# 20 Thieves Solution by Syed

## Initial Scenario

I received email from Tim Brewer at 11:42. After reading the email and the problem readme file. I was up to solve the problem by 12:00 PM. Now 48 hours mean, I must submit it before 12:00 PM Friday. That’s great. I liked the problem and I liked the approach taken by freelancer.com.

## My Approach Log

* Initially I just skimmed through the problem to get an idea of what the problem is all about. Then after starting to write this solution file, I got back to readme file, but this time to read it with more precision. It is important to understand the problem first rather than thinking about the solution. My initial analysis of the problem can be found under **Initial Problem Analysis** heading.
* After completing the initial problem analysis, I moved to the data analysis part. This doesn’t mean programmatically analyzing data, rather it is about reading and understanding the data. The details of initial data analysis can be found under **Initial Data Analysis** heading.
* After completing the initial analysis of the data and writing email to Tim Brewer about few questions that I had, I moved forward with exploratory data analysis of data to get insight of the data and to identify the needs for data preprocessing. Details are available below under **Initial Exploratory Data Analysis and Pre-processing** heading.
* After getting my important data ready for analysis. I started analyzing the data. The details of each analysis and my intensions for each one of them are briefed under First **Data Analysis and Pre-processing** heading.
* My work continued in initial data analysis heading and I was able to fetch initial 20 suspects using association rule mining technique. I used FP Growth algorithm for this purpose. However, during my next approach, I will also attempt to identify the suspects with my own custom build model. The details of the model and results are provided under heading **My Crude Model**.
* After completing the work on my crude model, I decided to first explore and strengthen my findings using well known models. The details of all my attempts can be found under the heading **Well-known General Models**.

## Initial Problem Analysis

Few important observations.

* There is at-least one thief (Yes, it is obvious, but I preferred to mark it down)
* Scanner only scan the name and DOB for anyone who enters the club. (Not who left, be careful)
* Ranked list of up-to 20 suspects is needed. From most suspicious to least suspicious. There could be fewer. (Ranking problem)
* Post mid-night time will be considered as previous day
* We have visitor and theft logs
* Freelancer.com need details of how I approached and solved the problem and the problems I faced during the journey. (That is why I have created this document, I hope this will help)

## Initial Data Analysis

Initial observations about the data:

* theft\_log.csv contains only the dates about the theft. (No time information is provided. This is lack of information, but we data scientist should work it out)
* visitor\_log.csv contains only the visit\_date, name, and dob. (Again, we only have the day information. We only know that individual entered the place on the day, but we don’t know either he/she left on the same day or not)
* The joining attribute between visit and theft is date.
* Before moving forward, inquire from Tim Brewer that should be we asking question related to problem? Just to make sure we don’t commit any sins of 09 sins of data mining.

## Initial Exploratory Data Analysis and Pre-processing

* Before, I start performing the exploratory data analysis, I preferred to get the data into a database. Well, it is not necessary. Many data scientist can process the same data using MS Excel or directly using any data mining tools. But I prefer to work using SQL. And it really helps me while working with large datasets. Other tools often start crying when data size grows. I used SQL Server 2016, again only for my personal preference. I created a database named “nct”, short for nightclubthieves. Created two tables each for theft\_log and visitor\_log. Then I bulk inserted data into tables. The queries for this step are provided as initialbulkinsert.sql with this document.
* *Before moving forward, I must backup my work on GIT. I have version controlled all my work at:* [*https://bitbucket.org/saif137/mybi*](https://bitbucket.org/saif137/mybi) *in freelancertask folder.*
* I plan to perform all possible exploratory data analysis, transformations and preprocessing in database using SQL. Once we will get done with our exploratory data analysis then we will move forward with the problem.
* I started with theft\_log.csv data. It is available in theft\_log\_i table. I first preprocessed the date field to separate out the year, month and day information and stored it into separated table.
* I firsts tried to identify, if there is any pattern for theft in terms of month? Either frequency of theft is more in few months or there is gradual increase or decrease in theft over months? For this purpose, I wrote following query and found out that yes, July, November, and December has higher theft frequency.

