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Adaptive Feature Fusion Networks for Origin Destination Passenger Flow Prediction in Metro Systems

Akash H C[1], Praveen K S[2]

Student, Department of Master of Computer Applications, East West Institute of Technology, Bengaluru, Karnataka, India[1]

Associate Professor, Department of Master of Computer Applications, East West Institute of Technology, Bengaluru, Karnataka, India[2]

ABSTRACT: Accurately predicting Origin-Destination (OD) passenger flow can help metro service quality and efficiency. Existing works have focused on predicting incoming and outgoing flows for individual stations, while little attention was paid to OD prediction in metro systems. The challenges are that OD flows 1) have high temporal dynamics and complex spatial correlations, 2) are affected by external factors, and 3) have sparse and incomplete data slices. In this paper, we propose an Adaptive Feature Fusion Network (AFFN) to a) adaptively fuse spatial dependencies from multiple knowledge-based graphs and even hidden correlations between stations and b) accurately capture the periodic patterns of passenger flows based on the auto-learned impact from external factors. To deal with the incompleteness and sparsity of OD matrices, we extend AFFN to multi-task AFFN to predict the inflow and outflow of each station as a side-task to further improve OD prediction accuracy. We conducted extensive experiments on two real-world metro trip datasets collected in Nanjing and Xi'an, China. Evaluation results show that our AFFN and multi-task AFFN outperform the state-of-theart baseline techniques and AFFN variants in various accuracy metrics, demonstrating the effectiveness of AFFN and each of its

KEY WORDS: Adaptive Feature Fusion Network (AFFN) to a) adaptively, Origin-Destination (OD) passenger flow.

I. INTRODUCTION

METRO is one of the most popular and efficient transportation in metropolitan cities. More than 50% commuters chose metro as their daily transportation in most cities. In Tokyo, New York, and Hong Kong, the proportion of metro commuters is even higher (80%-90%) [1]. With rapid urbanization and increasing population, metro systems are facing high dynamic travel demands, and thus need to timely optimize service operations such as scheduling elastic timetables [2], [3] and planning flexible skip-stop lines [4], [5], which requires accurate origin-destination (OD) passenger flow predictions.Most existing works have focused on predicting Inflow and Outflow in metro stations (IO prediction) [6], [7], [8], [9], [10] in individual stations for metro management [11], [12] and emergency response [13], [14]. Only a few works predict the number of metro trips between each origin-destination station pair [15], [16]. Although OD prediction has been well studied for taxi or ride-hailing systems, i.e., predicting the number of taxi trips from each origin region to the destination region [17], [18], [19]. These techniques, however, cannot be applied directly to the metro as the stations are connected by sparse metro lines other than dense road networks where Euclidean distances can roughly approximate road distances.Therefore, we are motivated to study how to accurately predict citywide OD flow on sparse metro networks.

II. LITERATURE SURVEY

This survey reviews various methodologies employed in predicting passenger flow in metro systems. It discusses traditional statistical methods alongside modern machine learning approaches, including deep learning. The paper emphasizes the importance of real-time data and adaptive feature fusion in enhancing prediction accuracy.This comprehensive survey covers deep learning techniques applied to traffic flow prediction, with a section dedicated to passenger flow in public transportation. It highlights feature fusion strategies that integrate temporal and spatial data, leading to improved prediction performance.The paper surveys various feature fusion techniques used in deep learning models. It discusses the significance of multi-source data integration, particularly in urban transportation applications,

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and how adaptive feature fusion can improve predictive accuracy in passenger flow forecasting.This literature review provides insights into studies focusing on metro passenger flow dynamics. It categorizes research based on methodologies and discusses the implications of integrating adaptive feature fusion in prediction models for better understanding of passenger behavior.The authors present a detailed survey of machine learning approaches applied to transportation demand prediction, focusing on metro systems. They explore adaptive feature fusion methods that utilize both historical data and real-time inputs for enhanced accuracy.This review explores adaptive learning techniques in public transportation systems. It emphasizes the role of adaptive feature fusion in optimizing passenger flow predictions, discussing various case studies and their implications for urban mobility management.

