN-Seq2Seq	15.02	13.82	13.62	14.15	-1.88	-7.59	-8.77	-6.08
Proposed	14.49	17.11	21.16	17.59	5.75	-2.95	-2.50	0.10
Buy and hold	NA			14.14	NA			-56.6

Table 3: Simulated portfolio gains (NFLX stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	2.89	9.68	8.66	7.08	-0.42	-2.09	-8.10	-3.54
CNN-LSTM	-1.89	-3.35	-5.96	-3.73	-3.42	-2.49	4.52	-0.46
Dilated CNN Seq2Seq	0.40	-2.97	-4.43	-2.33	-3.79	-8.74	-5.17	-5.90
GBTs	-0.93	-2.81	-2.66	-2.13	-3.66	-8.22	-0.98	-4.28
GRU-CNN	-1.15	-0.58	-0.59	-0.77	-20.19	-23.85	-24.64	-22.89
LSTM	-0.48	-2.39	-4.72	-2.53	-3.21	-15.66	-13.61	-10.83
Bi-LSTM	-2.70	-8.14	-9.02	-6.62	-5.22	-7.28	-1.61	-4.71
Polarity	-2.18	-6.72	-6.64	-5.18	-20.43	-23.37	-24.22	-22.67
Attention-CNN-LSTM	-2.40	-10.13	-12.16	-8.23	-3.76	-6.18	-1.12	-3.69
CNN-Seq2Seq	-2.15	-6.75	-6.19	-5.03	-2.90	3.85	8.28	3.08
Proposed	-0.84	-4.18	-6.61	-3.87	-2.05	1.35	-6.00	-2.23
Buy and hold	NA			-3.87	NA			-26.53

Table 4: Simulated portfolio gains (AMZN stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	-2.07	-9.96	-8.64	-6.89	-5.65	-24.03	-24.79	-18.16
CNN-LSTM	-0.09	-0.47	-0.93	-0.50	-0.57	-2.85	-5.69	-3.04
Dilated CNN Seq2Seq	-4.05	-11.32	-11.67	-9.01	-0.80	-3.98	-7.95	-4.24
GBTs	-0.30	-1.51	-3.02	-1.61	-3.41	-17.06	-25.78	-15.42
GRU-CNN	-5.09	-7.82	-4.87	-5.93	-8.60	-28.38	-31.68	-22.89
LSTM	-0.16	-0.79	-1.59	-0.85	-0.54	-2.72	-5.43	-2.90
Bi-LSTM	-2.69	-10.34	-11.32	-8.12	-1.22	-6.10	-11.80	-6.37
Polarity	-2.74	-3.35	-2.11	-2.74	-7.83	-27.48	-31.04	-22.12
Attention-CNN-LSTM	-5.88	-7.19	-6.63	-6.56	-0.13	-0.64	-1.27	-0.68
CNN-Seq2Seq	-6.08	-8.03	-4.25	-6.12	-1.45	-7.26	-13.54	-7.42
Proposed	0.06	0.28	0.55	0.30	-1.28	-12.72	-6.40	-6.80
Buy and hold	NA			-4.32	NA			-37.92

Table 5: Simulated portfolio gains (EBAY stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	0.77	1.33	1.67	1.25	0.46	-14.74	-14.76	-9.68
CNN-LSTM	-2.22	-6.42	-7.31	-5.32	-0.02	-0.12	-0.24	-0.13
Dilated CNN Seq2Seq	0.12	-3.73	-1.43	-1.68	2.45	7.62	10.16	6.75
GBTs	-0.59	-2.95	-7.93	-3.82	1.13	5.65	8.29	5.02
GRU-CNN	0.01	0.03	0.06	0.03	-0.92	-4.05	-1.24	-2.07
LSTM	-0.39	-1.96	-4.09	-2.14	0.56	2.79	4.32	2.56
Bi-LSTM	0.75	1.27	2.89	1.64	4.84	2.05	-1.81	1.69
Polarity	1.38	-1.71	1.29	0.32	1.75	-7.50	-9.49	-5.08
Attention-CNN-LSTM	-0.03	2.04	2.92	1.64	1.54	5.74	5.71	4.33
CNN-Seq2Seq	0.56	-2.74	-0.74	-0.97	2.06	6.20	7.81	5.36
Proposed	0.82	1.87	2.67	1.78	4.91	9.85	2.39	5.72
Buy and hold	NA			2.49	NA			-20.86

