Saptiotemporal Analysis of Gastech Employees' Movement Data

Chen Yuxi
Singapore Management University
yuxi.chen.2020@mitb.smu.edu.sg

Lim Yong Kai
Singapore Management University
yongkai.lim.2020@mitb.smu.edu.sg

Jovinka Hartanto
Singapore Management University
jovinkah.2020@mitb.smu.edu.sg

ABSTRACT

The research paper should include an abstract of not more than 300 words. The actual research paper itself should not more than 6 pages excluding figures, tables, formula and references. The practice research paper must be edited by using R Markdown and the ACM: Association for Computing Machinery template of rticles should be used.

1. INTRODUCTION

The VAST 2021 Mini Challenge 2 outlines a hypothetical scenario in which several GAStech employees have gone missing and the organisation, Protectors of Kronos (POK), is suspected of being involved. The dataset includes two weeks of GPS tracking data for company cars assigned to employees, credit and loyalty card transactions of employees before the disappearance. ESRI shapefiles for the city of Abila & country Kronos are also provided. The challenge requires identification of suspicious activities hidden in data and determine any dubious people and locations that should be reported to the law enforcement.

The dataset was wrangled to develop a Shiny app that aims to provide users actionable insights based on the following analyses:

- Exploratory Data Analysis (EDA) of GPS tracking data and credit and loyalty card transaction patterns
- Visualisation of employee movements over time and associated purchase transactions
- Network analysis of employees based on their visited locations

This paper details our efforts to design, create and implement a web-based analytics tool to assist users from the law enforcement to derive insights and accelerate the investigation process of the disappearance of GAStech employees. The paper consists of six sections. Section 1 presents a general introduction of the paper. Section 2 provides an overview of the motivation and objectives of our project. Section 3 provides a review of techniques used in Vast Challenge 2014 and similar spatiotemporal visualisations. This is followed by a detailed description of the design principles used and data visualisation elements built, and a demonstration of the user interface in section 4 and 5. Insights and uses of the system are documented in section 5. Finally, the paper concludes by highlighting how the system can be extended or refined in the future.

2. MOTIVATION AND OBJECTIVES

Our research and development effort were motivated by the general lack of effective and easy to use web-enabled data visualisation tool to conduct data analysis on the GAStech employees related dataset. The project aims to enable the Kronos law enforcement the ability to easily analyse, drill down and identify key suspects and suspicious locations, and thereby speeding up the investigation process.

The use cases of the data visualisation tool include but are not limited to the following:

- The most popular locations and when they are popular
- Infer the owner of each credit card and loyalty card
- Identify potential informal or unofficial relationships among GASTech personnel
- Analyze unusual and suspicious activities of the employees
- Analyze daily routines of GasTech employees

3. REVIEW AND CRITIC OF PAST WORKS

The project drew inspirations from previous works by Singapore Management University (SMU) students and submissions of the 2014 Vast Challenge.

In the project, Dino Holmes Series, [dinoholmes], heatmap enabled readers to easily determine patterns and trends over a time. However, static heatmap is not reader friendly enough to determine what was the count at specific time slots. As each heatmap box represents a discrete count by using a gradient color fill, it was difficult to accurately determine the specific count. The analysis may benefit from making the heatmap plot interactive, allowing the details to be displayed at the tooltip when hover across. This would allow granularity data to be more well-presented in the report.

Submission from Fraunhofer IAIS and City University London (Andrienko, Andrienko, and Fuchs 2014) and RBEI-Bangalore (Singhal et al. 2014) both used network cluster and analysis to investigate the relationships between GAStech employees. Fraunhofer IAIS university used an ego-centric graph whereas RBEI used a combination of fragmented and node-only layout to visual the relationship by connecting employees. Network analysis is an informative visualisation that provides an overview of potential relationships between employees or even connecting employees to different mediums such as the locations or emails.

Although network analysis provides an overview of the relationships between nodes, usually the plot will be cluttered which make it difficult to drill down to specific or individual relationships. An alternative would be to make the plot interactive so that readers will be able to drill down on specific areas to investigate the relationships.

