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“Technical Research and Development for Road Policy Quality Improvement”
Study Summary

No.	Title	Principal Researcher
No.30 - 3	Development of tourism congestion management based on learning-based monitoring and traffic flow forecasting	Univ. of Tokyo Prof. Takashi Fuse

The research aims to develop learning-based traffic condition monitoring and forecasting methods and adaptive traffic demand management to improve traffic flow in congested tourism areas.

1. Backgrounds and Objects

To use roads wisely, it is essential to manage traffic flow based on appropriate monitoring and traffic flow forecasting. In particular, traffic flow management based on monitoring and traffic flow forecasting are effective for tourism congestion, which requires consideration of the non-stationary nature of traffic and the significant variation in characteristics according to seasons and events.

In recent years, big data, such as fixed-point observation data and mobile observation data, have been acquired. In addition, learning methods, such as AI, are being developed, and it is expected that highly accurate monitoring methods and road traffic management using traffic condition forecasting will be developed using big data and learning methods. Furthermore, there is a need to establish an integrated methodology from monitoring and traffic condition forecasting to road traffic management and social implementation based on this methodology.

This study aims to develop a learning monitoring system, a traffic condition forecasting system, and a traffic flow management scheme for the area based on monitoring and forecasting, contributing to the study of efficient and effective traffic congestion countermeasures for tourism.

2. Activities in Research Period

In Theme 1, we construct a learning-type monitoring system that recognizes the movements of vehicles and people from various data. The monitoring system makes it possible to estimate the current values of traffic conditions. Based on this result, we construct a learning-type traffic condition forecasting system in Theme 2. In particular, this system is designed for short-term forecasting. Theme 3 is to build a traffic flow management scheme. To link these themes, we will develop the basic technology for the linkage in Theme 4.

3. Study Results

Theme 1: Development of a learning monitoring system

We developed models using a unified approach based on data assimilation for fixed-point cameras, GNSS, Wi-fi, and satellites. We developed a model with deep learning to recognize and track vehicles and people by fixed-point cameras. We extended it to a simultaneous estimation method of the number of objects and tracking. We also developed a model for simultaneous estimation of the number of people staying and moving in a mesh unit based on the conservation law by integrating GNSS and Wi-fi data (Figure). In addition, we developed a vehicle density estimation method using deep learning and a high-resolution/high-image-quality method for nano-satellites.

Figure: Estimation in Kamakura City

Theme 2: Development of a traffic condition forecasting system

We developed an analytical framework using deep learning to forecast the temporal concentration of vehicles in a short period (30 to 90 minutes). Since data such as traffic volume is time-series data with a strong dependency on the time direction, we used LSTM, a model suitable for forecasting time-series data in deep learning. We verified the forecasting accuracy of the model for each season, the effects of precipitation

and social events, and the forecasting accuracy during congestion periods on the actual data. We confirmed that the error rate was lower during times when there was a large influx of vehicles.

Theme 3: Development of a traffic flow management scheme

The framework for dynamic pricing was organized into themes 1 and 2, and a method for base price based on basic trends (seasons, holidays, time of day, etc.) and pricing adjustment based on real-time observation information was developed. We developed a model based on the equilibrium allocation of users with variable demand by time for trend-based pricing. Useful findings were obtained from the results for the cordon charge policy for the city of Kamakura. In addition, we developed a method for adjusting the prices based on real-time observation information by introducing reinforcement learning for trial-and-error adjustment. We experimented with the framework of experimental economics and analyzed the behavioral changes of individuals.

Theme 4: Development of basic technologies for inter-thematic collaboration

To strengthen inter-thematic collaboration, we developed a method for interpolation in arbitrary links for areas with different characteristics or for which observation data are not available. We developed a dynamic spatio-temporal model for interpolation in arbitrary links. In addition, we have developed a method for estimating the behavior of individual vehicles in real-time from the traffic conditions on the link obtained through monitoring, forecasting, and interpolation. This paper introduced data assimilation and developed an optimization method based on large-scale analysis using deep learning to resolve the differences between observed data and simulations efficiently. The developed method was applied to the OD inverse estimation problem, and the method's effectiveness was confirmed.

4. Papers for Presentation

(1) Sakai, K., Seo, T., Fuse, T: Traffic density estimation method from small satellite imagery: Towards frequent remote sensing of car traffic. IEEE 22nd International Conference on Intelligent Transportation Systems, pp.1776-1781, Auckland, New Zealand, 2019.

(2) Qian, Q., Fukuda, D., Han, K. and Song, W.: Reservoir-based surrogate modeling of dynamic user equilibrium. The 23rd International Symposium on Transportation and Traffic Theory (ISTTT23), Lausanne, 2019.

(3) Murakami, D. and Griffith, D.A.: A precompression approach for fast spatial mixed effects modeling. Spatial Statistics 2019, Sitges, Spain, 2019.

(4) Ichimura, T., Fujita, K., Yamaguchi, T., Hori, M., Wijerathne, L., Ueda, N.: Fast multi-step optimization with deep learning for data-centric supercomputing, 4th International Conference on High Performance Compilation, Computing and Communications, 2020.

(5) Sato, K., Seo, T., Fuse, T.: A reinforcement learning-based dynamic congestion pricing method for the morning commute problems, Transportation Research Procedia, Vol.52, pp.347-355, 2021.

5. Study Development and Future Issues

In each theme, we have developed a learning method. It is necessary to secure training data in each case, so it is essential to consider the methodology. Another problem with deep learning, in general, is the difficulty of interpretation. To address this issue, it is expected that the introduction of explainable AI methods will enable the understanding of models and results. In addition, a mechanism for automatic selection of explanatory variables can be introduced and extended to improve both interpretation and estimation accuracy. It is also possible to expand the model to other cities.

6. Contribution to Road Policy Quality Improvement

The results of this research are very versatile. Further improvement of the accuracy, stability and speed of the system will increase its usability. It will also be helpful to identify the specifications of observation instruments. It is also expected to be used as a more realistic forecasting method, although the difficulty of short-term forecasting has been pointed out. Trend-based billing has yielded findings that contribute to policy. In addition, it was confirmed that trial-and-error pricing eliminated congestion, which is also considered to contribute to practical use.

7. References, Websites, etc. [None]