Table 6: Simulated portfolio gains (SBUX stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	7.12	14.25	17.91	13.09	1.95	-22.32	-21.45	-13.94
CNN-LSTM	18.83	39.66	41.31	33.26	-0.17	-0.84	-1.67	-0.89
Dilated CNN Seq2Seq	35.41	44.91	43.53	41.28	-14.49	-21.80	-18.07	-18.12
GBTs	21.57	30.04	33.29	28.30	-2.74	5.05	-17.50	-5.06
GRU-CNN	0.71	3.53	7.06	3.77	-0.47	-2.34	-4.69	-2.50
LSTM	19.59	51.51	50.52	40.54	-4.79	-16.78	-10.55	-10.71
Bi-LSTM	45.77	55.97	53.21	51.65	-21.82	-20.82	-12.62	-18.42
Polarity	11.03	35.75	32.66	26.48	-9.98	-11.73	-8.49	-10.07
Attention-CNN-LSTM	46.33	54.28	52.19	50.93	-24.51	-33.23	-28.59	-28.78
CNN-Seq2Seq	35.59	45.80	46.43	42.60	1.45	-3.97	-1.44	-1.32
Proposed	43.76	49.28	46.46	46.50	-9.51	-2.30	-1.35	-4.39
Buy and hold	NA			57.55		NA		15.00

Table 7: Simulated portfolio gains (TSLA stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	-7.92	-10.57	-8.94	-9.14	-18.83	-8.76	-7.18	-11.59
CNN-LSTM	-6.90	-5.07	-4.54	-5.50	-0.72	-3.95	-8.05	-4.24
Dilated CNN Seq2Seq	-4.65	-9.46	-9.99	-8.03	-22.99	-13.69	-17.62	-18.10
GBTs	-2.28	-5.48	-10.74	-6.16	-11.70	-13.52	-19.56	-14.93
GRU-CNN	-8.74	-11.64	-11.92	-10.77	-26.63	-27.25	-26.37	-26.75
LSTM	-9.85	-3.23	8.21	-1.62	-11.75	-19.08	-16.35	-15.73
Bi-LSTM	-12.44	-2.18	1.17	-4.48	-27.15	-28.58	-30.44	-28.72
Polarity	-5.86	-3.17	-0.39	-3.14	-40.75	-34.43	-29.73	-34.97
Attention-CNN-LSTM	-14.47	-11.73	-9.97	-12.06	-5.20	-19.09	-23.06	-15.78
CNN-Seq2Seq	-14.57	-15.41	-14.32	-14.77	-22.50	-7.33	-4.48	-11.44
Proposed	1.77	2.70	1.23	1.90	-7.35	-23.23	-29.74	-20.11
Buy and hold	NA			-2.40	NA			-45.61

