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Review

A novel Bluetooth low energy based system for spatial exploration in smart cities

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ABSTRACT

Smart Cities are employing information and communication technologies in the quest for sustainable economic development and the fostering of new forms of collective life. They facilitate connections between citizens and organizations that are of paramount importance for their long-term sustainability. As cities become more complex and their communities more dispersed, questions such as 'where can I find …' are increasingly pertinent. In this paper, we introduce NomaBlue, a new vision of spatial recognition in smart cities, the proposed system is based on an intelligent nomadic data collection and users' collaboration using smart Bluetooth technology. We demonstrate using two case-studies that our approach is capable of proposing an efficient spatial recognition service while supporting a range of users' constraints, our system is disconnected from the internet, it can operate in any indoor/outdoor area, it doesn't require pre-defined geographic databases and uses a new concept of nomadic data collection and sharing to speed-up the circulating information in smart cities.

1. Introduction

The concept of Smart City (SC) as a means to enhance the quality of citizens' lives has been gaining increasing importance in the agendas of research communities. There is no unique definition for a smart city. The interpretations and definitions used by different interest groups, stakeholders and regions vary substantially. However, there is wide agreement about the fact that SCs are characterized by a pervasive use of information and communication technologies (Zanella, Bui, Castellani, Vangelista, & Zorzi, 2014), which, in various urban domains, help cities make better use of their resources, and assure future viability and prosperity in metropolitan areas. In Anthopoulos and Reddick (2016), SCs are defined as innovation not necessarily but mainly based on information and communication technologies, which aims to enhance urban quality of life in terms of people, governance, economy, mobility, environment and living.

One of the evolving domains of Smart Cities is smart buildings in which researchers are adopting sustainable building technologies to create smart living and working environments. These entities will keep a range of continuous calculations to propose efficient services to citizens (e.g. Aspects related to the quality of life in a residential building such as comfort, lighting, and heating (Medina, Gómez, Romera, Gómez, & Dorrozoro, 2012)). Furthermore, these smart buildings will provide a real-time extern information to the city and its citizens, information that will facilitate the urban development and the citizens' quality of life. Consequently, people will no longer visit an ordinary place, but a smart place of interest (SPOI is a smart (urban) geo-referenced object where a person may carry out a specific activity) that provides enhanced information both unobtrusively and in real time. For instance, SPOI will provide continuously a set of static metadata (the nature and the type of the building, number of floors, opening hours, …etc.) and dynamic metadata (temperature, humidity, the number of people inside the building, discounts of the day if the building is a shop, menu of the day if the building is a restaurant, …etc.). In SC, the update of this metadata needs to be instantaneous in order to provide an efficient information

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about the users' context. This characteristic will increase the use of such service to become a primary input for a new class of mobile services such as smart traffic monitoring, social networking, marketing and cognitive assistance.

Though, existing geographic data providers (Ballard, 2012; Brinkhoff, 2016; Shekhar & Xiong, 2008) encounter difficulties to meet the problem of updating information in smart cities, information that can change every hour. In fact, existing geo-exploration techniques are based on pre-defined spatial databases that provide a static information about the concerned geographic entity, e.g. the geographic shape, amenity, entrance…etc. However, this information is insufficient when used in smart cities because of the inability to provide richer and updated information, in fact, the majority of spatial data used around the world suffers few months' delay (Holland, 2003). For instance, let us take the case of a recommendation application that suggests a set of shops located in the surroundings of users, and imagine that a new shop has just opened in the neighborhood. As the existing spatial analysis techniques refer to the pre-defined spatial databases for the recommendation process, this new shop is unrecognizable by these services until the next database update which can take several months. Moreover, every shop may have a specific daily information that it would like to share, e.g. new products, discounts, new opening hours …etc. Handling these daily updates may become unfeasible using the existing spatial analysis techniques due to the time and the cost needed for such daily data collection and management.

In order to address such weaknesses, we propose a new vision of spatial recognition that offers to the citizens of SCs, an instantiate spatial service without any use of pre-defined spatial databases. Basing on a nomadic data collection and sharing, our work will offer an updated information about the Smart Cities' geographic entities. In this paper, we introduce NomaBlue, a smart Bluetooth-based and battery-friendly offline service that operates on users' phones without any additional connections requirement.

