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TAXONOMY FOR THE REPRESENTATION OF SPATIOTEMPORAL DATA

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ABSTRACT

Several visualization applications of urban mobility have been presented recently, either by the analysis of space occupation, or through the representation of trajectories. However these visualizations are highly dependent on the data type and often only applicable to the selected data type. This paper presents our initial work to create a taxonomy for the representation of spatiotemporal data, sufficiently flexible for various types of mobility data and different forms of visualization of the urban mobility.

INTRODUCTION

The mobility of citizens in an urban area is the source of various problems: traffic congestion, urban planning, among others. For this reason it is important to understand the behaviour of individuals in space, and space itself, and that these make use of urban space as a way to reduce and possibly eliminate these difficulties. However, the dynamics associated with the mobility in an urban area always has two components: Time and Space, rising new questions on how to represent and visualize these dynamics. As referred by Yu and Shaw (Yu and Shaw 2004) the current Geographic Information Systems (GIS) are structured to represent the spatial component of data but lack the temporal component. For this reason several studies, presented recently, investigate the spatiotemporal data visualization problem through different forms of visual representation. Although our research work is focused on visualization of the dynamics of urban space, our initial aim is to create a flexible and comprehensive taxonomy for the spatiotemporal representation of movement data that allows the same concepts to be applied to different types of data from different sensors, as well to the different scenarios of urban mobility.

RELATED WORK

One of the visualization techniques used in the representation of urban mobility is based on the creation of temporal snapshots of space occupation (Reades et al. 2007; Sevtsuk 2005). However, due the dynamics of the urban space, this approach may not be the most indicated for the analysis of pattern changes (Hagen-Zanker and Timmermans 2008). We believe that deep understanding of the phenomena associated with urban mobility involves the visualization of trajectories, which truly reflect the movements of individuals. In this area, one of the ways to represent trajectories is with vectors, where each vector represents an element in space and time, speed and direction of its movement (Moreira et al. 2010). Through this approach it is possible to have some sense of mobility, since it allows the representation of an individual according to a spatiotemporal reference. However as this representation is based on the observation of the instantaneous movement, the simultaneous perception of the origin and destination of the movement is not easily transmitted. In order to address this issue, some works are using a different technique for representing trajectories through interconnected source-destination pairs (Brockmann and Theis 2008). Although with this approach it is possible to visualize the trajectories, several questions arise regarding the outcome of the visualization. First, if the interval between samples is large we lose intermediate movements, as such there may be behaviours that are not represented. Second, to connect the source to destination we may have to affect the Time component, since the analysis is not done continuously, but by time intervals, consequently losing this representation the notion of space change over the time.
In our research work we intend to study these and other issues relating to the visualization of mobility through the representation of trajectories so as to explore new paradigms of representation of mobility. To achieve this goal we believe that it is important to, first, properly structure the information in order to have a taxonomy for the representation of mobility in an urban area.

CONCEPTS OF DATA REPRESENTATION

The work that we have done so far defined four general concepts that characterizes our taxonomy for the representation of data mobility (Figure 1) relating to an artefact. These concepts are designed to fit the data since its acquisition, until we get the same data on the form of trajectories, be they individual or group of individuals.

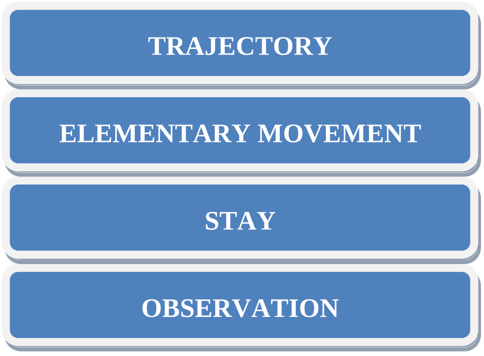

Figure 1: Layered Structure of the Information Concepts

Observation

Regardless the sensor used to acquire the mobility data, that data reflect the observation of a phenomenon and as such the first concept of our representation is the Observation, and can be described abstractly as: ***The observation of an artefact in a specific spatiotemporal space***.

Stay

As in the work of Reades et al. (Reades et al. 2007) the artefacts observed may reflect the presence of such a space and time. To include this notion, the next layer of our taxonomy defines the Stay as: ***Time interval between the first and last observation of an artefact in the same place***.

Elementary Movement

As the artefacts are characterized by the mobility, it is expected that there are changes in space over the time, so there must be a concept that represents this variation that we called Elementary Movement and described as: ***Change of Place to the next one that occurs in time***.

Trajectory

Finally, at the top layer of our representation we have the concept of trajectory that represents a set of Elementary Movements ordered in time for the same artefact and is described as: ***Time-ordered list of Elementary Movements of an artefact over the space***.

In turn, the set of existing trajectories at given spatiotemporal moment for a given artefact allows the representation of flows or dynamic movements that exist in the urban space.

DISCUSSION AND CONCLUSIONS

In order to normalize and validate the concepts of our taxonomy for the representation of spatiotemporal data, information about the use of the Wi-Fi network at the University of Minho was used for the first instantiation of the concepts. This first exercise allowed to draw some interesting conclusions and uncover issues that need to be studied. One of the next steps is to start the study the conceptof *space leap* (the lack of information of the individual status between observations) since its existence will always include errors in the inference of trajectories of individuals because we never know if in this period there exists an Elementary Movement. The definition of this concept is very important because, for certain mobility data, there are often time intervals where there are no observations. Another of our concerns is related to the huge amounts of movement data and its storage in databases. Because we are working with individual data without any kind of aggregation, this leads to a large number of records. So we have to evaluate the results of the visualizations and understand if it makes sense to work with individual data or taking into account these results, the information extracted from visualizations is not compromised when using the data in aggregated form. Although currently the instantiation of our taxonomy is done only for one type of data, we intend to extend our study to other mobility data, such as GPS positions, data from public transportation ticketing, tolls, and others.

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