Dodeca-Rings Map: Interactively Finding Patterns and Events in Large Geo-temporal Data

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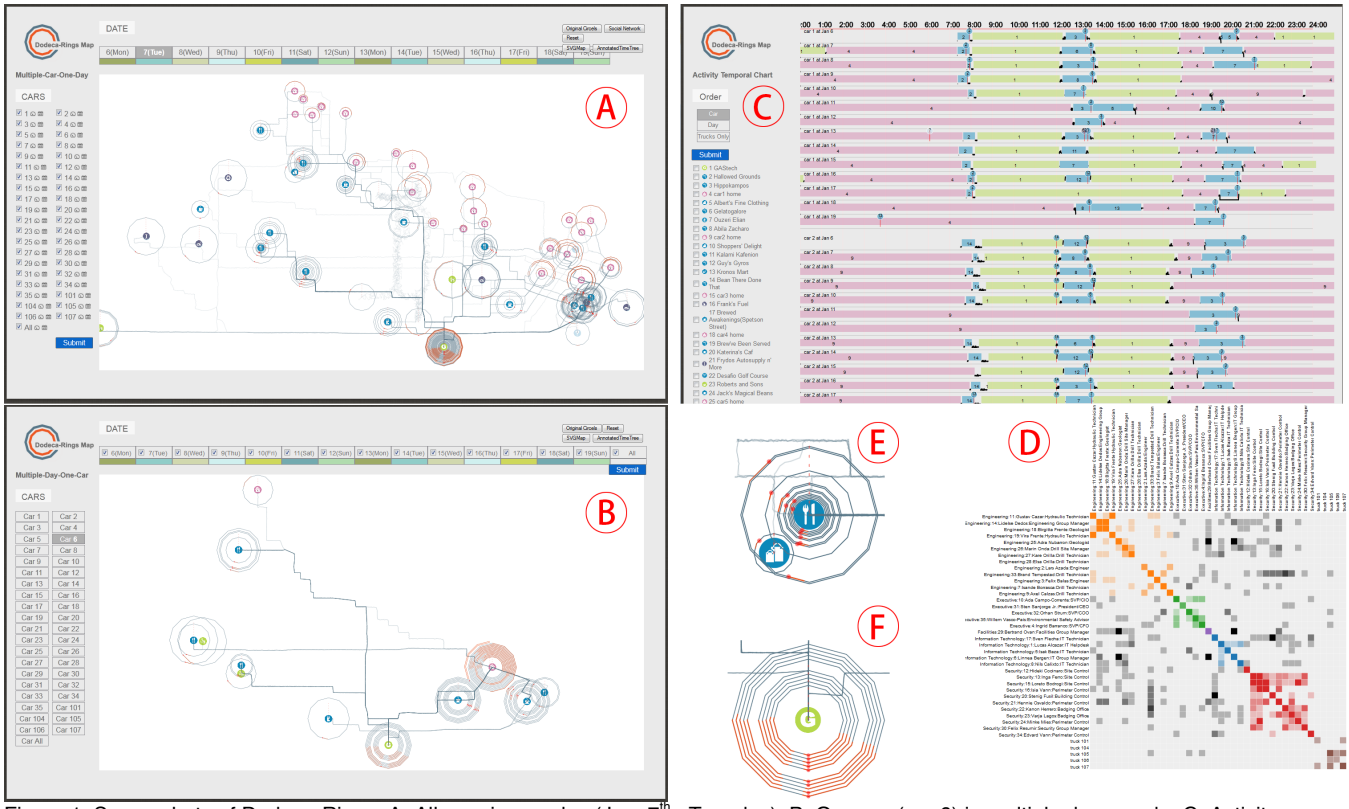

Figure 1: Screenshots of Dodeca-Rings. A: All cars in one day (Jan. 7th , Tuesday). B: One car (car 6) in multiple days mode. C: Activity temporal chart. D: Social relationship matrix. E: Dodeca-rings in Multiple-Car-One-Day mode. Red dots on the rings show transactions. Some cars love to come to this restaurant for lunch (around 12pm to 1pm) or dinner (around 8pm). F: Dodeca-rings in Multiple-Day-One-Car mode.

Index Terms: [Human-centered computing]: visual analytics, geographic visualization, information visualization; [Information Systems]: spatial-temporal systems.

1 Introduction

Dodeca-Rings Map is the visual analytics system we designed to analyze geo-temporal traffic problems. The system is organized by three kinds of visualizations: dodecagons that show events on the map (Fig.1 A & B), activity temporal charts (Fig.1 C), and a social relationship matrix (Fig.1 D). We used it to solve the VAST 2014 Mini-Challenge 2 and then the Grand Challenge. The given data sets include two weeks of vehicle GPS tracking data, credit and loyalty card transaction data, as well as vehicle assignments data. The challenge requires us to describe common daily routines for the car drivers, identify unusual events, and address the uncertainties and conflicts inherent in this data.

Dodeca-Rings map enables analysts to identify geo-temporal relationships quickly among the events on the map and provides rich interactive links to facilitate massive data analysis. According to Peuquet [1], three key components in spatial-temporal data are space (where), time(when), and objects (what). Dodeca-Rings map uses dodecagons as an innovative approach to integrate and visualize these three components in an elegant way. Each dodecagon visualizes the parking locations and time periods of stay for one car within one day. In the map, several dodecagons nested together to make concentric rings, which helps the analyst to see the patterns and events at first glance (Fig.1 E & F). The analyst can interact to zoom in and investigate the data. As the supplements in the system, activity temporal chart allows the analyst to read and compare events of all cars in all the days and the social relationship matrix provides a concluded social network overview. To support the visualization, we used different data

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mining techniques such as association, anomaly detection and clustering to extract information from the source data.

