An Implementation of Mobile Sensing for Large-Scale Urban Monitoring

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Abstract

The extent of human flow in the urban space has reached unprecedented levels, and is therefore the focus of the present study. Unlike common practice on urban monitoring which utilizes cameras or sensors, this research aims to introduce a new platform of urban analysis and monitoring by using mobile sensing to recognize urban behaviour. Population density and its moving pattern can thus be visualized from the usage of the mobile phone.

The mobile sensing system is implemented on a web-based interface in order to maximize compatibility and interoperability. The aggregate mobile usages and antenna-mast positions are interpolated into grid-density surfaces. We then analyze urban patterns at a point of time to illustrate how people experience their city. Furthermore, the analytical results help to detect and to explain geographical 'hot spots' and clusterings of the unique characteristics of each urban space. Finally, we present visualizations of the results such as pseudo color and contour maps in order to demonstrate the urban dynamics.

I. INTRODUCTION

With the ubiquity and ever-increasing capabilities of mobile devices, cell phones and their locations could potentially become a powerful source to describe the pattern of the urban space. Traditionally, urban monitoring and analysis rely on a fixed location and a considerable amount of statistical data. This procedure does not permit the identification of multi-temporal events in wide areas. Another key problem is how to acquire and update the statistical data of the moving objects, for instance, humans and their activities in the whole city space.

In this research, the usage of mobile devices will be treated as a medium for data collection. Erlang data that represent a distribution of call duration in the Global System for Mobile Communication (GSM) network could be performed as aggregate-data sources to estimate the population density of a city. For the large scale monitoring, clusters of Erlang data from mobile base stations are excellent at providing indirect interpretations of spatial patterns of urban life and its temporal dynamic. This aspect is very useful in the view of public monitoring. It could potentially become a new way to extract or identify invisible problem spots from the complex urbanized areas. Furthermore, mobile sensing is potentially applicable for public-marketing analysis. The distribution of a population at different points of time in each city space could be an ideal source to help people decide a place for urban advertising or opening a shop. In addition, an exploration of mobile sensing data would give the urban planner a better understanding on flowing patterns of people at specific times of the day. If we look at broader contexts, then population transfers from city to city during special events or public holidays could also be determined.

Study area

The research takes place at Bangkok Metropolitan, Thailand. Bangkok city has a well developed mobile network and has a high degree of mobile usage. We received the support of the Erlang data and base station locations from Advanced Info Service PLC (AIS), a leading mobile operator in Thailand.

YSTEM ARCHITECTURE

In the early research, the system was implemented as a fundamental tool for spatial exploration and visualization which permitted the data to be obtained, integrated and displayed quickly, easily and flexibly. Since the internet has now made distance virtually disappear, we questioned the traditional method of urban monitoring by enhancing the way how to instantaneously integrate and obtain large amounts of data via the network.

Back end application servers

To maximize compatibility and interoperability, open standards such as XML and web services are utilized for data exchange and sharing. Data analysis is assisted by the open source statistical package R (http://www.r-project.org), integrated into the PostgreSQL database via the PL/R procedural language.

