日本―米国　国際共同研究 「新型コロナウイルス感染症（COVID-19）により求められる 新たな生活態様に資するデジタルサイエンス」 2022 年度　年次報告書	
研究課題名（和文）	新型コロナウイルス・パンデミック・総合災害管理向けのマルチモーダルデータの統合解析
研究課題名（英文）	Multimodal Data Analytics and Integration for Effective COVID-19, Pandemics and Compound Disaster Response and Management
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1．日本側の研究実施体制

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2．日本側研究チームの研究目標及び計画概要

The coronavirus disease 2019 (COVID-19) pandemic has caused around 500 million confirmed cases and more than 6 million deaths in the global. Furthermore, pandemic and other natural disasters' co-occurrence, such as hurricane, blizzard, typhoon, and earthquake, is even more challenging. In our project, we expect to utilize mobility, social media, and other modality (hurricane tracks, demographic, etc.) data, and leverage advanced intelligent data analysis and data fusion techniques to assist the pandemic and compound disaster response and management. Specifically, (1) epidemic forecasting has been a key research topic

again as it can guide the policymakers to develop effective interventions and allocate the limited medical resources. Thus, we aim to develop a brand-new model for multi-time multi-region epidemic forecasting based on the big mobility data and advanced deep learning technologies. On the other hand, (2) we consider that each disaster event including COVID-19 is distinct and almost unpredictable. Human mobility under disasters will deviate from its routine, which makes the human mobility nowcasting under disasters more challenging. Fortunately, we have social media data that can provide valuable information to sense the collective sentiment under disasters. Thus, we aim to incorporate the disaster-related social media data for human mobility nowcasting under disasters. Last, (3) without relying on extra data sources such as social media data, could we have a robust "event-aware spatiotemporal forecasting" model that can automatically perceive and adapt to the anomalous spatiotemporal signals (i.e., crowd flow, traffic flow, transportation demand under disaster situations)? To find the solution for this research question, we visited Prof. Chao Zhang at Georgia Tech who is leading an NSF funded research project called "An Uncertainty-Driven Predict-and-Optimize Learning Framework" and established a collaborative research relationship.

3. 日本側研究チームの実施概要

First, epidemic prediction is a fundamental task for epidemic control and prevention. Human mobility is seen as one of the most important factors to understand and forecast the epidemic propagation among different regions. Thus, we propose a novel hybrid model called MepoGNN for multi-step multi-region epidemic forecasting by incorporating Graph Neural Networks (GNNs) and human mobility graph into Metapopulation SIR model. Our model can not only predict the number of confirmed cases but also explicitly learn the epidemiological parameters and the underlying epidemic propagation graph from heterogeneous data in an end-to-end manner. Experiment results demonstrate our model outperforms the existing mechanistic models and deep learning models by a large margin. Furthermore, the analysis on the learned parameters illustrates the high reliability and interpretability of our model and helps better understanding of epidemic spread. In addition, a mobility generation method is presented to address the issue of unavailable mobility data, and the experiment results demonstrate effectiveness of the generated mobility data as an input to our model. We published this work at European Conference on Machine Learning and Data Mining（ECMLPKDD） 2022,

one of the best machine learning and data science conferences. This work is the first epidemic metapopulation model driven by deep learning technologies and big mobility data.

Second, we develop a novel model called Meta-knowledge-Memorizable Spatio-Temporal Network (MemeSTN) to learn the cross-modal correlations and inter-dependencies between the social media and mobility data. The tweet count is utilized as an effective covariate for human mobility nowcasting during disasters, which guides the modeling of the heterogeneity in the responses to the disasters across different regions and the differences in human mobility under normal and abnormal scenarios. Specifically, we first extract the spatial meta-knowledge (SMK) and temporal meta-knowledge (TMK) from the social media data through one spatio-temporal network, then utilize the SMK and TMK to parameterize another spatio-temporal network for modeling the mobility data.
Essentially, this “learning-to-learn” meta-learning procedure is to perform data fusion by “learning-social-to-learn-mobility”. Furthermore, we utilize a learnable memory bank to store the socio-temporal prototypes (e.g., normal days, disaster coming) learned from the history, and let the current refer to the history via attention mechanism, through which the abnormality caused by the disaster can be quickly perceived. We published the work at International World Wide Web Conference, （TheWebConf）2023 (WWW2023), the best computer science on Information Retrieval and Artificial Intelligence.

Last, we connected with Prof. Chao Zhang at Georgia Tech, who is developing uncertainty-aware deep predictive models for spatial networks by modeling complex spatiotemporal dependencies while capturing the inherent uncertainty of the system. We agree that meta-learning is the key technique for to achieve event-aware spatiotemporal forecasting. We will continue to seek the solution together through online meeting.