--First check if theft occurrence is same or varies across month

select

tyear [Year of theft]

, tmonth [Month of theft]

, count (\*) [Total theft]

from theft\_log

group by

tyear, tmonth

order by

tyear, tmonth

* I also plot the same data using MS Excel PivotChart as show in Figure 1. Visualization is very important for exploratory data analysis. It is very important task for data scientists in addition to data preprocessing and modeling.

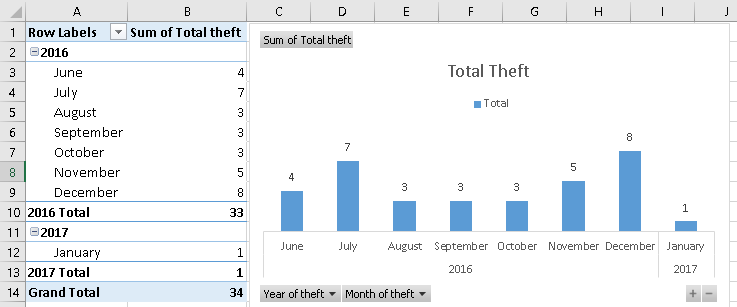


Figure 1: Month-wise Theft

* Another important exploration will be that either there are any specific days when more thefts have occurred? I identified day-wise theft occurrences using the query given below:

select

tdayname [Day]

, count(\*)

from

theft\_log

group by

tdayname

* Above query result only provided a hint that there has been less theft on Tuesday and Wednesday, but there is no day when there was no theft. Nor we can convincingly say that there are some days with more theft occurrences. I further attempted to separate it out on the basis of month and day using query below:

--Theft occurrences on basis of month and day

select

tmonthname [Month]

, tdayname [Day]

, count(\*)

from

theft\_log

group by

tmonthname, tdayname

order by

tmonthname, tdayname

* Above query result only provided a hint that theft occurrences have been more on Sunday and Monday of December. But still I didn’t found any significant pattern. Visualization of theft pattern for days on monthly basis is shown in Figure 2.

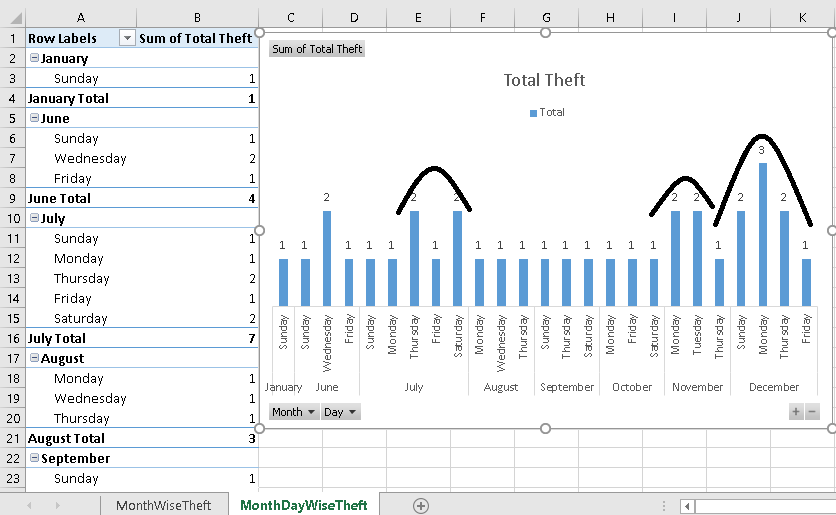


Figure 2: Theft pattern for Days on Monthly Basis

* I immediately realized, that week-wise analysis should also be done to identify if there are some weekly patterns for theft. I added week number column to our table after recreating it with updated query. The updated queries are provided with this document as theft\_log\_pp.sql.

