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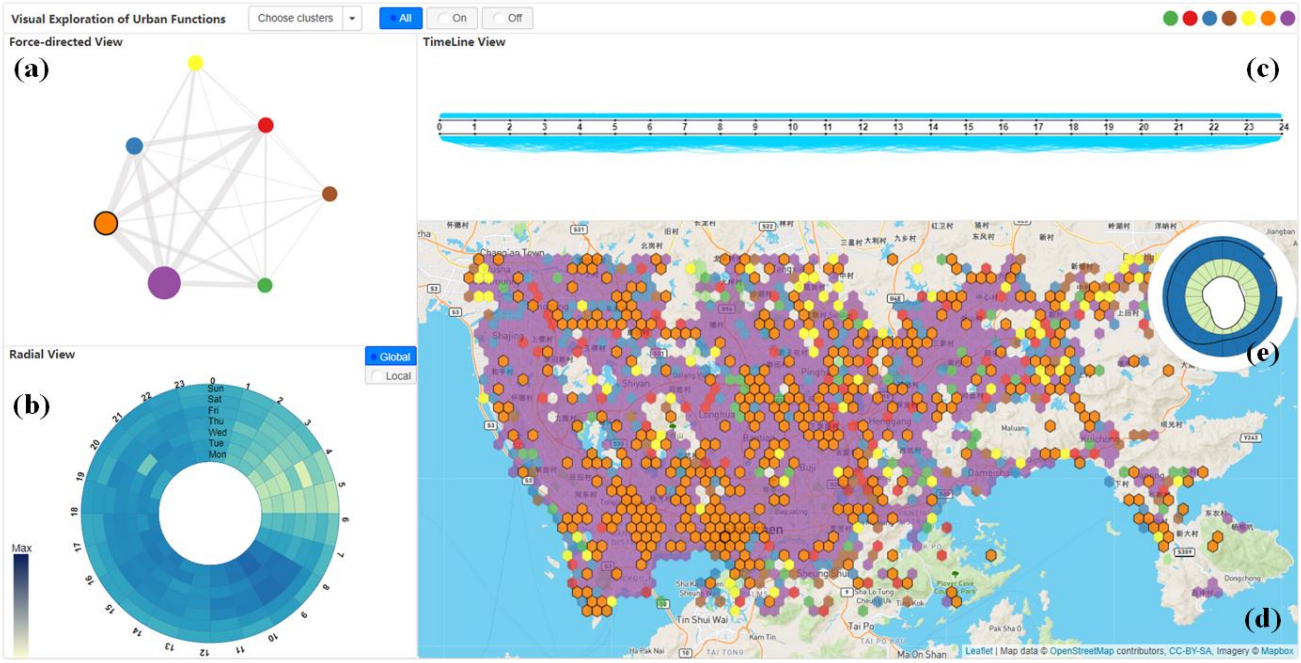

Fig. 1. Visualization for a spatio-temporal taxi OD dataset: (a) a force-directed view to present the correlation between functional areas. (b) a radial view to visualize traffic volume changes over time. (c) a timeline view to present the distribution of pick-up/drop-off and the travel time within or between functional areas. (d) a map view to present global urban functions, in which the temporal distribution of traffic flow volumes of a local area of interest can be checked by means of Glyph designed as shown in (e).

Abstract—City is a complex system containing various kinds of functional areas. They are always defined by government planning and refining based on the actual requirements of citizens, which are of significant importance to urban developments, ranging from environmental governance and rail transportation to disease prevention and public security. Taxi is a major means of urban transportation, and the taxi trips record human behaviors and mobility patterns, which offer a valuable opportunity for users to get insights into urban functions. Therefore, we propose a visual analysis system in this paper, for an insightful exploration of urban functions based on spatio-temporal taxi OD trips. First, a matrix is constructed to restructure spatio-temporal attributes of taxi OD data, and a Non-negative Matrix Factorization(NMF) is applied to classify and identify urban functional areas. Then, a set of visual encodings are designed to visualize mobility patterns of urban areas with different functions, such as the radial chart, the timeline view and the force-directed view. In addition, the spatio-temporal clustering model and the visual designs are all implemented in a visualization framework, with a set of convenient interactions integrated, enabling users to quickly identify areas of different urban functions and analyze the human mobility patterns across different urban areas. Case studies based on real-world datasets and interviews with domain experts have demonstrated the effectiveness of our system.

Index Terms—matrix factorization, visual analytics, urban functions, spatio-temporal

1 Introduction

The morphology of a city affects its ecological and socioeconomic functions, thus how a city is spatially structured has important bearings on urban sustainability. Urban functional areas are often formulated according to citizens actual lifestyle, reflecting the different requirements of citizens live. Urban functional areas can serve as a valuable organizing technique to frame detailed knowledge of a metropolitan. First, areas of different functions are able to support a variety of valuable applications. For example, it can provide people with a quick understanding of a complex city and social recommendations. The tourists can easily differentiate some scenic areas from business districts given these functional areas, thereby reducing efforts on trip planning. Second, functional areas can calibrate the urban planning of a city and contribute to the future planning to some extent. Finally, functional areas would also benefit the location for a business or an advertisement. When building a super-market, we need to consider the distance between the location and residential areas. For the advertisement of a training course, it could be better to consider those areas with geospatial

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