R Shiny Investigative Tool into GASTech Personnel Disappearance

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ABSTRACT

A fictitious scenario was created as part of VAST Challenge 2021. A group of staff members from GASTech, an oil and gas company situated on an island known as Abila on Kronos, had gone missing mysteriously. A group known as Protectors of Kronos (POK) was the prime suspect into the disappearance. A series of unprocessed data were made available to the law enforcement agencies to investigate on. The data were split across three mini challenges, which our team had undertaken Mini Challenge 1 and 2.

Mini Challenge 1 consists of email correspondences, employee records and resumes, historical documents and news articles. The ojective of this mini challenge is to identify the complex relationships among the people and organisations, and possibly infer the disappearance of GASTech to any individuals/group who might be involved. Mini Challenge 2 consists of gps tracking, transaction and loyalty card records, together with car assignment records - linked to the gps tracking data. The objective of this mini challenge is to discover anomalies and suspicious activites that may require additional investigating.

The objective of this research paper is to share on the methods and models used to develop an online investigative tool where a law enforcement at Kronos and Tethys could use, to piece the raw data into useable information and evidences.

1. INTRODUCTION

A fictitious scenario was created as part of VAST Challenge 2021. A group of staff members from GASTech, an oil and gas company situated on an island known as Abila on Kronos, had gone missing mysteriously. A group known as Protectors of Kronos (POK) was the prime suspect into the disappearance. While Mini Challenge 1 and 2 provided a set of raw data that allow investigators to establish and identify complex relationships among the people and organisations, discover anomalies and suspicious activities, such investigative work may require humongous man hours and effort, without data analytics and visualisation.

We would be using Shiny R to develop an online investigative tool to aid in the analysis into the disappearance of GASTech Personnel, allowing investigators to explore information and inferential statistics derived from the unprocessed data available.

2. MOTIVATION

The motivation of this project would be two-fold. First, the data presented to the investigators were raw and unprocessed, and to link and derive insights from these data would require tremendous man hours and effort. Second, while insights could be derived and useful information could be formed, there would be a need to present the information in a visually appealing format to facilitate information dissemination and to allow quick collective appreciation of events among the investigators.

To this end, we would be looking to develop a R Shiny app based on three principles: (a) informative; (b) intuitive and; (c) interactive. Our 3Is principles would have the data undergoing baseline cleaning, making them into suitable formats for subsequent processing for information delivery. The user-interface would be made intuitive so that the investigator would be able to use the application without much references to our user guide. The online investigative tool would also be interactive, such that the investigator would be able to provide varied inputs into the formation towards the final visualisation report.

The R Shiny app would comprise of two main modules: (a) Exploratory Data Analysis allowing investigators to draw information such as transaction records, employee records, email correspondences and such; (b) Inferential Statistics allowing investigators to infer relationship linkages among user-selected employees, possible coded words within email correspondences within an identified group of personnel, their movements towards identified locations and possible anomalies at the locations and transaction analysis using both credit card and loyalty card data.

3. REVIEW AND CRITIC OF PAST WORKS

Taking reference on a submission by students from International Institute of Information Technology Hyderabad, they had derived an interface that uses geotools to show the paths of the cars, moving at a particular time or date. While it was a useful tool to visualise the movement of the vehicles, it was unable to plot the locations where the vehicles may had visited. This would be addressed in one of our module.

While credit card data and loyalty card data were provided for, to the investigators, there are no direct linkages between both set of data, except for the locations and price of item. The timestamp for both data are recorded differently with the credit card indicating the time of transaction while loyalty data indicating date of transactions only. Reviewing past work from members of University of Calgary, they attempted Parallel Coordinates plot by linking the locations, timestamp, price and employees, to establish possible linkages among the four variables. Inspired by their work and the sharing from Prof Kam on using Parallel Coordinates Plot on R, we would attempt to create parallel plots and allow the investigators to decide the variables that they are keen to establish linkages with.

4. DESIGN FRAME

Our R Shiny Investigative Tool's design would be based on our 3Is principle.

