Digging for Non-Dominant Mobility Patterns

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Abstract—**In this paper we investigate non-dominant collective urban mobility patterns in user-generated mobile network traffic data using a visual analytics tool. Based on our previous approach and results, we herein focus on the next level of mobility detail: we visually dig deeper and disclose some non-dominant, potentially hidden mobility patterns in four urban test areas in Northern Italy. The results reveal interesting insights into the cities' functional structure in terms of human mobility, for instance mobility hotspots and mobility gateways.**

Keywords**—Visual Analytics, Collective Urban Mobility, Mobile Network Traffic, Geographic Information Science**

I. Introduction

User-generated mobile network traffic is frequently used for examining human behaviour patterns in urban environments (cf. [1], [2]). In contrast to previous work, we demonstrated in [3] that a purely visual analytics approach can reveal significant spatio-temporal mobility information derived from millions of handovers in a mobile network. A handover is the automated transfer of an active communication session of a mobile user from one service cell of the mobile network to another; handovers are managed by the network's backend.

In this paper we use the results obtained in [3] and "dig deeper" in order to reveal non-dominant mobility patterns.

II. Related Work in a Nutshell

Visualisation is not only a method to present results; in fact it can be seen as a tool for exploring and analysing various data sets in an intuitive and interactive manner in order to better understand the data's underlying real-world phenomena [4]. Whereas consolidated models for spatio-temporal phenomena are lacking and the statistical analysis of the corresponding data sets is still subject to research [5], visual analytics tools can be used for a rather inductive approach. Mobile network data as a proxy for collective mobility are one of the currently "hot topics" in this context [6].

Although different studies deal with mobile network traffic data (cf. [7], [8]), they are most often based on trajectories (cf. [9], [10]) and use visualization rather for presentation than for exploration and analysis.

As shown in [3] visual analytics is suitable for the extraction of information about collective mobility from large handover data sets. Referring to [11], the problem of biased views on the data due to the granularity and scale could have been tackled with interactive, explorative functions like "zooming", filtering and aggregating.

III. Methodology

The mobile network traffic data sample used in this study comprises the four urban environments of Gorizia, Pordenone, Trieste and Udine (all in the Friuli Venetia Giulia Region, Northern Italy). The data sample contains among other information for more than 88 million movements between pairs of radio cells for a time period of more than two months.

A. Handovers in Mobile Networks as Proxy for Mobility

Herein we use the number of handovers per time interval between pairs of radio cells ("cell-links") as a proxy for collective human mobility. The network operator that provided the data sample used in this study has a market share of about 30% in the four study areas. Therefore, this sample is supposed to be representative for the total population.

B. Exploratory Visual Data Analysis

In our approach (Fig. 1), we focus on the identification of characteristic patterns, particularly non-dominant mobility patterns. The iterative and interactive filtering approach applied enables the exploration of handover mobile network traffic, thereby providing insights into urban mobility.

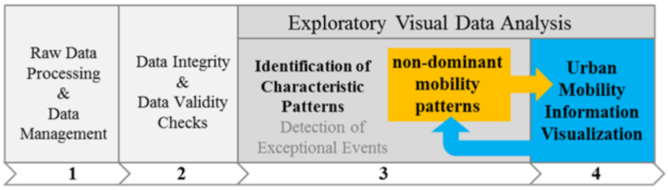

Fig. 1: the visual analytics approach (modified from [3])

We filtered the cell-links that comprise visually outstanding, i.e. high, magnitude of handovers. After rescaling the plot, non-dominant patterns become visible. These patterns indicate characteristic real-world phenomena for a particular area and time interval on a local scale.

IV. Results

In this section we show the analysis results for one urban study area (Udine) due to the limited space; the analysis results for the other three urban environments follow the same methodology. The "total mobility" refers to the total number of handovers per cell-link in both directions; the "absolute net migration flow" refers to the absolute difference, the net flow.

In Udine (Fig. 2), U1 shows a clear morning peak from Monday to Friday, which transforms into a balanced double-peak on Saturday and Sunday.

