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Phd Summary:

Traffic Theory Inspired Spatiotemporal and Multimodal Deep Learning Models for Trustworthy Short-Term Urban Traffic Forecasting

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In this doctoral dissertation, a complete methodological framework and an associative toolkit of methods and concepts are proposed for the problem of short term urban traffic forecasting that aim to increase the accuracy, trustworthiness and actionability of deep learning models for traffic management based on features such as multimodality and causality and on aspects of Traffic Flow Theory.

Specifically, a multimodal forecasting framework based on the concept of Multiplex Networks is developed for urban road networks, taking into account spatio-temporal relationships between the two considered modes (road traffic and metro demand). Towards the extension to network-level forecasting, multiplex neural networks based on the principles of Multitask Learning are being developed, which are able to provide travel time forecasts for multiple routes across the network, using a single model and data from multiple traffic data sources. Moreover, to enhance the trustworthiness of the prediction process, the Granger Causality Deep Learning adaptation, Neural Granger, is applied to detect causal relationships between road network locations. In addition, aspects of traffic flow theory are incorporated into a causal and multitask Physics-Informed Neural Network forecasting model, using an innovative loss function derived from Traffic Flow Theory, which, in addition to the prediction error, takes into account the distance of the forecasts from the corresponding fundamental diagram. The above framework is applied to segment trajectory data from the city of Xi'an, China, and to traffic and public transport demand data from the greater area of Athens.

The results reveal important traffic patterns that describe the mechanics of the road network and have the potential to increase the predictability of traffic conditions, as indicated by the corresponding experiments. Furthermore, the detection of causal relations and the incorporation of basic knowledge of Traffic Flow into the loss function significantly increases both the accuracy and trustworthiness of the short-term predictions and the robustness of the model to noisy data.

Future research will focus on evaluating the feasibility of transferring these structures to other locations on the same road network and other road networks, as well as using more complex structures and Deep Learning techniques to further improve the prediction performance.

Finally, an attempt will be made to combine all the above structures into a theoretically informed, causal, multimodal and network-level prediction framework.