Human Movement Analysis Using Heterogeneous Data Sources

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ABSTRACT

The analysis of urban mobility has been attracting the interest of the research community recently. The research challenges in this domain are diverse and include data acquisition and representation, human movement modeling and the visualization of dynamic geo-referenced data. Some of the direct applications for these studies are urban planning, security, intelligent transportation systems and wireless networks optimization. One of the drivers for recent work in this area is the availability of large datasets representing many aspects of the urban dynamics. Quite often, the proposed approaches are highly dependent on the data type. However, the analysis of urban dynamics could benefit from the combined and simultaneous use of multiple sources of spatio-temporal data. This paper describes the definition of a set of basic concepts for the representation and processing of spatio-temporal data, sufficiently flexible to deal with various types of mobility data and to support multiple forms of processing and visualization of the urban mobility. For this purpose the authors define a set of concepts and describe how real data from heterogeneous sources is mapped into the proposed framework. Available results obtained by the integration of geometric and symbolic data reveal the adequacy of the proposed concepts, and uncover new possibilities for the fusion of heterogeneous datasets.

Keywords: Human Movement, Sensor Fusion, Space-Time Dynamics, Trajectories, Urban Modeling

INTRODUCTION

The mobility of citizens in an urban area is the source of various problems: traffic congestion, environmental pollution, overcrowding of public transportation systems and spreading of diseases, among others. For these reasons many efforts have been put to understand the mobility behavior of individuals in space, understand space itself, and understand the use people make of the urban space as a way to reduce and possibly eliminate these difficulties.

The dynamics associated with mobility in urban areas have always two components, Time

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and Space, rising new challenges on how to capture, represent and visualize these dynamics. While capturing the presence and mobility of people in urban spaces has evolved enormously in recent years, movement representation and visualization still faces many challenges. Actually, the huge size of datasets being collected these days is creating more challenges to representation, modeling and visualization rather than solutions (in spite of their great potential for mobility analysis).

As referred by Yu and Shaw (Yu & Shaw, 2004) existing Geographic Information Systems (GIS) are structured to represent the spatial component of data but lack good support for the temporal component. For this reason, some authors have developed platforms that provide support for spatio-temporal data, such as SEC-ONDO (De Almeida, Güting, & Behr, 2006), with the aim of representing the time dependence of mobile artifacts through the use of abstract definitions to represent the positions or shapes of objects over time and space, respectively (Erwig, Güting, Schneider, & Vazirgiannis, 1998). On the other hand there are also challenges in how this information could or should be presented for human movement analysis. Thus, several studies presented recently explore different forms of visual representation of movement data, such as the iSPOTS project (Sevtsuk & Ratti, 2005) which illustrates the occupation of space or, for example, the visualization of human travel behavior based on the trajectory of money bills (Brockmann & Theis, 2008).

However, regardless of how the dynamics of an urban space is represented, most of these works focus only on one, homogeneous, type of mobility data. Although our research work is focused on the analysis of the dynamics of urban space, our initial aim is to create a flexible and comprehensive conceptual framework for the representation of movement processes that allows the same concepts to be applied to different types of data from different sensors, such as GPS, Wi-Fi, GSM, ticketing systems, as well to the different modalities of urban mobility.

Our approach to capture the dynamics of the urban space is based on merging the individual mobility profiles of people. This approach aims to benefit from the current capability of smartphones and other personal devices to be used as proxies to observe human spatio-temporal behavior. In our approach, the first step in the analysis of the urban dynamics is, then, the automatic creation of personal mobility profiles from multi-sensor data. On a previous paper we set the foundations for the above mentioned framework, and proposed a method for place learning based on a probabilistic model applied to observations obtained from GPS, Wi-Fi and GSM sensors (Peixoto & Moreira, 2012). That previous work has been useful to assess the effectiveness of the proposed concepts and to identify different perspectives on the analysis of human mobility. In this article we intend to extend that work and discuss some of the open issues that were previously identified, namely the concepts of Place and Trajectory.

The next sections describe: some of the work developed in the field of analysis and visualization of urban mobility; the concepts that are the basis of our proposed framework for the representation of spatial-temporal data; one dataset composed of data from three types of sensors and how it is mapped into the proposed concepts. Finally, in the last section, some conclusions and open questions are discussed.

**RELATED WORK**

Recently, several studies have been presented in the area of modeling and visualization of urban mobility dynamics, using different techniques. One of these techniques analyze urban mobility using the temporal variation of the occupation that individuals make of the urban space (Sevtsuk & Ratti, 2005; Reades, Calabrese, Sevtsuk, & Ratti, 2007). This type of representation is based on the creation of temporal snapshots of space occupation. However, due to the dynamics of the urban space, this approach may not be the most appropriate for the analysis of pattern changes (Hagen-Zanker & Timmermans, 2008). Another problem is the definition of mobility in these approaches, because they represent the
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