Although U2 does not exceed U1 in terms of the median number of handovers per hour, however, U2 is the most mobility gateway when considering the entire day, which is

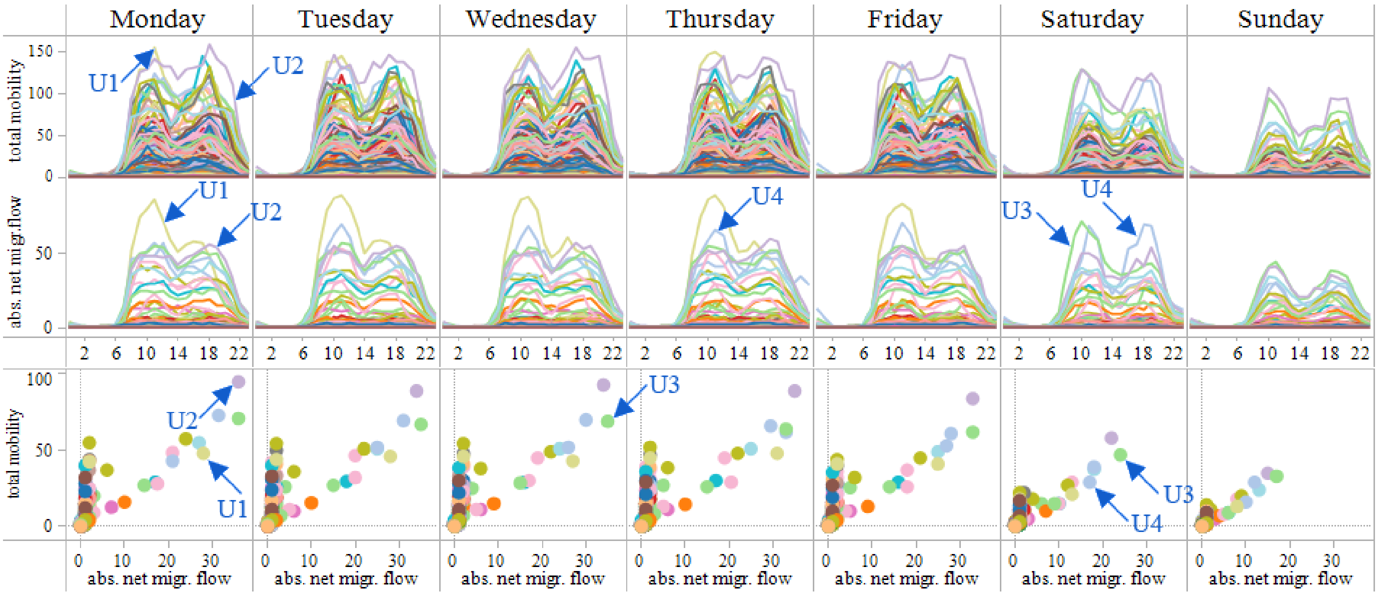

Fig. 2 characteristic non-dominant mobility patterns in urban Udine per day of week: total mobility and absolute net migration flow

valid for all weekdays (Fig. 2 scatter-plot).As seen in the scatter plot (Fig. 2), U3 has a similar absolute net migration flow as U2 but a lower total mobility; U3 is therefore a more distinct mobility gateway than U2. During the week U4 shows a similar behavior as U1 but with less activity. On weekends the mobility at U4 is notably higher than at U1, and shows a more distinct double-peak pattern especially on Saturdays.

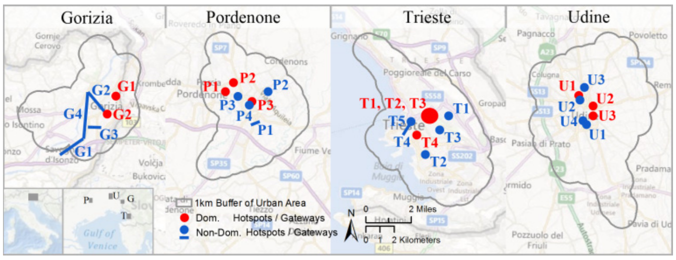

Fig. 3: dominant (more details in [3]) and non-dominant mobility hotspots and mobility gateways in the four urban test areas in Northern Italy

When looking at the functional configurations of the urban environments in terms of non-dominant mobility hotspots and gateways, their spatio-temporal patterns show that the intensity of collective human mobility varies in space and time. For instance in Udine from Monday to Friday: high mobility is observed in the morning (Fig. 3 U1)—but not in the evening—in the North of the city center; in contrast, the gateway U2 (Fig. 2) shows high mobility in the evening and early night but not in the morning.

V. Discussion and Conclusions

In this paper we investigated non-dominant collective urban mobility patterns that were derived from vast mobile network traffic data by means of visual analytics. In addition to our previous results [3], we showed that these non-dominate mobility patterns can provide additional insights into the functional configuration of cities in terms of mobility, i.e. the spatially different morning/evening gateways shown herein.

Acknowledgment

We thank Euro Beinat for offering his valuable thoughts. We also thank Tableau Software. This research is partially funded by the Austrian Science Fund (FWF) through the Doctoral College GIScience (DK W 1237-N23).

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