select

tweek [Week]

, count(\*) [Total Theft]

from

theft\_log

group by

tweek

* The weekly theft count also didn’t gave us any specific pattern except a minor observation that last three weeks of the year has more theft occurrences together and similarly week 27 to 32 has continuous pattern of theft.
* *Before moving forward, I must backup my work on GIT. I have version controlled all my work at:* <https://bitbucket.org/saif137/mybi> *in freelancertask folder.*
* I will stop working on theft\_log data and now I will move to visitor\_log data that we have already loaded in visitor\_log\_i table in our database. I just attempted to sort-out, how each individual can be identified. After checking with distinct and group by queries, it was clear that we should identify each visitor using both name and dob.
* Before, I try to find out individuals, whom we may suspect of theft. I preferred to eliminate individuals, who are innocent. **(Later, I identified it was a mistake, and according corrected my solution)** I filtered the records/visits for days when no theft was reported. This will reduce our search space. I created a separate table named visitor\_log\_t to store visit information for days when theft has occurred. While moving the data, we also separated the date parts of the visit using query shown below:

insert into visitor\_log

select

visit\_date

, [name]

, [dob]

, convert(integer, SUBSTRING(visit\_date, 1, 4)) as tyear --can also use datepart

, convert(integer, SUBSTRING(visit\_date, 6, 2)) as tmonth

, convert(integer, SUBSTRING(visit\_date, 9, 2)) as tday

, datename(dw, visit\_date) tdayname

, datename(mm, visit\_date) tmonthname

, datepart(wk, visit\_date) tweek

from visitor\_log\_i where visit\_date in (

select theft\_day from theft\_log\_i

)

* Above query reduced our search space from 42727 to 7288. Now we only need to consider individuals in these 7288 records to identify the probable thieves.
* *Before moving forward, I must backup my work on GIT. I have version controlled all my work at:* <https://bitbucket.org/saif137/mybi> *in freelancertask folder.*

## First Data Analysis and Pre-processing

* I started my analysis to answer few questions that I had. How many individuals visited on the days, when theft has occurred. I found out that between 195 to 245 visitors were present each day when theft was occurred.
* Next, I was curious to know, either there are visitors who were present on every theft day? Or I can ask the same question as, list the visitors according to their presence of number of theft days. There are 34 distinct theft days. The maximum theft days a visitor was found to be present is Karen Keeny and its 30 days, but beware, Karen could be the most loyal customer of the night club. We are still far away from making any prediction. The only thing that we can take away is that there is more than one thief.
* Next, I was curious to know, either there are visitors who were present together on every theft day? This can also be answered using Association Rule mining. Here I got stuck for two hours, because I tried to get it done using T-SQL and then the datatype limit issue arise when I attempted to generate a table with separate column for each visitor. *I worked so hard but in the end got stuck while creating a query for table with each visitor as a column.* But I got the same work done using MS Excel Pivot table in a minute. Yes, it happens many times. The snapshot is given below in Figure 3, where each id on column represent a unique visitor. However, this effort allowed me to replace name and dob with a unique identifier that I will be using for any further processing. This will anyhow reduce the data processed during analytics.

