Are there networks in maps?
An experimental visualization of personal movement data

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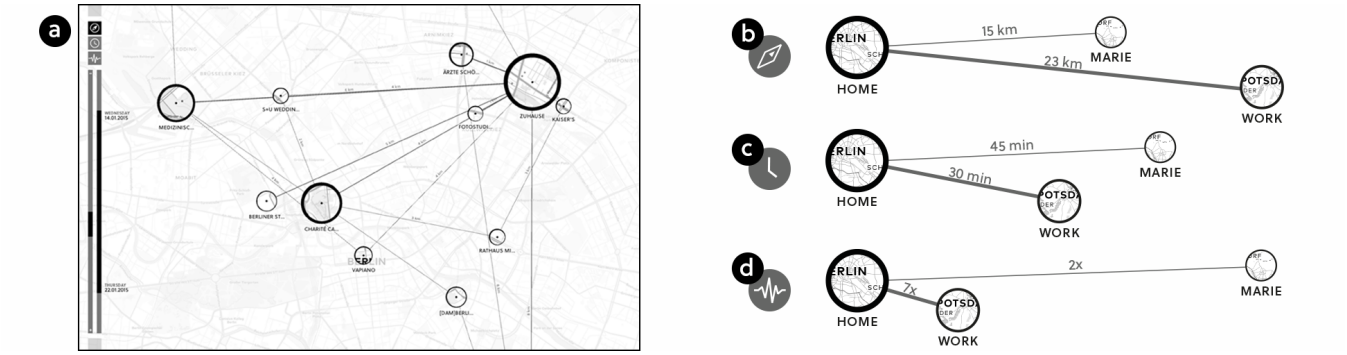

Figure 1: The Shifted Maps visualization (a) and three viewing modes for spatial (b), temporal (c), and frequency (d) networks of places.

Abstract

Shifted Maps proposes a novel visualization method to generate personal geovisualizations of individual movement data. The resulting visual appearance can be characterized as a map network consisting of visited places and their connections. The visited places are shown as circular map extracts scaled according to the time spent there and the movements between the places are represented as edges between the places. A key feature of the Shifted Maps visualization is the possibility to explore the data in three different arrangements based on geo-spatial position, travel time, and frequency of movements. By combining map and network visualizations of movement data, it becomes possible to analyze and compare spatial and temporal topologies.

Keywords: Geovisualization, Maps, Personal visualization, Spatiotemporal Data.

1 Introduction

Due to the increasing amount of collected personal data we witness a growing need for tools for analyzing these datasets. Conventional visualizations are prone to represent mass data, which tend to lack accessibility and personal relevance. Especially with the rise of the mobile phone and its tracking capabilities, more and more people use their devices to collect a wide range of personal data. While personal datasets offer the possibility to recognize small-scale patterns in individual behavior, they also increasingly result in more comprehensive and complex patterns at a larger scale and consequently require new methods to make sense of them.

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With Shifted Maps we present a visualization of individual movement data, which enables people to discover recurring patterns in long-term mobility traces. In order to reveal diverse relationships between places, we developed a novel visualization consisting of a network of map extracts. We designed this technique to facilitate the representation of multiple correlations through nodes, while maintaining a reference to the spatial information through maps.

2 Related Work

In the visualization community, there is a growing interest in visual analysis tools to support casual data visualization [6]. Over the last few years several projects started to investigate the visualization of personal movement data. The default view of the Moves app [2], which allows people to log their mobility, is a non-spatial visualization of places on a timeline using simple glyphs to represent the temporal length of trips and stays. Move-o-Scope [1] uses simple traces on a map but additionally provides a flow diagram of selected places indicating the most related places based on co-visitation. The web-based visualization Visits [8] puts map extracts on a timeline showing visited places, thus highlighting the relationship between time and space along a travelog. We aim to take these efforts further and explore the non-linear relationships between places emerging over time.

Representing spatiotemporal data is one of the core themes of geovisualization. At the most basic, this consists of showing different time snapshots of spatial data side by side or sequentially. Plenty of techniques aim to visually integrate temporal with spatial properties [3], ranging from flow maps to space time cubes. Often these techniques are used to visually analyze large amounts of aggregated movement data. We are interested in finding new approaches to explore smaller scale personal data sets. Revealing additional information such as visit duration and frequency allows people to better understand the temporality of their movement. These aspects can be harnessed to expose significant parts of one's personal environment. A number of techniques such as lenses have been introduced to emphasize certain parts of maps. A few of these techniques can be used to highlight several areas simultaneously [5,

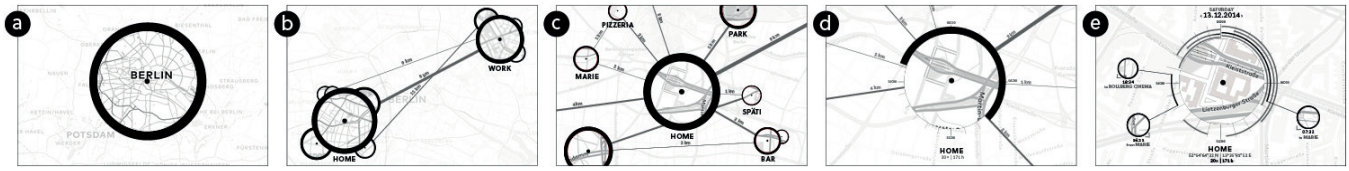

Figure 2: Semantic zoom showing more and more details. When zooming in (a to e) finer grained spatial relations emerge, then revealing the journeys between near-by places, and finally visualizing the stays at a single place (e).

