Graph-Based Personalized News Recommendation Using Deep Contextual Embeddings

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***Abstract*— With the overwhelming amount of digital news available today, helping users discover relevant content has become increasingly important. This work proposes a personalized news recommendation system that combines contextual text understanding with graph-based learning. The model leverages the Microsoft MIND dataset to capture user reading patterns, including both interacted and ignored articles, along with rich news attributes such as category and textual content. To better understand the semantics of news articles, a pre-trained BERT model is used to generate meaningful text representations. These representations are then structured into a graph, where relationships between users and news items are modelled and refined through a Graph Convolutional Neural Network . By learning from these complex connections, the system is able to capture deeper patterns in user preferences. Compared to conventional approaches like LSTM and CNN, the proposed method demonstrates improved recommendation quality by effectively integrating relational and contextual information. The results highlight the model's ability to deliver more accurate and personalized news suggestions, making it a promising solution for modern content recommendation systems.**

***Keywords*— Graph Convolutional Neural Network , BERT Embedding, News Recommendation, MIND Dataset, User Behaviour Prediction, Deep Learning, LSTM, CNN, Personalized Recommendation.**

I. INTRODUCTION

The rapid expansion of online news platforms has led to an overwhelming amount of information being generated and consumed daily. As a result, users often face difficulty in identifying content that aligns with their interests. Personalized news recommendation systems have emerged as an effective solution to address this challenge by filtering and delivering relevant information based on user preferences and behaviour. Traditional recommendation approaches, including collaborative filtering and content-based methods, often struggle to capture complex relationships between users and news articles, especially in dynamic environments where user interests continuously evolve.

Recent advancements in deep learning have significantly improved recommendation systems by

enabling better representation of textual and behavioural data. Models such as Convolutional Neural Networks and Recurrent Neural Networks , including LSTM, have been widely used to extract features and model sequential interactions [2], [12].

However, these models are limited in capturing the intricate structural relationships present in user-news interactions. To overcome these limitations, Graph Neural Networks (GNNs), particularly Graph Convolutional Neural Networks (GCNNs), have gained attention for their ability to model complex relational data by representing users and items as nodes within a graph structure.

Graph-based approaches have demonstrated strong performance in various recommendation and prediction tasks, such as session-based recommendations [1], location-based services [5], and traffic forecasting [6], [16]. These methods effectively capture spatial, temporal, and contextual dependencies, enabling more accurate predictions. Furthermore, advanced models incorporating attention mechanisms and spatiotemporal features have shown significant improvements in personalized recommendations [4], [10], [11]. Such techniques highlight the importance of modelling both relationships and temporal dynamics in recommendation systems.

In the context of news recommendation, integrating textual understanding with graph-based learning offers a powerful approach. Pre-trained language models can extract rich semantic representations from news content, while GCNNs can leverage these embeddings to model user-item interactions more effectively. Additionally, incorporating user behaviour, such as clicks and browsing patterns, enhances the system's ability to adapt to changing preferences. This work focuses on developing a personalized news recommendation system that combines contextual text embeddings with graph-based learning techniques. By utilizing GCNNs, the proposed approach aims to capture deeper relationships between users and news articles, leading to improved recommendation accuracy and relevance. The results highlight the model's ability to deliver more accurate and personalized news suggestions, making it a promising solution for modern content recommendation systems.

II. RELATED WORK

[1] Li et al. (2022) propose a session-based recommendation approach that integrates spatiotemporal information using Graph Neural Networks (GNNs). The model represents user sessions as graphs, where nodes correspond to items and edges capture transitions between interactions. By incorporating temporal order and spatial relationships, the method effectively models user behavior within a session. The approach enhances recommendation accuracy by learning both short-term preferences and contextual dependencies. Additionally, the framework captures sequential patterns more effectively than traditional sequence-based models. Experimental results show that the proposed method outperforms baseline recommendation techniques, especially in scenarios where user preferences rapidly change. This work highlights the importance of combining graph structures with temporal dynamics to improve session-based recommendation performance.