A browser front end

The web browser we use as a universal front end, an Ajax mashup, is a hybrid web application which presents a rich UI to update and integrate contents asynchronously from multiple sources. This makes combining data easier, not only spatial data from the host server but also third-party sources from the services available on the internet. The calls can also be made directly to the third-party sources from the browser or back to the originating server, which acts as a proxy for the third-party contents.
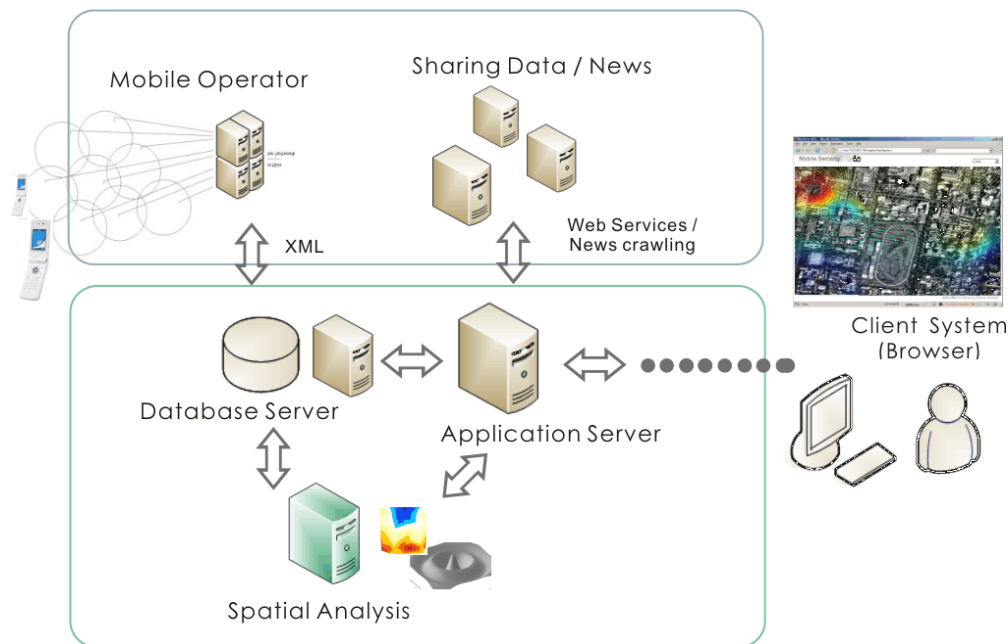

Fig. 1. System architecture of mobile sensing system

Data manipulation

We first simulate a connection with a mobile operator in our local environment instead of communicating directly to the mobile-operator system. The mobile-log data during the period from February to April 2008 that cover a part of the central Bangkok area are transformed and inputted into a database. The data established in the database mainly include cell-id, the base station geographic position, update time and Erlang data. The Erlang data

which is calculated from call duration are performed as a sample distribution in order to estimate the population density of the whole area.

cellid	lat	lon	Start_time	erl
BKKC1	13.75697	100.5594	2008/03/01 9:00	33.98
BKKC2	13.75697	100.5594	2008/03/01 9:00	18.93
BKKC3	13.75697	100.5594	2008/03/01 9:00	33.17
PTWA1	13.75138	100.5402	2008/03/01 9:00	20.75
PTWA2	13.75138	100.5402	2008/03/01 9:00	17.93
PTWA3	13.75138	100.5402	2008/03/01 9:00	33.07

Table 1. Sample data from the Base Station Controller (BSC)

Population and prediction model

To present population data in a continuous space, we need interpolation techniques to generate a surface from discrete points. There are many interpolation techniques, each with its own weaknesses and strengths. In this paper, we introduce an inverse distance weighted (IDW) and ordinary kriging method to predict population density in our prototype system. In order to increase the resolution of the interpolation results, we calculate the weight in each sector cells separately by using voronoi tessellation to increase a discrete set of points.
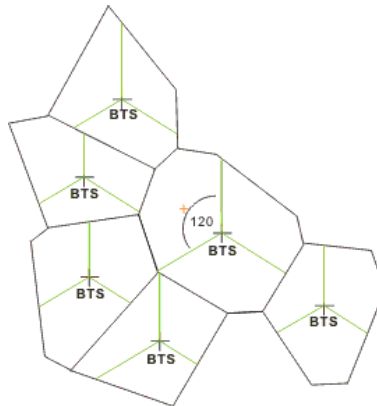