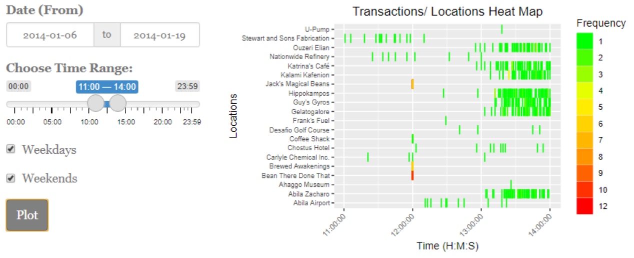
Informative - A series of informative modules would be made available under the Exploratory Data Analysis (EDA) tab, comprising of: (a) Locations Exploration; (b) Transactions Exploration; (c) Cards Exploration; (d) GASTech Employees Information; and (e) Email Correspondences. Details of each modules would be covered under the sub-sections later.

Intuitive - The entire UI design would be simple and intuitive, allowing investigators to use it without frequent references to our user guide. This would be done by ensuring that appropriate input methods were used and that the UI would be kept as clean and simple as possible.

Interactive - The respective modules would require specific inputs from the investigators before a representative visualisation could be produced. It would be made interactive such that the investigators would have the flexibility to select various variables or inputs to create the desired visualisation. Similarly, the investigators would have the option to save the produced visualisation separately.

5. EXPLORATORY DATA ANALYSIS

5.1 Locations - For Exploration!



Date (From)
2014-01-06 to 2014-01-19

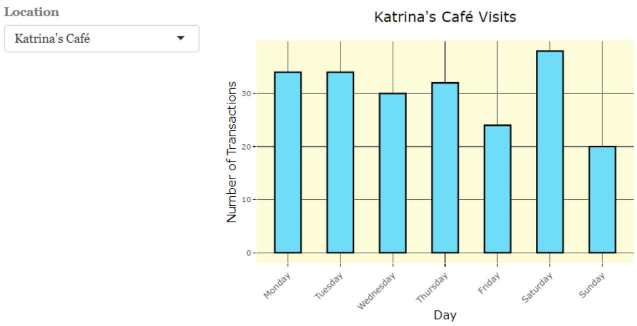
Choose Time Range:
11:00 — 14:00

☑ Weekdays

☑ Weekends

Plot

The intention of this module would be to allow the investigators to explore the popularity of the locations through the analysis of transaction records. It would be conducted in a manner by aggregating the transaction records based on the time of transactions. The transaction counts would be plotted against the aggregated time of transactions and locations using a heatmap to infer the peak periods for the locations. The selected records would be filtered based on the range of date inputs, time range of transactions, with the ability to toggle between weekdays, weekends or both.

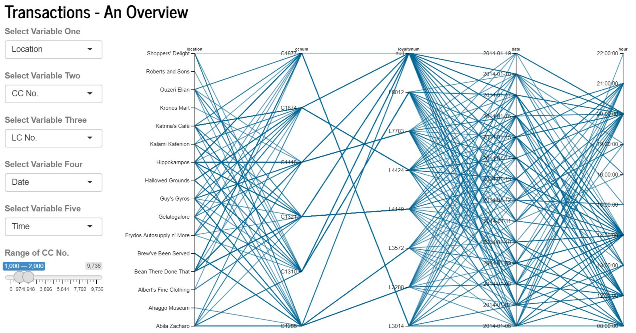


Location
Katrina's Café

The function of this module would be to identify the operating days of the locations through the analysis of credit card transactions, through the aggregation of records based on the day of transactions. The output of this visualisation would suggest the days where the locations would be having transactions, thus inferring their operating days of the week.

5.2 Transactions - For Exploration!

The intention of this module would be to allow investigators to explore all credit card and loyalty card transactional records at each location. The type of visualization chosen enables the investigators to see the linkages between all variables in one view.



Transactions - An Overview

Select Variable One: Location

Select Variable Two: CC No.

Select Variable Three: LC No.

