Interpreting Pedestrian Behaviour by Visualising and Clustering Movement Data

Gavin McArdle[1], Urška Demšar[2], Stefan van der Spek[3], and Seán McLoone[4]

[1] National Centre for Geocomputation, National University of Ireland Maynooth, Maynooth, Co. Kildare, Ireland
gavin.mcardle@nuim.ie
[2] Centre for GeoInformatics, School for Geography and Geosciences, University of St Andrews, Fife, Scotland, UK
urska.demsar@st-andrews.ac.uk
[3] Department of Urbanism, Faculty of Architecture, Delft University of Technology, Delft, the Netherlands
s.c.vanderSpek@tudelft.nl
[4] Department of Electronic Engineering, National University of Ireland Maynooth, Maynooth, Co. Kildare, Ireland
sean.mcloone@eeng.nuim.ie

Abstract. Recent technological advances have increased the quantity of movement data being recorded. While valuable knowledge can be gained by analysing such data, its sheer volume creates challenges. Geovisual analytics, which helps the human cognition process by using tools to reason about data, offers powerful techniques to resolve these challenges. This paper introduces such a geovisual analytics environment for exploring movement trajectories, which provides visualisation interfaces, based on the classic space-time cube. Additionally, a new approach, using the mathematical description of motion within a space-time cube, is used to determine the similarity of trajectories and forms the basis for clustering them. These techniques were used to analyse pedestrian movement. The results reveal interesting and useful spatiotemporal patterns and clusters of pedestrians exhibiting similar behaviour.

Keywords: Geovisual Analysis, Clustering, Space-time Cube, Movement Data Analysis.

1 Introduction

Movement of individual objects such as animals, humans, human-operated objects or complex natural phenomena represents one of the main processes in the physical environment. For the purposes of data representation and modeling, such moving objects are considered as entities, whose position and/or geometric attributes change over time [1]. Despite the diversity of sources of movement data, fundamentally the same process is captured: how objects move through the basic framework of the physical world, defined by geographic space and time.

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While the ubiquitous nature of location technologies has created issues for analysing movement data, specifically for pattern recognition and path prediction [2], it also provides an opportunity to understand how moving objects interact with each other and their environment. Due to interest in understanding human spatial behaviour, pedestrian mobility has long been an active research area in location based services [3], emergency management [4], determining infrastructural requirements [5] and urban planning [6]. Within urban planning and design, the vitality of a city is not generally measured using spatial analysis but by quantifying the number of people visiting the city and the economic value that brings. However, understanding the spatial and temporal aspects of the city, for example, the time spent and routes used by pedestrians can enhance a city's vitality. Current techniques in urban analysis, map the city based on its morphology, but questions about how the city network is used still remain. By analysing the activity patterns of individual pedestrians, repetitive behaviour and similar goals can be identified. This information can be translated into designs which address the requirements of the population, which is a key goal in urban design [6], [7].

This paper introduces a geovisual analytics tool for trajectory exploration, which contains novel techniques to help analysts comprehend movement datasets by visually representing the temporal and spatial aspects of movement simultaneously. The tool is applicable to a wide array of end users interested in interpreting movement data from disparate sources. Details such as principal routes and frequent stopping locations can be determined using the Space-time Cube visualisation which forms a central element of the tool. A new approach for identifying clusters of similar behaviour based on their speed and acceleration in orthogonal directions, also forms part of this research. A case study, using pedestrian data collected in the city of Delft in the Netherlands demonstrates these techniques.

This paper is structured as follows; the next section provides some related work in the area of movement data visualisation and analysis. Section 3 presents the novel visualisation and analysis techniques used to cluster movement data. A case study of pedestrian data, which reveals interesting spatiotemporal patterns and classifies pedestrians based on behaviour, is presented in Section 4. The paper concludes with a discussion and future work in Sections 5 and 6.

2 Visualisation and Analysis of Trajectory Data

Driven by the increase in the quantity of movement data, this section examines questions regarding techniques to represent, interpret, analyse and compare movement data.

2.1 Trajectory Representation and Visualisation

The path of a moving object is usually represented as a trajectory which is a sequence of positions in a two-dimensional (2D) geographic environment with