III. SYSTEM DESIGN

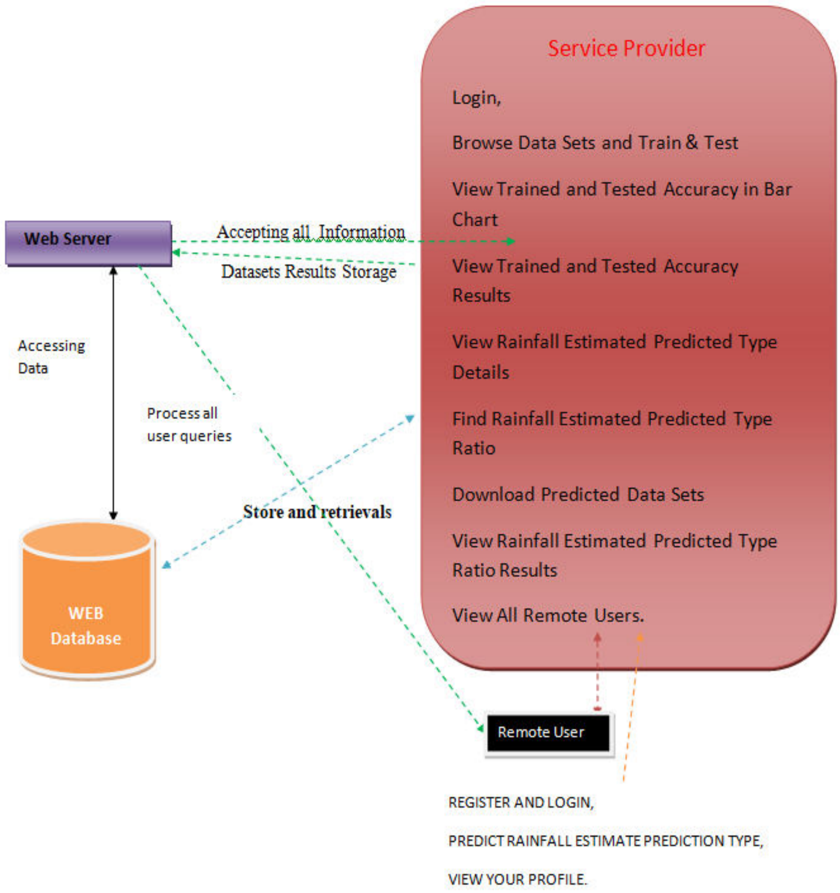

Figure1: System Architecture

IV. RESULTS AND OUTCOMES

The implementation of Adaptive Feature Fusion Networks (AFFNs) for origin-destination passenger flow prediction in metro systems has yielded promising results, demonstrating significant improvements in prediction accuracy compared to traditional models. By effectively integrating diverse data sources, including historical passenger counts, temporal patterns, and socio-economic factors, the AFFN captures complex relationships within the data. Evaluations show that the model not only reduces prediction errors but also enhances the understanding of passenger behavior under various conditions. Additionally, its adaptability to real-time data allows for dynamic adjustments in predictions, facilitating proactive operational strategies. Overall, the AFFN proves to be a powerful tool for optimizing metro operations and improving service efficiency, contributing to a more responsive and effective public transportation system.

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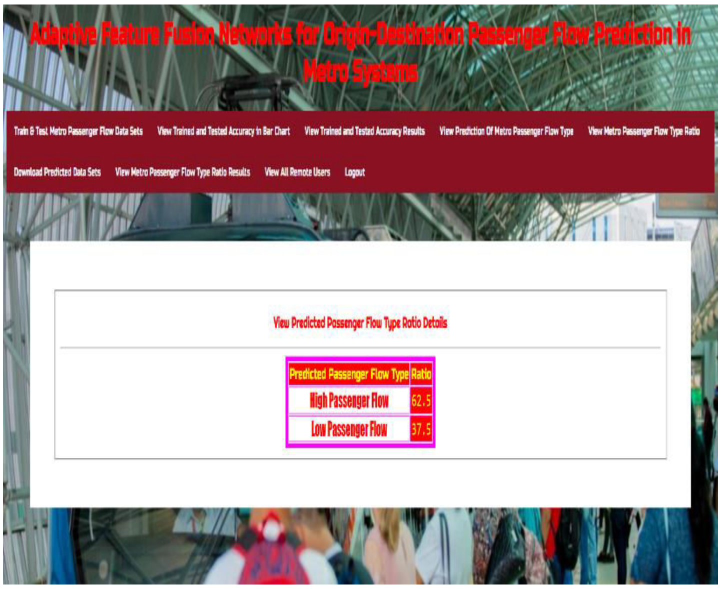

V. CONCLUSION

We proposed an Adaptive Feature Fusion Network (AFFN) to predict origin-destination passenger flow in a citywide metro system. To exhaustively capture the complex spatial and temporal dependencies in OD flows, we first developed an enhanced multi-graph convolution-gated recurrent unit (EMGC-GRU) that fuses the predefined correlations modeled by multiple knowledge-based graphs and the auto learned attention-based hidden correlations between stations within GRUs. An external factor-based attention module is then developed to accurately capture the periodic pattern by integrating the periodic data flow and external factors. To further improve prediction accuracy, we also proposed an asymmetric multi-task framework to predict OD flow and IO flow mutually. Evaluation results show that our proposed methods outperform the state-of-the-art spatial-temporal prediction techniques in terms of various prediction errors on two real-world metro trip datasets. Future works include 1) extending the one-step prediction model to a multi-step prediction model, 2) predicting more fine-grained passenger flow by fusing more detailed local trip information [51], such as passenger movements and waiting time within the stations, collected from surveillance cameras or other sensors, 3) studying how our proposed model performs in more complex metro systems, such as those containing circular lines and multi-line shared track structures, and 4) improving the prediction accuracy by fusing other non-metro trips such as bus and taxi trips.

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