Select Variable Four: Date

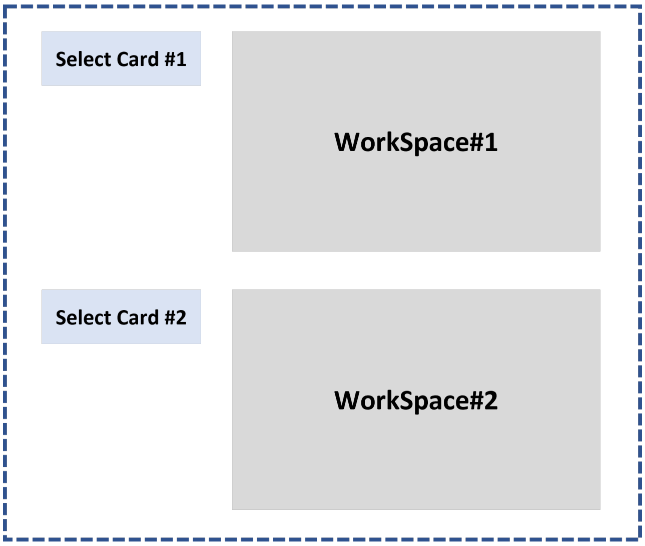
Select Variable Five: Time

Range of CC No.: 1,000 — 2,000

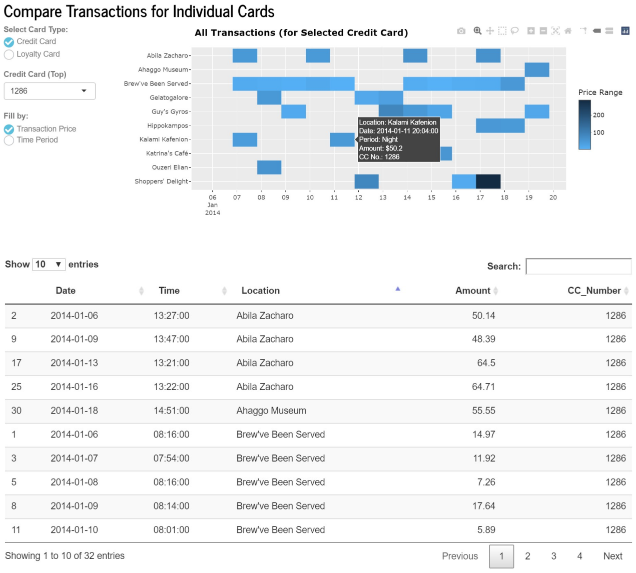
The plot has multiple functions which would allow the investigator to customize his/her view and get more insights, such as (1) Variables to be included can be selected, (2) Variables can be reordered, (3) Range of Credit Card Numbers to display records for can be selected, (4) Specific ranges of each variable can be selected so that only associated links would be shown, (5) Selected ranges can be glided along the axis to see how the connections change dynamically. These customizations and flexibilities are important so that the user can zoom in and out on selected areas of focus, especially when exploring raw data sets. If a certain value, say for a specific credit card number, appears in multiple observations, its associations would be clearly displayed in the form of the series of lines.

5.3 Individual Card Transactions

This module allows the investigator to visualize the transactions made by individual cards for a more in-depth exploration. The page allows the investigator to select two different cards to be displayed, akin to a workspace for comparison between cards. This is essentially a deep-dive compared to the parallel coordinate plot, which gives an overview.



The investigator could select the card type, credit card or loyalty card. If credit card is selected, an additional field would appear to allow selection of type of fill for the tiles.


Compare Transactions for Individual Cards

Select Card Type:
● Credit Card
○ Loyalty Card

Credit Card (Top): 1286

Fill by:
● Transaction Price
○ Time Period

All Transactions (for Selected Credit Card)

Location: Kalami Kafenion
Date: 2014-01-11 20:04:00
Period: Night
Amount: $50.2
CC No.: 1286

Show 10 entries

Search:

	Date	Time	Location	Amount	CC_Number
2	2014-01-06	13:27:00	Abila Zacharo	50.14	1286
9	2014-01-09	13:47:00	Abila Zacharo	48.39	1286
17	2014-01-13	13:21:00	Abila Zacharo	64.5	1286
25	2014-01-16	13:22:00	Abila Zacharo	64.71	1286
30	2014-01-18	14:51:00	Ahaggo Museum	55.55	1286
1	2014-01-06	08:16:00	Brew've Been Served	14.97	1286
3	2014-01-07	07:54:00	Brew've Been Served	11.92	1286
5	2014-01-08	08:16:00	Brew've Been Served	7.26	1286
8	2014-01-09	08:14:00	Brew've Been Served	17.64	1286
11	2014-01-10	08:01:00	Brew've Been Served	5.89	1286

Showing 1 to 10 of 32 entries

Location is plotted against each day. If there was a transaction at the location for that day, a tile would appear. For this module, the tile plot is chosen as its uniform tiles allow a straightforward view of whether transactions were made consecutively for each day, or on separate days. The color intensity of the tile would give an indication of the magnitude of the transaction amount - the darker the intensity, the higher the amount. Hovering over each tile would display a tooltip indicating the details of that particular transaction. A data table for the selected card would also appear below the tile plot to list down all observations, it can be sorted and filtered, to allow for the investigator's further exploration.