Table 8: Simulated portfolio gains (ADBE stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	0.76	3.79	3.93	2.83	0.15	0.76	1.52	0.81
CNN-LSTM	-0.19	-1.07	-0.55	-0.60	-6.45	-7.28	-5.44	-6.39
Dilated CNN Seq2Seq	-5.30	-10.39	-10.17	-8.62	-6.85	-7.55	-8.55	-7.65
GBTs	-1.29	-6.43	-6.65	-4.79	-2.81	-8.42	-7.40	-6.21
GRU-CNN	-0.51	-0.60	-0.92	-0.68	-5.43	-0.39	2.58	-1.08
LSTM	-1.02	-5.12	-8.59	-4.91	-1.68	-7.66	-4.54	-4.63
Bi-LSTM	-5.58	-9.71	-10.37	-8.55	-5.41	-7.14	-8.02	-6.86
Polarity	3.09	-1.78	-2.16	-0.28	-3.19	-4.62	-5.51	-4.44
Attention-CNN-LSTM	-5.30	-10.39	-10.17	-8.62	-5.81	-6.51	-5.13	-5.82
CNN-Seq2Seq	-5.03	-10.76	-9.80	-8.53	-7.20	-13.45	-14.99	-11.88
Proposed	-0.68	-2.34	-1.82	-1.61	-5.65	-3.27	-3.83	-4.25
Buy and hold	NA			-4.60	NA			-6.07

Table 9: Simulated portfolio gains (IBM stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	2.87	17.58	29.39	16.61	-9.02	-19.77	-23.35	-17.38
CNN-LSTM	45.91	48.26	47.32	47.16	-0.08	-0.42	-0.83	-0.44
Dilated CNN Seq2Seq	41.40	39.55	29.65	36.87	-7.12	-25.59	-24.27	-18.99
GBTs	4.72	25.70	32.34	20.92	-11.73	-31.87	-41.13	-28.25
GRU-CNN	39.50	47.82	47.08	44.80	-8.36	-20.78	-20.22	-16.45
LSTM	4.61	28.23	34.03	22.29	-6.61	-30.30	-29.54	-22.15
Bi-LSTM	3.21	22.48	29.66	18.45	-34.49	-35.15	-36.20	-35.28
Polarity	41.57	43.42	34.22	39.74	-47.65	-55.96	-59.06	-54.22
Attention-CNN-LSTM	3.04	17.56	19.42	13.34	-22.17	-14.58	-12.57	-16.44
CNN-Seq2Seq	45.94	48.41	47.63	47.33	-8.84	-28.10	-27.34	-21.43
Proposed	14.15	54.07	53.50	40.57	-0.17	-13.42	-15.65	-9.75
Buy and hold	NA			57.55		NA		-55.24

Table 10: Simulated portfolio gains (NVDA stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	0.03	0.15	0.30	0.16	-0.98	-11.18	-17.09	-9.75
CNN-LSTM	22.19	22.81	22.92	22.64	-4.35	0.71	2.85	-0.27
Dilated CNN Seq2Seq	22.41	24.11	25.79	24.10	-3.57	1.72	5.17	1.11
GBTs	2.65	13.10	12.65	9.47	-0.98	-3.24	-4.86	-3.03
GRU-CNN	-0.79	-1.43	0.14	-0.70	-3.53	-11.07	-11.05	-8.55
LSTM	5.33	21.32	21.60	16.08	-1.62	-7.03	-0.23	-2.96
Bi-LSTM	22.41	24.11	25.79	24.10	-3.85	0.42	-4.11	-2.51
Polarity	15.62	24.17	25.30	21.70	-9.56	-11.82	-18.32	-13.23
Attention-CNN-LSTM	22.41	24.11	25.79	24.10	-4.16	-1.04	1.69	-1.17
CNN-Seq2Seq	22.41	24.11	25.79	24.10	-3.43	-0.11	1.00	-0.85
Proposed	22.75	24.15	25.80	24.23	2.32	7.91	1.65	3.96
Buy and hold	NA			29.47		NA		-1.49