Citizens in smart cities play an important role in the evolution patterns of SCs as they represent one of the mobile agents of the city. They move in the various corners of the city taking their mobile devices with them everywhere. On the other side, the mobile phone is no longer a communication device only, but also a powerful environmental sensing unit that can monitor a user's ambient context discreetly and incessantly. As such, we will combine the sensing power of mobile phones and smart buildings in order to provide an efficient smart spatial recognition service.

The main idea of our system is based on the observation of a real-life situation, when a person is searching for some place in the city, he would probably start asking people around him if they know where to find this place, he would continue asking the people that he meets until finding his way. NomaBlue reproduces the same process but more efficiently; when two users meet each other in the street, they share a quantity of data instantly and unobtrusively using low energy Bluetooth signals, without any physical contact or even knowing what the other user is searching for.

NomaBlue is designed for SCs where Bluetooth beacons are amply deployed in the city. However as the proposed system prerequisites are only the user smartphones and the Bluetooth beacons, NomaBlue can be used in any environment where these two technologies are present such as malls, offices and airports, not necessarily in SCs only. More examples of NomaBlue usage will be presented in Section 3.

The following sections detail our contribution where we will answer the following questions: (i) how can the sensing power of mobile phones and smart buildings be combined in order to provide an efficient smart spatial recognition service? (ii) is it possible to create a geographic data source without using the internet or predefined geographic databases ?.

Section 2 reviews related works; Section 3 presents our research methodology by highlighting three parts: the overall process of our approach, the privacy and security in Nomablue as well as a third part where we illustrate some usage examples of the proposed solution; Section 4 describes the experimentations. Finally, conclusion and future focus, are summarized in Section 5.

2. Background

Our proposal provides a new geographic data source for location-aware systems by using the emerging social interaction in the cities to create a dynamic flow of information. This flow is built using transparent digital interactions between the citizens of the city. In order to discuss the different parts of our proposal, we divide our related works section into three parts: geographic data sources, social interactions in the city and Bluetooth systems.

2.1. Geographic data source

Geospatial analysis in urban areas has been well-explored in the last decades (Geographic Information Analysis and Spatial Data, 2010; Holland, 2003). Moving from the realms of academic research, the technology was first harnessed to the needs of large information-hungry organizations such as local authorities, environmental agencies, emergency services and utilities providers. More recently, GIS has leapfrogged onto the back of advances in desktop and mobile computing to find applications in every conceivable area of business activity (Ruta, Scioscia, Ieva, Loseto, & Di Sciascio, 2012; Shekhar & Xiong, 2008).

Location-aware mobile applications are fed from geographic warehouses in two ways: online and offline modes (Holland, 2003). Online services require the internet to communicate with the centralized geographic servers, this is insured using cartographic Web services such as Web mapping, feature and processing services (Geographic Information Analysis and Spatial Data, 2010). The geographic data can be produced manually by the application developers or by referring to one of the geo-data provider companies such as Google (Ballard, 2012), ESRI (Shekhar & Xiong, 2008) and OpenStreetMap (OSM) (Brinkhoff, 2016). Let us take the example of the Waze application (Waze, 2016), it is a community-based traffic and navigation app that shares real-time traffic and road information, the aim is to save everyone time and gas money on their daily commute. Every Waze user that went to share or get traffic information needs to be connected to the internet because they use Web Feature Services to store and defuse the users' notifications. Our work is similar to Waze in some points since both works are community-based systems. Moreover, as our work, Waze try to fill the gap between users and geographic data providers by offering information that does not exist in the providers databases, e.g. nearby police activity, accidents, traffic cameras, potholes,…etc. However, in our case, users don't need to be connected to the internet and don't need to harvest and share any information manually since in NomaBlue, the data collection and sharing processes are made without any user intervention.

The second technique to provide geo-data is offline mode, the concept is to avoid using the internet to get data, the main idea is to store the geographic database of the city in the user's mobile phone. In fact, many mobile GIS solutions such as Gis2go (2016) and GIS Cloud (2016) offer an offline version to avoid the constraints linked to the use of networks. For instance, Esri company, one of the world's biggest GIS companies, has provided a whole runtime (ArcGIS Runtime SDKs, 2016) to support offline mapping, it includes map viewing, interaction, editing and routing while fully disconnected from wireless. However, this technique requires