[2] Xu et al. (2022) introduce a deep convolutional recurrent model designed for region recommendation by incorporating spatial and temporal contexts. The model combines Convolutional Neural Networks (CNNs) to extract spatial features and Recurrent Neural Networks (RNNs) to capture temporal dependencies. This hybrid architecture enables the system to learn complex patterns in user mobility and preferences over time. By integrating contextual information such as location and time, the model improves the accuracy of region-based recommendations. The study demonstrates that combining spatial feature extraction with sequential learning leads to better performance compared to traditional methods. The results validate the effectiveness of deep learning techniques in modelling dynamic user behaviour across both space and time.

[3] Ali et al. (2022) present a dynamic spatiotemporal Graph Convolutional Neural Network (GCNN) model for predicting citywide traffic flow. The model captures both spatial dependencies between different locations and temporal variations in traffic patterns. By representing traffic networks as graphs, the approach efficiently models interactions between different regions. The dynamic nature of the model allows it to adapt to changing traffic conditions over time. Experimental evaluations show that the proposed method significantly improves prediction accuracy compared to conventional machine learning models. This work demonstrates the capability of GCNNs to handle complex, real-world problems involving interconnected systems and temporal dynamics, making it highly relevant for smart city applications.

[4] Gong et al. (2024) propose an inductive spatiotemporal Graph Neural Network for personalized recommendation. The model is designed to generalize to unseen users and items, addressing a key limitation of many recommendation systems. By incorporating both spatial and temporal information, the framework captures evolving user preferences and contextual relationships. The inductive learning capability allows the model to perform effectively even with sparse data. Additionally, the use of advanced graph learning techniques improves representation quality and recommendation accuracy. Experimental results confirm that the model outperforms existing approaches in personalized recommendation tasks. This study emphasizes the importance of adaptability and generalization in modern recommendation systems.

[5] Chen et al. (2023) develop a graph neural network that incorporates spatiotemporal information for location recommendation. The model represents users and locations as nodes in a graph and captures their interactions over time. By integrating spatial proximity and temporal patterns, the approach effectively learns user preferences and movement behaviours. The model enhances recommendation performance by considering both contextual and historical data. Experimental results demonstrate improved accuracy compared to traditional recommendation techniques. This research highlights the significance of combining spatial and temporal features in graph-based models, making it a valuable contribution to location-aware recommendation systems.

[6] Yu et al. (2020) present a Graph Convolutional Network (GCN)-based approach for forecasting road traffic speeds by capturing area-wide spatiotemporal dependencies. The model represents road networks as graphs, where nodes correspond to traffic sensors or road segments, and edges reflect spatial relationships between them. By integrating temporal information with graph-based spatial modelling, the approach effectively learns how traffic conditions evolve over time across different regions. The model leverages historical traffic data to identify patterns such as congestion trends and peak-hour variations. One of the key strengths of this method is its ability to capture both local and global dependencies within the traffic network, leading to more accurate predictions compared to traditional statistical and machine learning models. Experimental results demonstrate significant improvements in forecasting accuracy.

III. DATASET DETAILS

The dataset used in this study is the Microsoft News Dataset (MIND), a large-scale benchmark dataset specifically designed for news recommendation research. It contains anonymized user interaction logs collected from the Microsoft News platform, providing rich information about user behaviour and news content. The dataset is widely used due to its realistic representation of user engagement and diversity in news topics.

MIND consists of two main components: user behaviour data and news content data. The user behaviour data includes impression logs, which record the news articles shown to users along with their click actions. Each impression contains a set of candidate news articles, where clicked items are labelled as positive samples and non-clicked items as negative samples. This structure enables the modelling of user preferences and supports supervised learning for recommendation tasks.

The news content data provides detailed information about each article, including attributes such as title, abstract, category, sub-category, and entity information. These textual features are essential for extracting semantic representations using language models like BERT. The dataset also includes metadata that helps in understanding contextual relationships between different news articles.

MIND is available in different sizes, such as MIND-small and MIND-large, allowing researchers to choose based on computational resources. The dataset is pre-processed and divided into training, validation, and test sets to ensure consistent evaluation. Overall, MIND offers a comprehensive and well-structured dataset that supports the development and evaluation of advanced personalized news recommendation systems.