7], yet the resulting distortions can cause misinterpretation of the underlying map [4].

In sum, most spatiotemporal visualizations tend to prioritize spatial over temporal patterns by displaying the underlying map as the primary representation for positioning data nodes. We aim to subvert this relationship between space and time, in order to reveal diverse data topologies in personal movement patterns.

3 Shifted Maps - The Prototype

Shifted Maps visualizes personal movement data. Its main purpose is revealing patterns in one's own movement network and enabling users to gain a different, maybe more personal perspective on their own movements through their spatial surrounding. Our environmental perception is based on often visited places and frequently taken routes. The relationships between these personal places are complex, as some connections occur more frequently than others, the time needed to move between them can vary greatly, and the spatial distances between places is interwoven with networks of visitation sequences. Considering that these complex relationships are latent in all mobility datasets there is an opportunity to use existing network visualization techniques such as node-link diagrams. When visualizing movement data as node-link diagrams, geographic references and temporal sequences need to be integrated, for example, to aid the understanding of co-visitation patterns, i.e., which are the most visited places and what is the frequency of journeys between them. The design of our visualization is led by the objective of representing spatiotemporal networks of personal movements.

3.1 Visualizations

Shifted Maps proposes a network of map extracts to visualize the diverse relationships between the places one traverses. The spatiotemporal networks are represented as node-link diagrams with nodes being visited places displayed as map extracts and connections between them shown as straight lines. The rationale behind such a hybrid view is to harness people's growing familiarity with digital maps with the general versatility of node-link diagrams representing diverse topologies and relations. The map extracts are circular to correspond with a sense of perceiving the immediate spatial surrounding of a place, with a dot indicating its exact location. The area size of a circle corresponds to the time spent there, while the thickness of the ring represents the relative number of visits. Though the size of a circle may change the geospatial area it represents stays the same; it adjusts its zoom level according to the geometric size of the circle. To focus on the network structure between places, we simplify routes as straight lines with their thickness representing the number of trips.

The map extracts and the connections between them result in a graph representing the personal network of places and the movements between them. The advantage of a network of map extracts is the possibility to arrange it in different ways, while maintaining a reference back to the geographic positions through the map extracts. Shifted Maps offers three arrangements: In the geographic view, the arrangement of places is based on their geographic positions (Fig. 1a, b). In the temporal view, the places are arranged according to average time it takes to go from one place to another (Fig. 1c). For the frequency view, places with a frequent connection move closer to each other than places with a less frequent connection (Fig. 1d). The length of the edges and the numeric labels labels along them respectively indicate the spatial or temporal distance, or the frequency of travels.

3.2 Interactions

Though the static visualization already reveals interesting relationships, interaction with Shifted Maps enables a comparison of different places, time spans, and views. The three different views can be chosen via the buttons in the top left corner. A smooth transition between the views aims to ease the understanding of the shifting arrangements. In principle, data of any temporal length can be loaded into the visualization. A time-range slider enables the selection of a certain temporal period, making it possible to compare shorter spans or follow the growth of the network over time. Each view can be explored through a semantic zoom, which enables the user to get an overview of the connections in lower zoom levels, while revealing more detailed information about places and connections in higher zoom levels. Zooming in reveals overlapping circles making individual places and more connections visible. In parallel, details such as line labels, place names, and further information about the places are bit by bit revealed (Fig. 2). At the highest zoom level a detailed view displays the duration of stay at individual days, as well as connection details, i.e., which other places have been visited before and after the focused place.

4 First Uses

During the iterative design process we carried out a formative evaluation, in order to test the comprehension of our visualization, its effects and general functionality. As testing the prototype with real datasets was indispensable, we recruited three participants (one female, two males, aged 24-27) with datasets of about two weeks. The tested prototype contained all main functions, except the semantic zoom. All participants were eager to explore a visualization of their own movement data and quickly understood the geographic and the time view. The frequency view, however, caused problems of comprehension, which may result from inaccuracies caused by an error in the graph layout algorithm. In general, participants remembered and recognized frequently visited places, whereas rarely visited places were partly already forgotten and took longer to identify and rediscover. The interaction techniques were largely understood and used without problems, though some of the users wished there were more interaction opportunities, i.e., interacting with the circles or lines, and additional information about the places.

5 Conclusion and Future Work

The rising amount of personal movement data, collected with smartphones, provides the opportunity for individuals to gain valuable insights into their own movements. Shifted Maps proposes a visualization of personal movement data with a network of map extracts. The unique potential of this technique is the possibility to see places and movements in novel ways. Three different arrangements based on the geographic, temporal, or frequential connections between places were designed to help people reveal

patterns in their movements. An early user test showed that people are able to reveal forgotten places and connections through the prototype. For the next version of Shifted Maps, we are planning to include more interaction capabilities and additional place information. Currently, we are developing a web implementation of our visualization to make it accessible for a broader audience and enable a large-scale evaluation of the new technique.

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