4. DESIGN FRAMEWORK

Exploratory data analysis (EDA) with histogram, heatmap and boxplot were performed to give users an overview of GAStech employees' credit card and loyalty card transactions over the two weeks. Heatmap was used for a quick summary of the most popular locations based on transaction frequency. This function is meant for high-level visualisation and not detailed analysis. Detailed barchart faceted by location and classified by time period was used to visualise distribution and popularity of locations at different time of the day. Any transactions at odd timing could be isolated and scrutinise in detail. Boxplot shows the median and 25th and 75th percentiles of transaction amounts at each location, and to visualise any anomalies. Bar chart was chosen since it is easy to grasp without significant statistical knowledge. Interactivity is a significant feature of the EDA charts. Given that this is an exploratory phase, all dataset parameters were included as much as possible to aid the user in discovering insights.

Exploratory spatial data analysis (ESDA) investigates the location component of the provided dataset. With the Abila map and GPS routes visualised, we were able to explore the island map and determine movements and location of employees' cars at specific time periods. This was complemented by scatter plot of visits of employees by time and day at specific locations. This helps users to identify any overlaps in visit location and time of employees to determine any relationships among employees.

Parallel coordinate plot was used to map credit card and loyalty card to their respective owners since the card owners were not provided. Credit cards and loyalty cards transaction date, location and price (filtered by credit card numbers) were also mapped.

Network analysis was performed to allow users to depict relations among employees and locations to analyse the social structures that emerged from the recurrence of these relations.

The data visualization in these four components was synchronized using a set of data filters that allowed for data manipulation and interation coordination among multiple displays. The linked data presentation enabled the user to keep the filter selection when going between views without having to reapply the settings each time. The mouse hover tooltip provided on-demand details without having too much information cluttered on the data visual. These allowed users to follow the flow of "overview first, zoom and filter into details," bouncing back and forth, here and there, with ease and without breaking their train of thought.

4.1 Data preparation

The data set was extracted from the VAST Challenge 2021 website under the sub section Mini-Challenge 2. All the data wrangling and cleaning were performed using R.

(To be expanded)

4.2 Shiny Architecture

The application was developed with Shiny, an R tool for generating interactive web apps. The main advantage of Shiny is that users can easily change the variable inputs and almost instantly see the resulting charts and figures. Not only does it allow for interactivity, it provides an invaluable tool for users to derive insights. Shiny also uses the R packages available on R-cran, which expands on the core R functions and improves the app's functionality.

The Shiny application was designed according to the flow of the Vast Challenge questions.

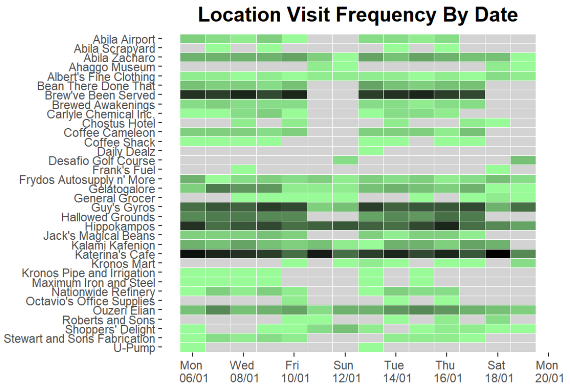
i) Overview - A brief background of the case challenge and the 5 questions to be answered. The links to the papers, documents and source code are also appended here.
ii) Abila Kronos Map - This provides a map view of employees' GPS movements filtered by time and employee.
iii) Location Transactions - This provides detailed transaction frequencies at various locations at different time, as well as transaction amount, enabling users to answer some of the questions posed by the case challenge.
iv) Card Mapping - This shows the cards ownership as well as transactions specific to individual cards.
v) Network Analysis - This allows users to visualise the relationships among employees and locations.

4.3 Analysis Techniques

4.3.1 Heatmap

Heatmap is a graphical representation of data that utilises colour-coded systems. A heatmap is able to better represent the volume of transactions/locations within a dataset and to guide users to the most important areas through the use of colours.