5.4 Employees of GasTech

Duis nec purus sed neque porttitor tincidunt vitae quis augue. Donec porttitor aliquam ante, nec convallis nisl ornare eu. Morbi ut purus et justo commodo dignissim et nec nisl. Donec imperdiet tellus dolor, vel dignissim risus venenatis eu. Aliquam tempor imperdiet massa, nec fermentum tellus sollicitudin vulputate. Integer posuere porttitor pharetra. Praesent vehicula elementum diam a suscipit. Morbi viverra velit eget placerat pellentesque. Nunc congue augue non nisi ultrices tempor.

5.5 Email Correspondence

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6. INFERENTIAL STATISTICS

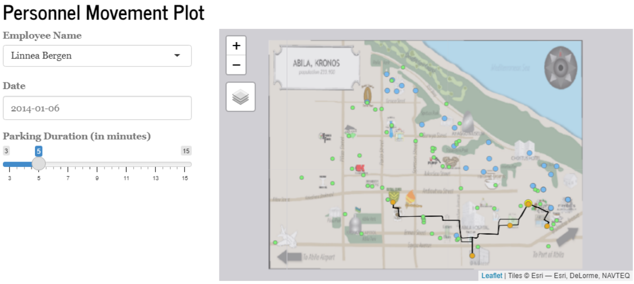
6.1 Email Network Analysis

Duis nec purus sed neque porttitor tincidunt vitae quis augue. Donec porttitor aliquam ante, nec convallis nisl ornare eu. Morbi ut purus et justo commodo dignissim et nec nisl. Donec imperdiet tellus dolor, vel dignissim risus venenatis eu. Aliquam tempor imperdiet massa, nec fermentum tellus sollicitudin vulputate. Integer posuere porttitor pharetra. Praesent vehicula elementum diam a suscipit. Morbi viverra velit eget placerat pellentesque. Nunc congue augue non nisi ultrices tempor.

6.2 Networks

Duis nec purus sed neque porttitor tincidunt vitae quis augue. Donec porttitor aliquam ante, nec convallis nisl ornare eu. Morbi ut purus et justo commodo dignissim et nec nisl. Donec imperdiet tellus dolor, vel dignissim risus venenatis eu. Aliquam tempor imperdiet massa, nec fermentum tellus sollicitudin vulputate. Integer posuere porttitor pharetra. Praesent vehicula elementum diam a suscipit. Morbi viverra velit eget placerat pellentesque. Nunc congue augue non nisi ultrices tempor.

6.3 Employee Movement Plot

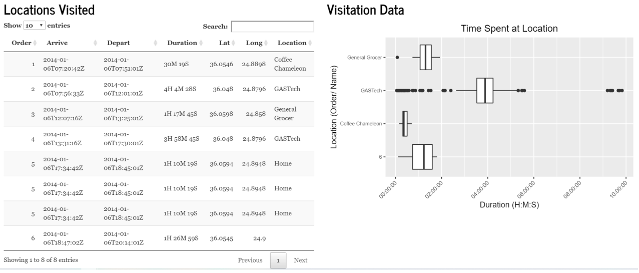

Personnel Movement Plot

Employee Name: Linnea Bergen

Date: 2014-01-06

Parking Duration (in minutes): 5

The data preparation for this module would be to identify Points-of-Interests (POI), using the gps records. Since the recording of gps would only occur while the vehicle is in motion, whenever there is a time interval (3g: 3 minutes), would be a good assumption that the vehicle is in parking mode, thus indicating it as a POI. The time interval may be adjusted based on the investigators' tolerance between 3 and 15 minutes. The POIs would be differentiated between homes of employees and other locations, thus allowing tmap to plot the route taken, and the stops taken.



