2 Enhancing Traffic Forecasting Models with Hierarchical Spatial Graph Modeling and Expert-Based Learning: Towards Accurate, Scalable, and Context-Aware Predictions

Angelo Furno, Rim Slama Salmi
angelo.furno@univ-eiffel.fr; rim.slamasalmi@entpe.fr

context

Traffic forecasting is a critical component of Intelligent Transportation Systems (ITS), supporting applications such as trip planning, road traffic control, and vehicle routing. Accurate traffic predictions enable better management of transportation networks and more efficient urban mobility. While traditional models, such as statistical and machine learning approaches, have provided valuable insights, recent advancements in Graph Neural Networks (GNNs) have transformed the field by leveraging the graph structures of traffic systems to deliver more precise predictions (Jiang et al., 2023).

However, challenges persist in enhancing both the spatial and temporal accuracy of these models, especially when scaling to large urban environments and accounting for cross-modality perturbations. A key limitation of existing GNN-based models is their difficulty in handling complex spatial representations and effectively integrating contextual information into temporal predictions(Singh et al., 2024). In response to these challenges, this internship proposes to explore strategies for improving spatial graph modeling, integrating contextual information into temporal modeling, and optimizing computational efficiency through expert-based learning (Cai et al., 2024).

Objectives and steps

- **Enhanced Spatial Graph Modeling:**
  Adapt existing spatial graph models by introducing hierarchical graph structures to enable more precise spatial analysis, capturing both local and global dependencies within traffic networks.

- **Attention-Based Temporal Modeling:**
  Implement a transformer-based attention mechanism that integrates contextual information and combines both long- and short-term temporal features

- **Expert-Based Learning Strategy:**
  Develop an expert-based learning framework, where specialized models ("experts") are trained from different features. The system will dynamically select the best expert, reducing computation time and improving overall prediction accuracy.

- **Comparison with State-of-the-Art (SOTA) & Experimental Application:**

  Application to Traffic Forecast Tasks: Implement the proposed models for traffic flow prediction and taxi demand forecasting, assessing performance improvements.
  Comparison with SOTA: Evaluate the proposed approach against state-of-the-art models in terms of accuracy, scalability, and computational efficiency.
  Valorization: Submit the results to a relevant conference

Materials

Python, datasets

Competencies

- Basic knowledge in data science, machine learning, or transport engineering.
- Comfortable with programming in Python and using tools like PyTorch.
- Interest in urban mobility and traffic prediction is a plus.

Internship location

ENTPE (Vaulx-en-Velin)

Application Process

To apply, please send your ZIP folder named `[MobilityTransferability_NameSurname]` to `rim.slamasalmi@entpe.fr` and in copy `angelo.furno@univ-eiffel.fr`.

This folder should contain your **CV**, a **motivation letter academic transcripts** from high school (post-baccalaureate) to the most recent year of your master's program, and any **certifications in deep learning** if you have any.

References

Cai, W., Jiang, J., Wang, F., Tang, J., Kim, S., & Huang, J. (2024). A survey on mixture of experts. *arXiv preprint arXiv:2407.06204*.

He, Y., Huang, P., Hong, W., Luo, Q., Li, L., & Tsui, K.-L. (2024). In-depth insights into the application of recurrent neural networks (rnns) in traffic prediction: A comprehensive review. *Algorithms*, *17*(9), 398.

Jiang, W., Luo, J., He, M., & Gu, W. (2023). Graph neural network for traffic forecasting: The research progress. *ISPRS International Journal of Geo-Information*, *12*(3), 100.

Li, Z., Xia, L., Shi, L., Xu, Y., Yin, D., & Huang, C. (2024). Opencity: Open spatio-temporal foundation models for traffic prediction. *arXiv preprint arXiv:2408.10269*.

Rochas, R., Furno, A., & El Faouzi, N.-E. (2023). Contextual data integration for bike-sharing demand prediction with graph neural networks in degraded weather conditions. In *2023 ieee 26th international conference on intelligent transportation systems (itsc)* (pp. 5436–5441).

Singh, V., Sahana, S. K., & Bhattacharjee, V. (2024). Graph convolutional neural networks for traffic forecasting and prediction: A review. In *Aip conference proceedings* (Vol. 3164).