2 THE SYSTEM

Dodeca-Rings Map is a web application built on a standard LAMP (Linux, Apache, MySQL, and PHP) environment. It is composed of three key components: data storage layer, data process layer and data visualization layer. The provided datasets are stored in a MySQL database. PHP is used to access and manipulate data. HTML5, CSS, SVG, JavaScript, jQuery and D3.js are used to visualize data and provide interactivity. The data visualization layer is presented in modern web browsers. The integrated visualizations allow analysts to comprehend the dataset quickly and grasp large-scale patterns with minimal cognitive load.

2.1 Maps of Dodeca-Rings

The default view of our system is a geo-spatial visualization with maps of dodecagons that visualize cars' daily activities on the map (Fig.1 A, B). One dodecagon on the map visualizes one car's stays and activities in different locations in one day. The center of the dodecagon is clearly marked as the parking location. We differentiate these locations with numeric IDs and use different color logos to show their types (e.g. a house, an office, a restaurant, or a factory). The orange thick segments on the dodecagon indicate the periods of stay and color dots mark activities such as credit card transactions. The 12-sided polygon divides 24 hours into two-hour intervals. Thus the analyst can easily estimate when the events happened and the time length of stay period. Polylines connecting centers of dodecagons show the cars' traces from one place to another. We can turn on or off the background map to display roads. According to the original GPS data, we observed that cars were parked closely in clusters since they should be normally parked in parking lots. We grouped these locations into common centers. Two locations will be merged as one if their distance is less than 50 meters. As a result, on one dodecagon, it is possible to have multiple segments and activity points to show that the car has stayed in this location for multiple time periods. For some missing information, this system also allows the analyst to detect and assign different names and types to different locations during the analysis process. We also use the radius of the dodecagon to encode the car ID or the date. Different radiuses show different cars or dates, so several dodecagons can be nested together to become co-centric rings. Depending on the encoded data, the dodeca-rings view has two modes: one shows multiple cars' activities in one day (Fig.1 E) and the other shows one car's activities in multiple days (Fig.1 F).

2.1.1 Multiple-Car-One-Day Mode

In this mode, from inside to outside, different radiuses of the rings represent vehicle IDs from car 1 to car 35 and 5 trucks. With this visualization, the common patterns of cars in one day are obvious: leaving their homes, having breakfast, going to office, leaving for lunch, returning to office, and dining out for dinner. In this view, the analyst can highlight, select and compare multiple cars' activities through mouse over and clicking. Mouse over on one dodecagon will cause the system to highlight all other dodecagons of the same car. Clicking on the location icon shows the detailed information of people and their activities of that day in a summarized table. We can compare credit card charges and loyalty card records simply with colored lines. In this mode, we can easily see events that involve in many cars to go to the same place at the same time. Also we found that some car drivers have very close relationship since they tend to go to the same restaurant at the same time, or frequently participate in the same event.

2.1.2 One-Car-Multiple-Day Mode

In this mode, from inside to outside, the rings indicate days from January 6th to 19th (Fig.1 B). With this visualization, one car's weekly patterns are clear. For example, car 1 came to office at 8 am and left at 5:30 pm during most of the weekdays. But on 6th and 9th, he came to the office at midnight. During the weekend, the car did not come to the office at all. Interaction in this mode is similar to the previous mode. Mouse over one dodecagon will high light other dodecagons of the same day. Thus the analyst can select and compare individual days. Clicking on the location icons will show all the detailed activities of the car in a summarized table.

2.2 Activity Temporal Chart

The activity temporal chart (Fig. 1 C) is an opened-up variation of the dodeca-rings. It compares cars' activities through rows of colored bars. Each row represents details of one car in one day. The analyst can read the car speed, card transactions, and stopped locations. Car stops are marked in bars with colors that are consistent with dodeca-rings. Activities such as credit card transactions are marked as color drops. The analyst can easily see problematic activities that do not match the car locations. The speeds of cars are visualized as black curves connecting the car stays. It is very obvious that there is no speeding record for all the cars in the two weeks. The analyst can choose different ordering sequences to compare activities. When ordering by cars, analysts can see the car's daily patterns for the two weeks and compare different days of the car. When ordering by day, analysts can see all cars activities in that day and compare different cars. When ordering by truck IDs, analysts can identify which driver drove which truck through matching the card holder's credit card transaction with the truck stop locations.

2.3 Social Relationship Matrix

The social relationship matrix (Fig. 1 D) is a summary of general social connections of all the GAStech vehicle drivers. Different types of occupations are coded in different colors. If two drivers stayed at the same location during the same period of time, we consider the two cars were meeting. Maybe one or two meetings are coincidence, but frequent meetings can definitely imply interaction. The darkness of cell is defined by the number of meetings. For example, it is obvious that several security employees and one engineer are engaging in multiple meetings.

3 INTERACTION

The two modes of dodeca-ring map, activity temporal chart and the social relationship matrix are closely linked together in the system. The analyst can switch across two modes, pan and zoom into regions of interest to see details of suspicious patterns, highlight dodecagons of selected cars or days, select rings to compare, and open up rings to charts for further investigation. Although there are errors and missing parts in the datasets, the system provides functions for the analyst to manipulate the data, for example, enter and modify location names and types based on the credit card transaction data. Combined with various visualization and interaction methods, the dodeca-rings gives us sufficient support to analyze the VAST 2014 challenge.

REFERENCES

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