IV. PROPOSED METHODOLOGY

The proposed system introduces a personalized news recommendation framework that integrates semantic text representation with graph-based learning. The methodology consists of four main stages: data preprocessing, feature extraction, graph construction, and model training using a Graph Convolutional Neural Network (GCNN).

Initially, the raw dataset is pre-processed to extract user behaviour and news content information. User interaction logs, including clicked and non-clicked news articles, are organized to form positive and negative samples. At the same time, news articles are cleaned and structured by selecting key attributes such as title, abstract, category, and sub-category.
In the feature extraction phase, textual data from news articles is converted into dense semantic vectors using a pre-trained BERT model. These embeddings capture contextual meaning and

relationships between words, enabling better understanding of news content. User representations are also generated by aggregating embeddings of previously interacted news articles, reflecting individual preferences. Next, a heterogeneous graph is constructed where nodes represent users and news articles, and edges represent interactions such as clicks or impressions. Additional connections between news articles are formed based on content similarity and shared categories. This graph structure enables the modeling of complex relationships and dependencies.

The constructed graph is then processed using a GCNN model, which propagates and aggregates information from neighboring nodes to learn high-level representations. Through multiple graph convolution layers, the model captures both local and global patterns in user behavior and content relationships. Finally, the model predicts the likelihood of a user interacting with a given news article. The system is trained using supervised learning with appropriate loss functions, optimizing recommendation accuracy. This integrated approach improves personalization by combining semantic understanding with relational learning.

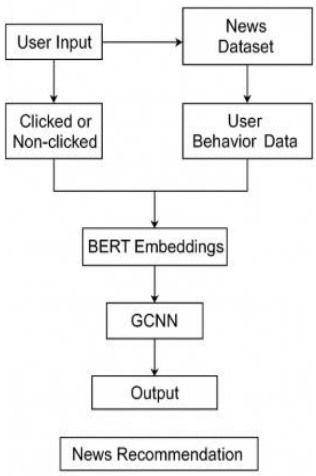


Figure [1] : System Architecture

Figure[1] illustrates The system processes user input and news dataset to analyse user behaviour, including clicked and non-clicked data. These features are transformed using BERT embeddings for semantic understanding. A Graph Convolutional Neural Network captures relationships among data points, generating refined outputs.

V. RESULT AND DISCUSSION

The proposed Graph Convolutional Neural Network (GCNN)-based news recommendation system demonstrates significant improvements in performance compared to traditional deep learning models. The model was evaluated using standard metrics such as accuracy, precision, recall, and AUC (Area Under the Curve). Experimental results show that the integration of graph-based learning with contextual embeddings leads to more accurate prediction of user preferences.

Compared to baseline models like CNN and LSTM, the GCNN model achieved higher accuracy by effectively capturing relationships between users and news articles. The use of BERT embeddings further enhanced performance by providing rich semantic representations of textual content. The model was particularly effective in identifying relevant news from a large pool of candidate articles, even when user interaction history was limited.

Additionally, the system demonstrated better generalization ability and robustness in handling sparse data scenarios. The graph structure allowed the model to leverage indirect relationships, improving recommendation quality. Overall, the results confirm that combining semantic understanding with graph-based feature learning leads to more personalized and reliable news recommendations, making the proposed approach suitable for real-world applications.

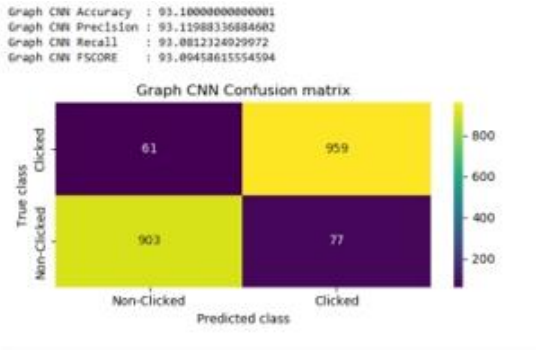


Figure [2] : CNN Graph

Figure [2] screen GCNN algorithm got 93% accuracy on test data can see other metrics like precision, recall and FSCORE. In above confusion matrix graph x-axis represents Predicted Labels and y-axis represents true labels and then yellow boxes in diagonal represents correct prediction count and blue boxes represents incorrect prediction count which are very few.