Locations Visited

Show 10 ▾ entries   Search: □

Order	Arrive	Depart	Duration	Lat	Long	Location
1	2014-01-06T07:20:42Z	2014-01-06T07:51:01Z	30M 19S	36.0546	24.8898	Coffee Chameleon
2	2014-01-06T07:56:33Z	2014-01-06T12:01:01Z	4H 4M 28S	36.048	24.8796	GASTech
3	2014-01-06T12:07:16Z	2014-01-06T13:25:01Z	1H 17M 45S	36.0598	24.858	General Grocer
4	2014-01-06T13:31:16Z	2014-01-06T17:30:01Z	3H 58M 45S	36.048	24.8796	GASTech
5	2014-01-06T17:34:42Z	2014-01-06T18:45:01Z	1H 10M 19S	36.0594	24.8948	Home
5	2014-01-06T17:34:42Z	2014-01-06T18:45:01Z	1H 10M 19S	36.0594	24.8948	Home
5	2014-01-06T17:34:42Z	2014-01-06T18:45:01Z	1H 10M 19S	36.0594	24.8948	Home
6	2014-01-06T18:47:02Z	2014-01-06T20:14:01Z	1H 26M 59S	36.0545	24.9	

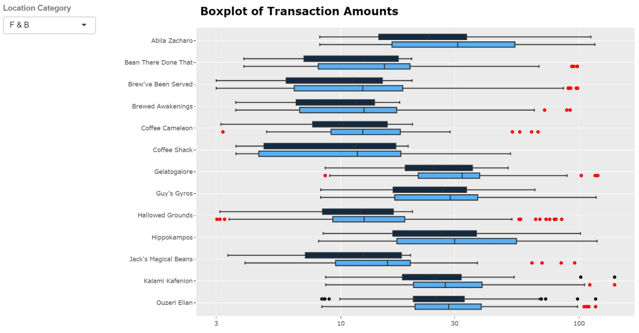
Showing 1 to 8 of 8 entries   Previous 1 Next

Visitation Data

The sub-module would be an extension where the selected gps plot would be sequenced based on the time of activity, and further identified based on marked locations such as their homes, GASTech or prominent locations that were named prior. The subsequent box plot would be an analysis of the duration of stop, by visitors, to the locations.

6.4 Transaction Amount Analysis

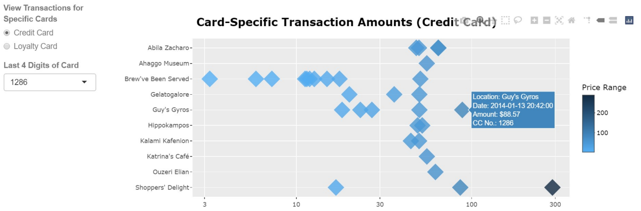
This module provides statistical analysis on the transactions made at each location, by each card type. The distribution of the spread of the transaction amounts is shown by boxplots. Outliers are highlighted in red to gain the investigator's attention.



Location Category: F & B ▾

The plots are categorized by the location types, as we believe transaction amounts should be compared with those made at similar locations (For e.g. F&B with F&B, Industrial with Industrial). It would not be logical to compare a transaction made at a supermarket, with one made at a chemical production factory. This would be useful if the investigator wishes to understand what is a normal range of transaction price for each location, and which transactions deviated from the normal ranges. An additional value-added feature that can be derived from this plot, is the investigator can identify credit card and loyalty card pairs as they would have the same transaction price, on the same day.

A further deep dive can be performed with the specific card transactions scatter plot positioned below the overall boxplot.



View Transactions for Specific Cards
● Credit Card
○ Loyalty Card

Last 4 Digits of Card: 1286 ▾

Location: Guy's Gyros
Date: 2014-01-13 20:42:00
Amount: $88.57
CC No.: 1286

This is a scatter plot of all transactions made by the card selected by the investigator. Each point represents one transaction, and positioned according to the transaction amount. How the amounts made at the same location are relative to each other can be seen by their colors as well - the darker the intensity, the higher the amount. As it is possible to have multiple points clustered close together, some transparency is set so that any overlaps are clearly visible.

7. FUTURE WORKS

(Additional point from Nikki on how the modules could be improved.)

(Additional point from Rhoda on how the modules could be improved.)

An improvement towards the Employee Movement Plot could include further analysis on the movement route, in terms of the distance/ speed, which may suggest the vehicle were kept in idle mode, which is currently unable to detected under the current module. In addition, the streets of Abila could be identified based on the movement routes, and thus, and analysis could be conducted whether the vehicle was travelling in a suspicious manner.

8. ACKNOWLEDGEMENTS

The authors wish to thank Professor Kam Tin Seong of Singapore Management University for his extensive guidance and support during this project.

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[3] Sahaf, Zahra et al. 2014. VAST Challenge 2014 Mini Challenge 2. *http://visualdata.wustl.edu/varepository/VAST%20Challenge%202014/challenges/MC2%20-%20Patterns%20of%20Life%20Analysis/entries/University%20of%20Calgary/*.