Table 11: Simulated portfolio gains (AAPL stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	2.22	-3.20	-3.68	-1.55	1.41	-9.89	-12.46	-6.98
CNN-LSTM	2.12	3.09	3.60	2.94	-8.80	-13.24	-17.53	-13.19
Dilated CNN Seq2Seq	2.65	4.54	5.41	4.20	-8.96	-12.08	-13.05	-11.36
GBTs	-1.33	-4.91	4.27	-0.66	-2.33	-5.89	-7.42	-5.21
GRU-CNN	2.65	4.54	5.41	4.20	-2.53	-7.99	-11.41	-7.31
LSTM	0.31	-0.17	-4.47	-1.45	-3.16	-5.68	-4.50	-4.45
Bi-LSTM	1.71	-0.82	-2.32	-0.48	-7.68	-20.91	-20.52	-16.37
Polarity	0.71	4.61	6.51	3.94	-0.17	-8.26	-9.64	-6.02
Attention-CNN-LSTM	2.52	4.37	5.08	3.99	-12.57	-22.35	-23.28	-19.40
CNN-Seq2Seq	2.65	4.54	5.41	4.20	-10.08	-15.71	-18.84	-14.88
Proposed	2.69	-0.16	-1.77	0.25	-2.77	-5.78	-3.71	-4.09
Buy and hold	NA			7.49	NA			-13.22

Table 12: Simulated portfolio gains (AMT stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	5.87	10.71	13.97	10.19	-0.44	-3.64	-12.01	-5.36
CNN-LSTM	27.00	31.44	31.92	30.12	-0.28	-1.39	-2.77	-1.48
Dilated CNN Seq2Seq	26.43	30.99	31.56	29.66	-6.12	-15.50	-15.43	-12.35
GBTs	1.77	5.87	11.90	6.51	-0.66	-3.31	-3.74	-2.57
GRU-CNN	23.20	29.02	28.79	27.00	-1.72	-8.62	-14.30	-8.21
LSTM	6.39	20.11	16.38	14.29	-2.00	-9.99	-16.05	-9.34
Bi-LSTM	21.87	22.14	17.73	20.58	-0.28	-1.39	-2.77	-1.48
Polarity	24.48	33.66	36.00	31.38	-26.32	-26.98	-28.01	-27.10
Attention-CNN-LSTM	26.83	31.35	31.95	30.05	-0.24	-1.21	-2.58	-1.34
CNN-Seq2Seq	26.26	30.84	31.36	29.49	-0.91	-4.56	-5.73	-3.73
Proposed	17.74	23.72	29.51	23.66	-2.19	-0.93	1.94	-0.39
Buy and hold	NA			39.83	NA			-31.26

Table 13: Simulated portfolio gains (PLD stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	-0.02	-0.45	-2.56	-1.01	0.58	2.88	5.76	3.07
CNN-LSTM	-0.01	-0.05	-0.10	-0.06	-0.19	-0.94	-1.88	-1.00
Dilated CNN Seq2Seq	-0.20	-0.98	-1.96	-1.05	0.63	3.14	5.69	3.15
GBTs	-0.15	-0.73	-1.46	-0.78	0.06	0.31	0.62	0.33
GRU-CNN	-0.46	-2.30	-4.60	-2.45	-0.01	-0.03	-0.06	-0.03
LSTM	-0.09	-0.44	-0.87	-0.47	0.08	0.42	0.84	0.45
Bi-LSTM	0.23	1.15	0.80	0.73	0.70	3.51	4.61	2.94
Polarity	-0.30	-2.98	-4.58	-2.62	2.95	14.08	16.53	11.19
Attention-CNN-LSTM	0.29	1.31	-0.75	0.28	1.34	6.89	9.80	6.01
CNN-Seq2Seq	-0.22	-1.11	-2.22	-1.19	1.76	9.83	11.83	7.81
Proposed	0.20	0.99	0.43	0.54	2.08	11.28	14.76	9.37
Buy and hold	NA			-3.63	NA			11.95