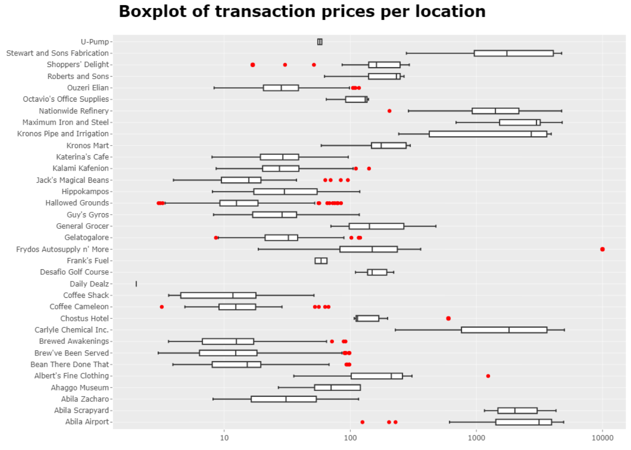
ggplot2 is used to create the heatmap of transaction frequency by location. The resultant ggplot2 graph is parsed into plotly which allows for interactivity with tooltips.



4.3.2 Boxplot

Boxplot displays the distribution of the data based on minimum, first quartile, median, third quartile and maximum. It is a good representation of the standard dispersion of transaction amounts at each location and thereby highlighting the outlier transactions. The parameters built in the application allow the user to change the structure and make up of the bar chart. Users are able to select specific locations, filter by employees, change the date range, as well as indicate the time period of the chart.

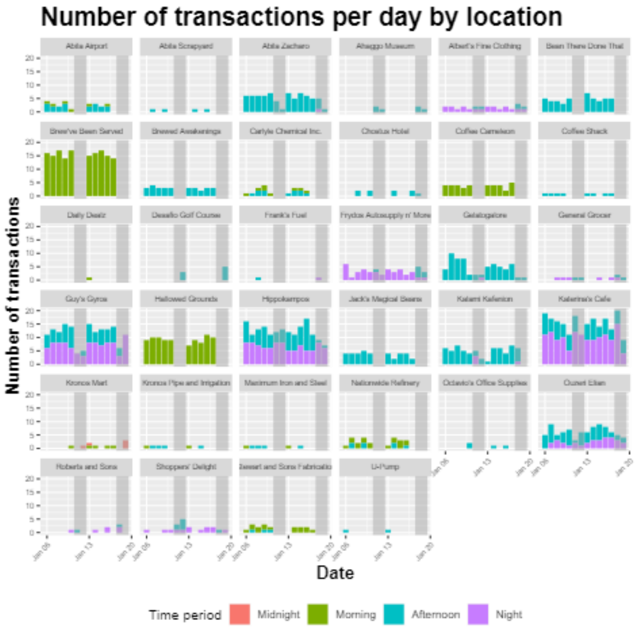
gglot2 is used to create the boxplot of credit card transaction values at different locations. The outliers are highlighted in red. plotly is used to enhance the interactivity of the chart with tooltips.



4.3.3 Bar Chart

A bar chart is used to visualise the frequency of visits at different days with varying length of bars. This chart is used to for comparing different number of visits over the period. The primary category used for the x-axis is the date variable. The chart is also faceted by location to show a more granular view. The parameters built in the application allow the user to change the structure and make up of the bar chart. Users are able to select specific locations, filter by employees, change the date range, as well as indicate the time period of the chart.

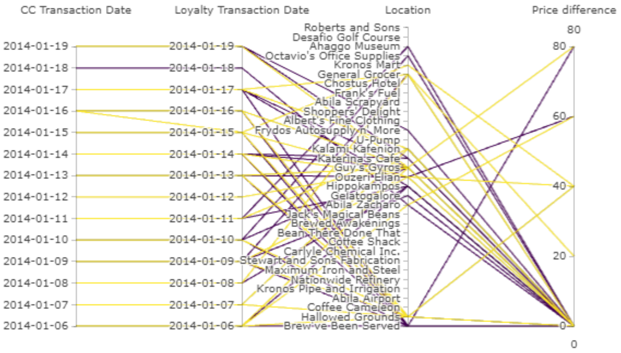
ggplot2 is used to create the bar chart as it is flexible and allows for faceting by groups. The ggplot2 graph is then parsed into plotly which enables interactivity with tooltips. As more categories are added to the chart, this helps to remove text elements from the bar charts, which tend to clutter the plot.