Fig. 2. Voronoi tessellation over sector base station

III. RESULTS AND DISCUSSIONS

We start by presenting our first results on querying the cumulative usage of mobiles over an hour interval. Histogram and time series statistics can be retrieved from specific locations on a map and display in a time-plot based graph. The first two types of graphs, day and month, were produced by implementing a getStat webAPI in conjunction with Timeplot, a DHTML-based AJAX widget. The exploration leads to a better understanding of each area's activities during one day, as well as the difference characteristics between weekdays and weekends. In Figure 3(a), we pick up an office area in central Bangkok, and the time plot shows the trends of increasing activities from early morning up to the peak at noon, then decreasing gradually after 5.00 pm. Figure 3(b) and (c) illustrate the overall activity on a monthly basis. We can capture a weekly rhythm of this area which clearly defines high activities on the weekdays and appears to decrease on Saturday and Sunday. Figure 3(c) presents a pulse in April: we can see a week of flat, low activities since it was a long holiday in Thailand.
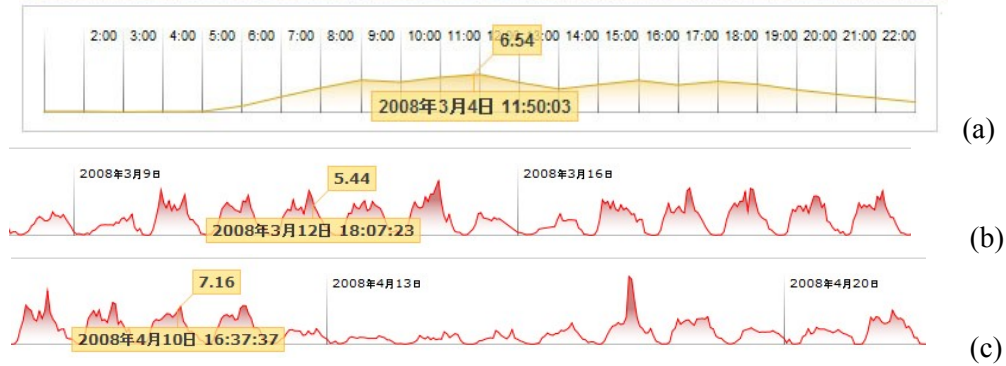
Fig. 3. Day and month statistics from cumulative mobile usages data

Temporal analysis of human flow

Another approach to explore the data is to generate a surface-flow pattern by interpolating the aggregate call traffic. Exploratory analysis of temporal data can give a clear view on how people flow into and out of the city throughout the day. Figure 4 shows the flow patterns in one local area from 6.00 am until 8.00 pm. This observation leads to the speculation on how one part of the central city is upscale, crowded and how long the area keeps busy until people move to another part of the city. It is extremely useful for the urban planner to figure out how type of land use, street network and other city landscapes could affect the flow and density of the urban area. Furthermore, results of the study not only provide 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.
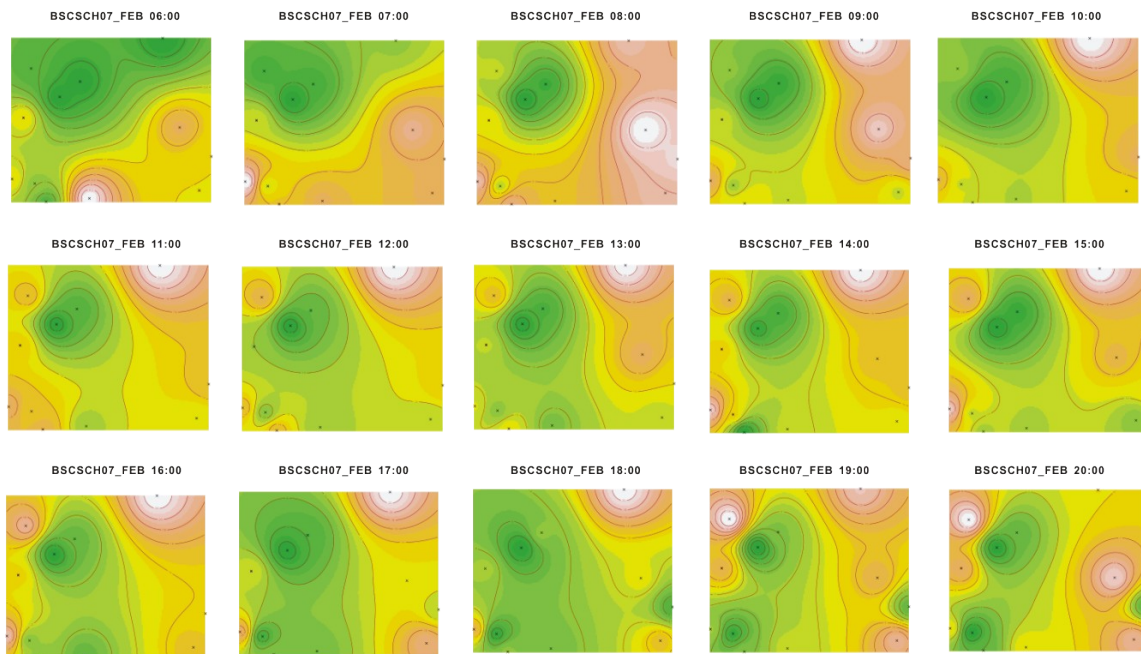

