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研究課題名（和文）DeepMob: Learning Deep Models from Big and Heterogeneous Data for Next-generation Urban Emergency Management

研究課題名（英文）DeepMob: Learning Deep Models from Big and Heterogeneous Data for Next-generation Urban Emergency Management

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研究成果の概要（和文）：本プロジェクトの研究進捗状況は非常に良好である。結果として、私たちの研究成果は、AAAI 2018、ACM IMWUT 2018、ACM KDD 2019、ACM IMWUT 2019、Applied Energy 2018と2019を含む、コンピュータサイエンスに関する様々な著名な出版物に掲載された。

研究成果の学術的意義や社会的意義
本研究は、フロンティアビッグデータ応用分野において大きな意義を持ち、大規模災害や緊急事態発生後の経済損失、交通機関の混乱、廃業などを最小限に抑えることで、重大な社会的・経済的影響を与える可能性を秘めている。

研究成果の概要（英文）：The research progress of this project is very good. Our research results were published in the eminent publications for computer science including AAAI 2018, ACM IMWUT 2018, ACM KDD 2019, ACM IMWUT 2019 and Applied Energy 2018 and 2019.

研究分野：情報学

キーワード：Disaster Informatics　Big Data and Data Mining　Artificial Intelligence　Urban Computing　Internet of Things

１．研究開始当初の背景

Human mobility understanding and modeling is core research for building smart cities and sustainable urbanization. However, this type of research is very difficult to perform due to the fact that there is no reliable method to accurately sense human mobility. Recently, however, people's mobile phone data, GPS trajectories data, location-based online social networking data, and IC card data have become readily available and this information has increased explosively. The explosion of this human mobile sensing data has become today's "Big Data", and offers a new way to circumvent the methodological problems of earlier research for human behavior modeling, because it offers high temporal and spatial resolution is: instantaneously available; has no interview bias; and provides longitudinal data for very large populations [1-4]. Lu et al. [3] collected data from 1.9 million mobile users in Haiti to analyze population displacement after the 2010 Haitian earthquake, and concluded that population movements during disasters may be significantly more predictable than previously thought. Song et al. [5-7] collected data from 1.6 million GPS users in Japan to mine and model population evacuations during the 2011 Great East Japan Earthquake and Fukushima nuclear accident, and demonstrated that the prediction of large population movements after large-scale disaster was very possible. However, this model cannot accurately predict behavior or mobility for individual people. Thus, Song et al. [8] proposed an HMM-based behavior model to accurately predict an individual person's evacuation behavior or mobility following large-scale disasters.

However, due to the uniqueness of these disasters, the existing models (including our previous research) are difficult to apply to different disasters or emergency events (e.g. small scale ones) and to places not affected by the disaster. Furthermore, human emergency behavior patterns following natural disasters or emergency events usually have a high degree of freedom and variation, and are impacted by many factors, e.g. disaster intensity, damage level, news reports, transportation conditions, people's social relationships, etc. Even though the existing models provide some of the fundamental hypotheses and characteristics for human emergency behaviors and mobility, answers or "deep knowledge" for them remain, mostly, largely unknown (e.g. how different factors will influence people's decisions after emergency events, how important are these factors, etc.) due to the fact that they are "shallow models" and difficult to apply to handle big and heterogeneous data sources.

The proposed research plans to make significant progress towards understanding of human emergency behavior and mobility, and to offer new models and systems to deal with these challenges and problems to achieve significantly more efficient next-generation urban emergency management.

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２．研究の目的

The frequency and intensity of natural disasters and emergency events (e.g. traffic accident, fire, extreme weather, etc.) has significantly increased over past decades and this trend is predicted to continue. Facing these possible and unexpected events, urban emergency management has become a big problem for governments across the world. To plan effective humanitarian relief, transportation scheduling, disaster management and long-term societal reconstruction, modeling, understanding and accurately predicting human "emergency behavior and mobility" will play a most important role for the next generation of urban emergency management. Hence, this project aims to understand what basic laws govern human behavior and mobility following emergency events by mining big and heterogeneous data, to develop deep and powerful models for human emergency mobility prediction and simulation. The project will also implement DeepMob - the intelligent system for next-generation urban emergency management.

It is well known that hurricanes, earthquakes, traffic accidents, extreme weather and other emergency events cause immense physical destruction, loss of life and property around the world. This project's research is of great significance in the frontier big data application field, and has the potential for enormous societal and economic impacts by minimizing the economic loss, transportation disorders, and business closures after major disasters or emergency events. The proposed intelligent system (DeepMob) play a critical role in effective humanitarian relief, urban planning, transportation management, and emergency management. The resulting data, models and systems are of direct benefit to Japan for building smarter cities and sustainable urbanization.

This project addresses human mobility understanding/urban computing/urban dynamic modeling, and it focuses on following tasks:

Task 1 - Data Collection and Knowledge Discovery: We collected big and heterogeneous data sources (e.g. GPS data, mobile phone data, IC card data, public information data, transportation network data, POI data, disaster data, traffic accident data, emergency events data, social networking data, etc.) to capture and analyze human behavior and mobility under different kinds of emergency situations. We also developed new approaches or algorithms to understand and discover general knowledge for human emergency mobility.

