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A Visual Analytics Design for Studying Rhythm Patterns from Human Daily Movement Data

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Abstract

Human's daily movements exhibit high regularity in a space-time context that typically forms circadian rhythms. Understanding the rhythms for human daily movements is of high interest to a variety of parties from urban planners, transportation analysts, to business strategists. In this paper, we present an interactive visual analytics design for understanding and utilizing data collected from tracking human's movements. The resulting system identifies and visually presents frequent human movement rhythms to support interactive exploration and analysis of the data over space and time. Case studies using real-world human movement data, including massive urban public transportation data in Singapore and the MIT reality mining dataset, and interviews with transportation researches were conducted to demonstrate the effectiveness and usefulness of our system.

Keywords: movement rhythm, event sequence, visual analytics

1. Introduction

In transportation and geographical information systems (GIS), human movements are usually presumed to engage in certain activities, e.g., work, study, and shopping. Hence, humans' daily movements can be described as "a scheduling of activities in time and space" [1], e.g., *home* $\rightarrow$ *work* $\rightarrow$ *home* and *home* $\rightarrow$ *school* $\rightarrow$ *tuition* $\rightarrow$ *home*. The movements can be further generalized as network motifs by abstracting the activity information [2], e.g., *home* $\rightarrow$ *work* $\rightarrow$ *home* can be generalized as $A \rightarrow B \rightarrow A$, and *home* $\rightarrow$ *school* $\rightarrow$ *tuition* $\rightarrow$ *home* as $A \rightarrow B \rightarrow C \rightarrow A$.

In this work, we denote these motifs as movement rhythms, each of which basically describes *a sequence of locations visited in time and space*. A better grasp of human movement rhythms can be highly beneficial for various applications, e.g., travel demand management. For instance, by studying individuals' activity and travel schedule, transportation researchers derived an integrated discrete choice model to analyze travel demands at different times of a day [3].

To explore the movement rhythms over space and time, an interactive visual analytical tool that facilitates transportation experts' exploration is preferred. Nonetheless, there are several challenges to overcome. First, a direct plot of all the human daily movements, such as to display the changes of geospatial positions in time in 3D space [4], can easily lead to visual clutter. Second, the movements of human daily movements can exhibit many different rhythms, e.g., $A \rightarrow B \rightarrow A$ and $A \rightarrow B \rightarrow C \rightarrow A$, etc. Appropriate data modeling should be developed to efficiently classify these movement rhythms. And lastly, human movements involve many different types of activities, which are happening at different locations in space, and take different times to finish the activities and to travel between locations. The visualization should present the spatial and temporal perspectives of information in an intuitive way.

In our previous work [5], we presented a visual analytics design for studying movement rhythms from massive public transportation data. This work presents an extended version by applying the approach on another human daily movement data, i.e., the MIT reality mining dataset [6]. We first describe an efficient movement modeling method to identify movement rhythms based on the movement's spatial and temporal characteristics (Section 4.3). All movement rhythms are organized into a hierarchical tree structure with a new tree construction algorithm (Section 4.4) devised from the association rule concept. We show that our algorithm can preserve more details about movement rhythms than typical methods, and can be generalized to aggregate event sequence data in a level-of-detail style. We then present the *Rhythm Sequence View* to depict the temporal perspective of movement rhythms, together with the *Rhythm Density View* plotting movement origin and destination distributions in spatial dimension, and the *Rhythm Statistic View* over-viewing the statistics of frequent movement rhythms (Section 5). In the end, we apply our approach to the study of real-world human daily movement data, i.e., massive urban public transportation data in Singapore and the MIT reality mining dataset (Section 6). Interviews with transportation researches are conducted to demonstrate the effectiveness and usefulness of our system (Section 7).

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