Origin-Destination Demand Prediction Via Spatial-Temporal Multi-Graph CNN

Siyuan FENG[a], Jintao KE[b] and Hai YANG[c]
[a] *Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology*
Email: sfengag@connect.ust.hk
[b] *Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology*
Email: jke@connect.ust.hk
[c] *Department of Civil and Environmental Engineering, The Hong Kong University of Science and Technology*
Email: cehyang@ust.hk

Keywords: OD demand prediction, multi-graph CNN, deep learning model

1. Introduction

Ride-sourcing service provided by transportation network companies (TNCs) such as Uber, Lyft and DiDi, has experienced rapid growth since 2009. As reported, Didi has offered service for more than 25 million trips and 400 cities in China, while Uber is developing its business to over 650 cities and 20 countries all over the world. A major challenge for ride-sourcing platform management is about how to attain better supply-demand balances in the dimension of time and space, which largely depends on modernized real time demand forecasting technology. The meaning of demand prediction for the ride-hailing platform, on the one hand, is to gain knowledge from the past mobility patterns and assist to assign orders for the whole systems through some order-matching technology like deep reinforcement learning. On the other hand, some further study can be implemented on the results of demand prediction to reveal the routes that generate best profits for the platform. The achievement of these goals asks for prediction technology that could not only forecasts the future passenger requests inside a single region, but also the destinations of each trip. With the rapid growing market of shared ride-sourcing service, the requirement for more precise forecasting of OD demand become important and urgent. For this problem, a wide range of approaches have been proposed, including the ARIMA family (Khashei et al., 2012), Bayesian inferring approaches (Fei et al., 2011) and local regression model, etc. Some recent studies explore the deep learning technology and mainly focus on demand prediction for only In- and Out- zone demand (Ke et al., 2017; Ye et al., 2019, Zhang et al., 2019), where artificial grids are designed and deployed on the studied region and demand within each zone are forecasted with combinations of traditional deep learning paradigms (e.g., CNN, RNN and LSTM). However, most demand information, especially those for OD requests, is provided in the form of graph data, where the regions are treated as a graph instead of grid network. To overcome the challenge, our study proposes a novel end-to-end deep learning framework named Spatial-Temporal Multi-Graph Convolutional Network (ST -MGC) to predict ride-sharing passenger OD demand. In this study, we capture different kind of correlations within studied zones and employ a multi-graph convolutional (MGC) network with externally designed parameters for the feature embedding work. The learned hidden representations are then decoded and fed into predictors for OD demand prediction.

2. Research problem

The studied city is first partitioned into various irregular zones according to the administrative zip codes. Each day is uniformly divided into intervals with a fixed length. The target of our study is to predict the quantity of requested orders with different origins and destinations, which cover all of the administrative zones, in each time interval based on historical OD demand information collected for a whole year.

3. Methodology

We first establish some different group of correlation measures for zones. Afterwards, the features are filtered and fed into embedding modules where designed graph CNN are employed and combined with correlation measures to gain multi-level knowledge from the features. After embedding, the generated hidden representations are fused and decoded by the predictor modules for OD demand forecasting. The whole experiment is implemented via the python deep learning toolbox PyTorch. A server with 64G RAM and NVIDIA 1080Ti GPUs is utilized to train, validate and test the proposed model. To show the performance of the ST-MGC model, we compare it with methods including HA (the average historical demand), LASSO (standard LASSO model with selection operator in the loss function.), RF (random forest model), GBDT (gradient boosting decision tree model), XGB (XGBoost model), MLP (multi-layer perception model) and GCN (an advanced graph CNN model by Kipf et al., 2016). Three kind of accuracy measures, Root Mean Square Error (RMSE), Mean Absolute Error (MAE) and Mean Absolute Percentage Error (MAPE) are utilized to compare performances.

4. Results

Our model can effectively improve the prediction accuracy compared to the baseline methods. For example, the model can reduce RMSE and MAE by more than 10%, and MAPE by over 6% compared to the performance of standard MLP for OD prediction. The model may be further tested and validated on other datasets with different mobility patterns from the current one.

5. Conclusion

Compared to the common zone demand prediction, OD demand prediction is more challenging since the requirement to predict the quantity and destinations of demands in a zone simultaneously, as well as the data sparsity issue. To address the problem, we first employ graph CNN to capture the mobility information from multiple graphs. The learned hidden representations are then decoded by predictor module to forecast future OD demand. The process is achieved by an end-to-end model named Spatial-Temporal Multi-Graph Convolutional Network (ST-MGC). The model is evaluated on the real-world ride-sharing datasets, which validates the proposed model outperforms baselines. The future work may be to implement more validations on OD demand prediction for other traffic modes.

References

Khashei, M., Bijari, M., & Ardali, G. A. R. (2012). Hybridization of autoregressive integrated moving average (ARIMA) with probabilistic neural networks (PNNs). Computers & Industrial Engineering, 63(1), 37-45.

Fei, X., Lu, C. C., & Liu, K. (2011). A bayesian dynamic linear model approach for real-time short-term freeway travel time prediction. Transportation Research Part C: Emerging Technologies, 19(6), 1306-1318.

Ke, J., Zheng, H., Yang, H., & Chen, X. M. (2017). Short-term forecasting of passenger demand under on-demand ride services: A spatio-temporal deep learning approach. Transportation Research Part C: Emerging Technologies, 85, 591-608.

Ye, J., Sun, L., Du, B., Fu, Y., Tong, X., & Xiong, H. (2019, July). Co-Prediction of Multiple Transportation Demands Based on Deep Spatio-Temporal Neural Network. In Proceedings of the 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining (pp. 305-313). ACM.

Zhang, K., Liu, Z., & Zheng, L. (2019). Short-Term Prediction of Passenger Demand in Multi-Zone Level: Temporal Convolutional Neural Network With Multi-Task Learning. IEEE Transactions on Intelligent Transportation Systems.

Kipf, T. N., & Welling, M. (2016). Semi-supervised classification with graph convolutional networks. arXiv preprint arXiv:1609.02907.