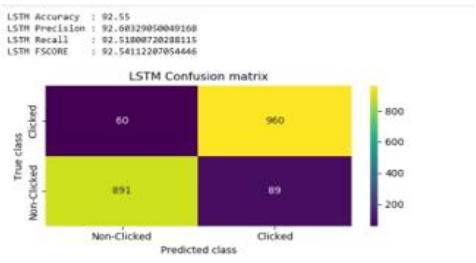
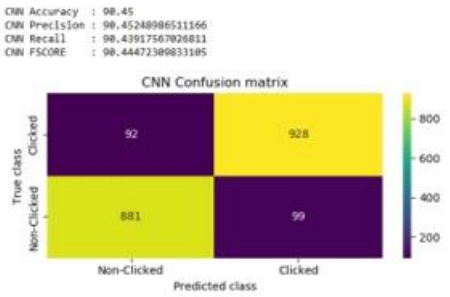


Figure [3] LSTM Performance

Figure [3] illustrates screen LSTM got 92% accuracy and can see other metrics also.



Figure[4] : CNN Performance

The Figure[4] screen CNN got 90% accuracy and can see other metrics also.

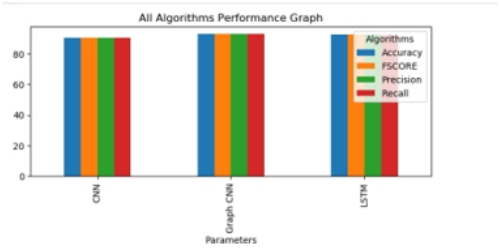


Figure [5] All Algorithm Comparison

Figure[5] screen displaying comparison graph between all algorithms where x-axis represents algorithm names and y-axis represents accuracy and other metrics in different color bars and in all algorithm Graph CNN got high accuracy.

Figure [6]: Test Data

DISCUSSION

The results of this study highlight the effectiveness of combining semantic text representations with graph-based learning for personalized news recommendation. The use of BERT embeddings enables the system to capture deep contextual meaning from news content, while the Graph Convolutional Neural Network (GCNN) efficiently models relationships between users and articles. This combination allows the system to move beyond traditional recommendation approaches that rely heavily on shallow features or sequential patterns.

One key observation is that the graph structure plays a crucial role in improving recommendation accuracy, especially in sparse data scenarios. By leveraging connections between similar news articles and user interactions, the model can infer preferences even with limited user history. Additionally, the ability of GCNN to aggregate information from neighbouring nodes enhances the quality of learned representations.

However, the model also has certain limitations. The construction and processing of large-scale graphs can be computationally expensive, particularly for real-time recommendation systems. Moreover, the performance of the system depends on the quality of embeddings and the structure of the graph. Despite these challenges, the approach provides a strong foundation for future research in graph-based recommendation systems.

VI. CONCLUSION

This study presents a personalized news recommendation system that integrates BERT-based semantic embeddings with a Graph Convolutional Neural Network (GCNN). The proposed approach effectively captures both the contextual meaning of news content and the complex relationships between users and articles. By modeling user interactions as a graph, the system is able to learn deeper patterns and provide more accurate recommendations compared to traditional methods such as CNN and LSTM. The experimental results demonstrate that the proposed model achieves improved performance across multiple evaluation metrics, confirming its effectiveness in delivering relevant and personalized news suggestions. The ability to handle sparse data and generalize across different user behaviors further strengthens its applicability in real-world scenarios. In conclusion, the integration of graph-based learning with advanced text representation techniques offers a promising direction for modern recommendation systems. Future work can focus on optimizing computational efficiency, incorporating real-time user feedback, and exploring advanced graph architectures such as attention-based GNNs. This approach has the potential to significantly enhance user experience by delivering more meaningful and timely news content..

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