Fig. 4. The flow pattern from early morning to late evening in central Bangkok

Hot spot capturing

In order to clearly highlight the extreme values in distribution surfaces, we now generate the volume of population density with an overlay contour diagram using a specific color palate. In Figure 5, to illustrate how

mobile density could reflect the real world daily activities, we capture Pathumwan area. This is one of the most active spots in Bangkok that has a mixed land use, for example high rise office buildings and a large-scale shopping complex. If we compare the same period of time at 1.00 pm. on Friday and Sunday, the result demonstrates that on Friday the activities are dense at the office area and, in contrast, a peak density moves towards the shopping area on Sunday. Obviously enough, this kind of hot spot extraction could be useful to capture some hidden aspects in the urban space. We are planning to collect a longer span of archive data and make a base urban signature in order to implement a real-time signature recognition and hot spot extraction.
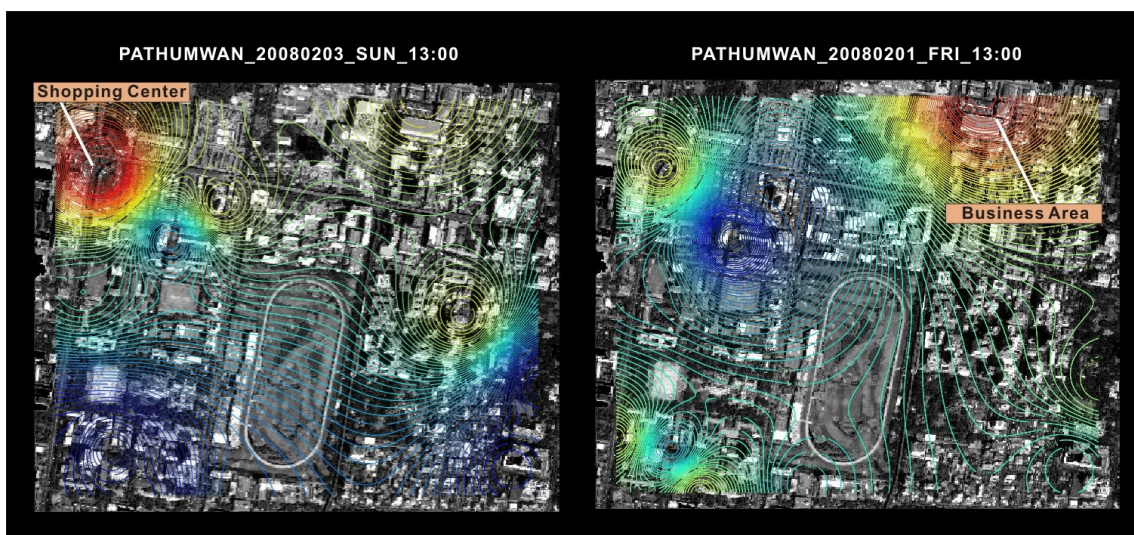

Fig. 5. Density contour in Pathumwan area on Friday and Sunday at 1.00 pm.

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