論文の内容の要旨

論文題目　A Study on Urban Mobility and Dynamic Population Estimation by Using Aggregate Mobile Phone Sources
（和文：　携帯電話情報を用いた都市における人々の移動特性分析と動的な人口推定手法に関する研究　）

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Sensing is becoming increasingly mobile and people-centric in a network enabled society. Urban activities are recognized from the footprint of the usages of ubiquitous urban infrastructure. This new paradigm is a combination of urban infrastructures, information and communication technologies and digital networks. The rapid technology development in the area of digital network and telecommunications has a significant impact on our societies, lifestyles and the way we interact with the city. The technological advances and the benefits resulting from the use of these technologies are capable of improving current urban management, and introduce new schemes for urban mobility studies. This dissertation explores a novel practice concerning how mobile devices can be employed as a new urban mobility sensor, location-aware and human in the loop system that enables city wide information collection and analysis.

Despite the growing concern for public health, urban securities and natural disasters, these studies have initially been developed to improve operational efficiency or to plan public space management. Understanding the population dynamics at high spatial and temporal resolutions, especially when incorporated into established population distribution models, will hopefully allow for detailed investigations of populations impacted by natural and manmade disasters and, subsequently, could lead to more appropriate emergency planning and responses, as well as better informed policy decisions.

Another promising application in utilizing digital footprints from the mobile devices is public marketing analysis. The distribution of a population at different points of time in each city space could be an ideal source for marketing executives to decide on a place to activate premium urban

advertising opportunities or campaigns that are geographically based with more targeted and efficient marketing. These finsights would allow them to offer more specific ad-funded and LBS services that stimulate uptake and increase their profitability.
In this research we explore and analyze the daily population distribution patterns in the city, using a unique data source from aggregate calling activity over time in a mobile phone network. This study will therefore address the following research questions: Would modification of calling activities be confirmed to correspond to actual population in the area? How do such patterns vary in different parts of the city? And how can human mobility be reconstructed from calling records of mobile phones? The questions are meant to explore whether the population distribution follows a trend of mobile phone call detail records (CDRs) and to investigate using such data for potential develop dynamic population estimation models.

To test the provided research questions, the study had been conducted in several major cities of the world starting from a test base scenario in central Bangkok in 2008. We developed a system call “Mobile Sensing”, a web based 2D and 3D GIS, to use as a fundamental tool for mobile phone data visualization and analysis. The initial results depicted and captured time series of interpolated mobile phone call traffic in a grid density surface. This observation leads to the speculation about how one part of the central city is upscale, crowded and how long the area remains busy until people move to another part of the city. The analysis of the mobile phone activities during one day and the mean transformation within a month has been examined to extract each cityscape’s communal pattern. In addition, results of the study not only provided a tool for area or zoning analysis but also could be used to specify hidden problems of the particular space over a period of time.

In 2009, millions of mobile phone users in Massachusetts were examined. It was the first time that a huge amount of mobile phone traces were used to analyze the mobility of the city. The numerical algorithms were developed to extract the revisit points of individuals, for instance, home and work locations. We preliminarily analyzed this data by characterizing mobility in a profile-based space (activity-aware map) that describes most probable activity associated with a specific area of space. This, in turn, allowed us to capture the individual daily activity pattern and analyze the correlations among different people’s work area’s profile. We also investigated how good a correlation exists between the presence of people and the mobile phone activities by inventing “SIM Mobility”, a mobile phone traffic simulation system. The product outcome has been validated with simulated trajectories and MassGIS census data. The results yielded evidence confirming that the mobile phone activities are significantly correlated to the existence of people.

The last part of this dissertation was implemented in the Tokyo metropolitan area. The Tokyo’s mobile phone traffic or call detail records (CDRs) were generated from the SIM Mobility simulation

system. The calling patterns of the Greater Tokyo region were built from analyzing mobile phone usage surveys, and the simulated trajectories were retrieved from Tokyo Person Trip data. Besides this, we developed new dynamic population estimation methodologies involving two different approaches and investigated the accuracy of results. The first methodology was implemented using a group based approach, and the population weighted factor has been modified by time-dependent OD metrics extracted from the observed mobile phone calling traffic. The second methodology was implemented using an individual based approach utilizing data assimilation process. The estimation results shown greatly accurate prediction and capable of being enhanced the existing algorithm previously developed by The Tokyo Metropolitan Region Transportation Planning Commission. By using a complete scale of this novel data type, the proposed methods would enable real-time reporting of city-wide population estimations and potentially paint a complex and dynamic portrait of the urban dynamic in which users are based.

Using mobile phones as sensing devices to accumulate aggregate “crowdsourced” data for urban analysis is still in the early phases of development. The contributions of this research would pave the way for future extensions to larger and more complex analysis.