Task 2 - Deep Model Development: We developed deep models to understand how different factors will influence people's decisions after emergency events, and to handle big and heterogeneous data sources.

Task 3 - Application and System Implementation: Built on collected data, already-developed models and our previous research, we implemented the intelligent system called DeepMob for next-generation urban emergency management. It provides a tool to predict and simulate population mobility following emergency events at a city, or national scale. It provides services for evacuation route recommendations, transportation scheduling, and traffic accident alerts.

３．研究の方法

Based on our previous research [5-8], we find that: although human behavior and mobility patterns following natural disasters have a high degree of variation and freedom, the majority of human mobility is based on random movement between a small set of important places, such as home location, working location, social relationship (friends' house, hometown, etc.) and some unknown places (e.g. shelters, hotels, etc.). These mobility patterns will also be impacted and influenced by various factors. For instance, if a small earthquake with low intensity occurs at midnight, people may stay at home and go back to sleep. In contrast, if a big earthquake occurs at midnight and causes some building destruction, people may leave the house to find safe places to stay, and they may need to consider the travel distance or travel time. If an extremely large and serious earthquake (such as 2011 Great East Japan Earthquake) occurs and becomes a composite disaster accompanied with negative news reporting, people may leave their city and move to a safer place (e.g. hometown) far from the disaster. We aim to understand how these factors will influence and govern people's decisions following natural disasters, and to develop a deep model by learning from big and heterogeneous disaster data.

This project utilizes deep learning technologies to construct deep models of human mobility and behavior. The proposed learning architecture consists of two tasks and needs to learn the knowledge from the heterogeneous data sources: (1) learning deep representation and predictive models of human behavior from human location transition sequences and disaster information data; (2) learning deep representations and predictive models of human mobility from mobility (e.g. GPS, Mobile phone and etc.) and transportation data. Even though the two tasks and the data sources are heterogeneous, they also share a lot of important information and are highly correlated with each other. This project uses multimodal learning to jointly learn the deep knowledge of human behavior and mobility following disasters. Therefore, the proposed deep model consists mainly of two parts: In the bottom layers, we employed a deep belief network (DBN) to perform knowledge discovery and unsupervised feature learning. For each task, we first train several hidden layers for each data source, and then train the shared representation for human behavior and mobility. In the top layer, we employed a sigmoid regression layer above DBN layers to perform supervised learning for human emergency behavior and mobility prediction.

４．研究成果

The research progress of this project is very good, and our research achievements can be summarized as follows: (1) we successfully collected big and heterogeneous data sources for the entire research. To manage these data, we developed a Hadoop cluster that consists of 32 cores, 32 GB memory, and 16 TB storage, and is able to run 28 tasks simultaneously. (2) we build an online system called DeepUrban-

Momentum to conduct the next short-term mobility predictions by using (the limited steps of) currently observed human mobility data. We apply our system to a real emergency scenario and demonstrate that our system is applicable in the real world. (3) we developed an online deep ensemble learning model for predicting citywide human mobility. Our approach was evaluated using a real-world GPS-log dataset from Tokyo and Osaka and achieved a higher prediction accuracy than baseline models. (4) we proposed a deep ROI-based modeling approach for effectively predicting urban human mobility. Experimental results demonstrate that the superior performance of our proposed approach to the baseline models and several real-world practices show the applicability of our approach to real-world urban computing problems. (5) we developed a novel approach to extract the deep trend only from the current momentary observations and generate an accurate prediction for the trend in the short future, which is considered to be an effective way to deal with the emergency event situations. (6) we developed a novel decentralized attention-based human mobility predictor in which: 1) no additional training procedure is required for personalized prediction, 2) no additional training procedure is required for incremental learning, and 3) the predictor can be trained and predicted in a decentralized way. (7) we developed a novel approach for analyzing the potential reduction in emissions associated with the adoption of a bicycle-sharing system.

Our research results were published in the eminent publications for computer science including AAAI 2018, ACM IMWUT 2018, ACM KDD 2019, ACM IMWUT 2019 and Applied Energy 2018 and 2019.

５．主な発表論文等

〔雑誌論文〕　計12件（うち査読付論文　12件／うち国際共著　3件／うちオープンアクセス　0件）

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1．著者名 Xia Tianqi、Song Xuan、Fan Zipei、Kanasugi Hiroshi、Chen QuanJun、Jiang Renhe、Shibasaki Ryosuke	4．巻 1
2．論文標題 DeepRailway: A Deep Learning System for Forecasting Railway Traffic	5．発行年 2018年
3．雑誌名 Proc. of 2018 IEEE Conference on Multimedia Information Processing and Retrieval (MIPR)	6．最初と最後の頁 51-56
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1．著者名 Renhe Jiang, Xuan Song, Zipei Fan, Tianqi Xia, Quanjun Chen, Satoshi Miyazawa, Ryosuke Shibasaki	4．巻 1
2．論文標題 DeepUrbanMomentum: An Online Deep-Learning System for Short-Term Urban Mobility Prediction	5．発行年 2018年
3．雑誌名 Prof. of Thirty-Second AAAI Conference on Artificial Intelligence (AAAI) 2018	6．最初と最後の頁 784-791
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〔学会発表〕　計0件

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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6．研究組織

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