Table 14: Simulated portfolio gains (VICI stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	0.08	0.38	0.76	0.40	-1.25	-5.13	-5.17	-3.85
CNN-LSTM	-3.54	-3.03	-3.16	-3.25	-0.42	-2.10	-3.69	-2.07
Dilated CNN Seq2Seq	-4.23	-4.18	-4.97	-4.46	-1.02	-6.81	-11.04	-6.29
GBTs	-0.59	-1.70	1.71	-0.19	-0.50	-2.52	-6.09	-3.04
GRU-CNN	-3.72	-2.40	-1.96	-2.69	-0.00	-0.02	-0.05	-0.02
LSTM	-1.36	-6.34	-4.74	-4.14	-0.29	-1.46	-2.03	-1.26
Bi-LSTM	0.18	1.29	2.18	1.21	-5.86	-7.15	-11.20	-8.07
Polarity	-0.32	-1.62	-3.16	-1.70	-3.55	-0.71	-0.87	-1.71
Attention-CNN-LSTM	-4.85	-4.72	-4.13	-4.57	-0.42	-2.10	-3.68	-2.07
CNN-Seq2Seq	-4.02	-3.81	-4.83	-4.22	-0.69	-3.46	-6.68	-3.61
Proposed	-0.46	-1.43	-0.77	-0.88	0.48	-0.12	-0.92	-0.18
Buy and hold	NA			4.53	NA			-3.05

Table 15: Simulated portfolio gains (JNJ stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	0.37	1.83	3.55	1.92	-1.20	-3.81	0.56	-1.48
CNN-LSTM	0.00	0.01	0.02	0.01	0.00	0.01	0.02	0.01
Dilated CNN Seq2Seq	0.14	0.70	1.39	0.74	0.79	3.32	5.65	3.25
GBTs	1.06	5.30	8.88	5.08	0.07	1.04	-2.86	-0.58
GRU-CNN	0.16	0.80	1.60	0.85	-0.52	-2.15	-2.55	-1.74
LSTM	0.52	2.62	5.24	2.79	0.85	4.25	7.32	4.14
Bi-LSTM	0.08	0.42	0.83	0.44	2.84	11.51	14.89	9.75
Polarity	14.20	25.03	26.56	21.93	1.99	-2.06	-0.78	-0.29
Attention-CNN-LSTM	0.62	3.12	2.65	2.13	0.75	2.89	6.21	3.28
CNN-Seq2Seq	0.08	0.38	0.76	0.41	1.10	5.55	7.60	4.75
Proposed	2.03	10.15	15.65	9.28	1.08	5.52	8.48	5.03
Buy and hold	NA			25.97	NA			-1.97

Table 16: Simulated portfolio gains (CVS stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.

Method	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**	**Gain % (1)**	**Gain % (5)**	**Gain % (10)**	**Avg %**
ARIMA	1.90	1.74	-0.38	1.09	-12.42	-14.46	-20.51	-15.80
CNN-LSTM	11.53	13.02	13.50	12.69	-2.02	-5.89	-7.91	-5.27
Dilated CNN Seq2Seq	12.98	12.29	13.07	12.78	-1.43	-6.27	-8.35	-5.35
GBTs	1.95	14.83	14.74	10.51	-22.60	-14.74	-10.89	-16.08
GRU-CNN	-3.52	-2.30	-1.45	-2.42	-10.27	-8.96	-6.51	-8.58
LSTM	8.22	4.81	-4.25	2.93	-15.85	-26.76	-24.66	-22.42
Bi-LSTM	7.92	-1.72	-0.58	1.87	-16.16	-22.18	-23.17	-20.50
Polarity	11.45	12.72	13.50	12.56	-29.48	-36.37	-37.13	-34.33
Attention-CNN-LSTM	8.38	5.51	6.18	6.69	-1.21	-5.74	-6.36	-4.44
CNN-Seq2Seq	11.53	13.02	13.50	12.69	-1.43	-6.27	-8.35	-5.35
Proposed	6.14	17.57	18.63	14.11	-15.03	-24.61	-22.83	-20.82
Buy and hold	NA			15.14	NA			-37.69

Table 17: Simulated portfolio gains (BIO stock) in Uptrend (left) and Downtrend (right): relative (percentage) with respect to the initial investment, with all models and different Max Shares configurations. The last column highlights average gains for each model computed across all Max Shares configurations.