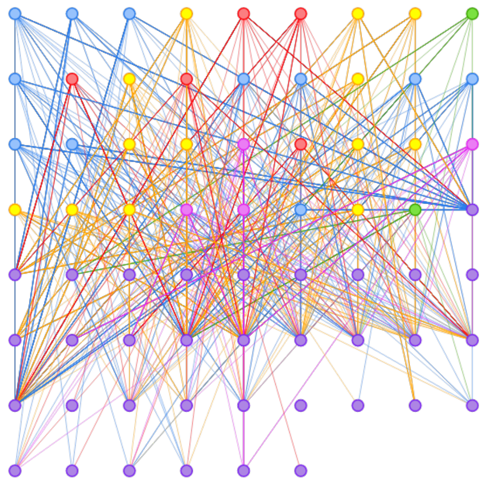
4.3.4 Thematic Map

Thematic map is used to visualise the movement of cars using the GPS tracking data over time and is used for geospatial analysis.

4.3.5 Parallel Coordinate Plot



4.3.6 Network Analysis



5. DEMONSTRATION

The final interactive plots in the Shiny application can help to identify a wide range of insights, specifically in the area of suspicious people and locations.

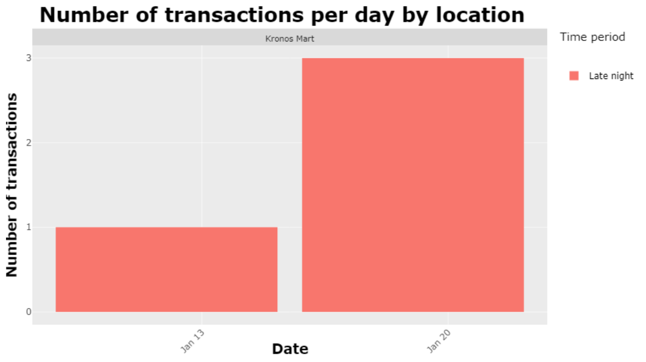
5.1 Abila Kronos Map Interface

Referring to the first map interface. . .

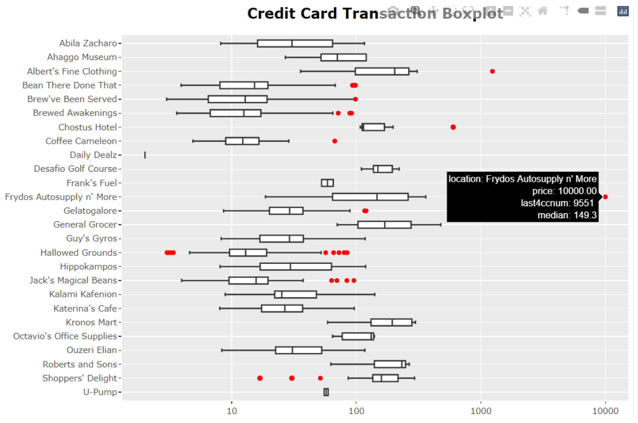
5.2 Locations Transactions Interface

Based on the heatmap and barplot, we noticed that the most popular places during weekdays are Brew've Been Served, Katerina's Cafe, Guy's Gyros, Hippokampos and Hallowed Grounds. Many places that are not open during weekends. The most frequently visited places over the weekends are Katerina's Cafe (more popular on Saturdays) and Hippokampos.

Late night transactions are relatively more suspicious and hence are shown in isolation. Noticed 4 transactions made on different credit cards at Kronos Mart at late night on various days.



In the boxplot, there was an extreme outlier of a 10,000 dollars spent by credit card 9551 at Frydos Autosupply n'More while the median price was only 149 dollars. There was also an outlier of 1,239 dollars at Albert's Fine Clothing



location: Frydos Autosupply n' More
price: 10000.00
last4ccnum: 9551
median: 149.3

6. DISCUSSION

What has the audience learned from your work? What new insights or practices has your system enabled? A full blown user study is not expected, but informal observations of use that help evaluate your system are encouraged.

7. FUTURE WORK

A description of how your system could be extended or refined.

References

[1] Ong, H.Y. 2017. Dino Holmes Series.