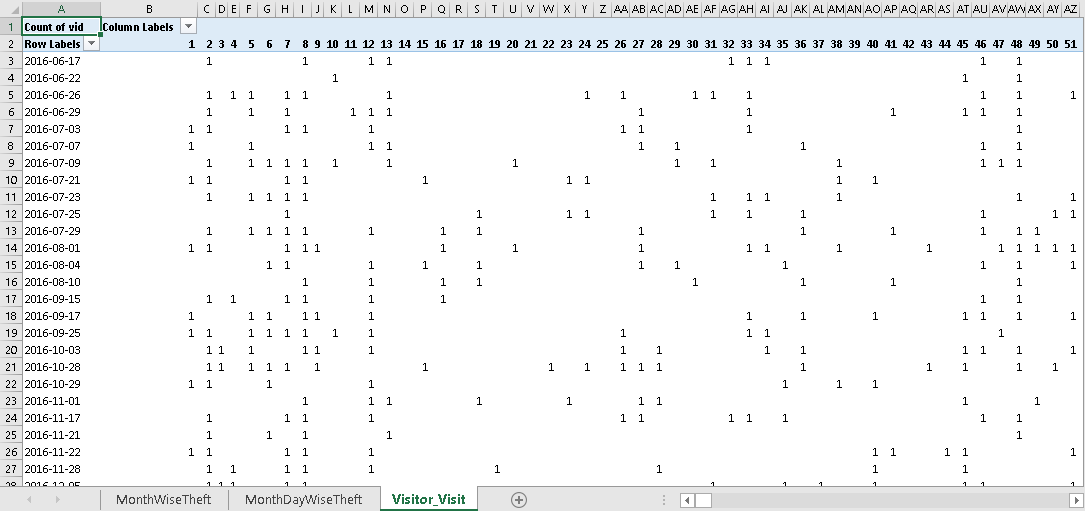


Figure 3: Visitors Visiting Together on Each Theft Day

* Using this tabular view of the data as shown in Figure 3, I was able to perform association rule mining using FP-Growth algorithm to identify, which visitors visited together during theft days. I was able to complete the initial model execution with default values using rapid miner, but then it became time to take break as library is closing. I will start again on this after2 hours from home.
* The first approach I am using for identification of theft suspect is using Association Rule Mining. I will make use of FP Growth algorithm, however, Apriori can also be used for similar problems. After updating the parameters, i.e., minimum confidence to 0.99 (to fetch only important and strong associations, we found that visitors are of interest for us. But this doesn’t mean that they are thieves, they could be our loyal customers as well.

Association Rules (Ignored results: Better result were generated)

[726] --> [464] (confidence: 0.909)

[538] --> [464] (confidence: 0.909)

[289] --> [464] (confidence: 0.909)

[207] --> [464] (confidence: 0.909)

[773] --> [563] (confidence: 0.909) (Lift = 1.145)

[650] --> [302] (confidence: 0.909) (Lift = 1.145)

[207] --> [302] (confidence: 0.909) (Lift = 1.145)

[100] --> [632] (confidence: 0.909) (Lift = 1.236)

[679, 455] --> [464] (confidence: 0.909)

[563, 744] --> [464] (confidence: 0.909)

[464, 152] --> [563] (confidence: 0.909) (Lift = 1.145)

[563, 145] --> [464] (confidence: 0.909) (Lift = 1.145)

[464, 54] --> [455] (confidence: 0.909)

[744, 145] --> [464] (confidence: 0.909)

[563, 744] --> [152] (confidence: 0.909) (Lift = 1.189)

[744, 152] --> [563] (confidence: 0.909) (Lift = 1.145)

[784] --> [464] (confidence: 0.913)

[748] --> [464] (confidence: 0.913)

[142] --> [464] (confidence: 0.913)

[563, 455] --> [464] (confidence: 0.913)

[464, 302] --> [455] (confidence: 0.913) (Lift = 1.15)

[455, 302] --> [464] (confidence: 0.913)

[709] --> [464] (confidence: 0.917)

[145] --> [464] (confidence: 0.923)

[455] --> [464] (confidence: 0.926)

[701] --> [302] (confidence: 0.952) (Lift = 1.199)

[455, 54] --> [464] (confidence: 0.952)

[848] --> [464] (confidence: 0.955)

[455, 145] --> [464] (confidence: 0.955)

* I also attempted to get another perspective of the generated rules using the graph view. It gave me an interesting insight. As it can be observed in Figure 4, visitors 100 and 632 are present on theft days without any association with other visitors. It may be interesting, but it will need further investigation.

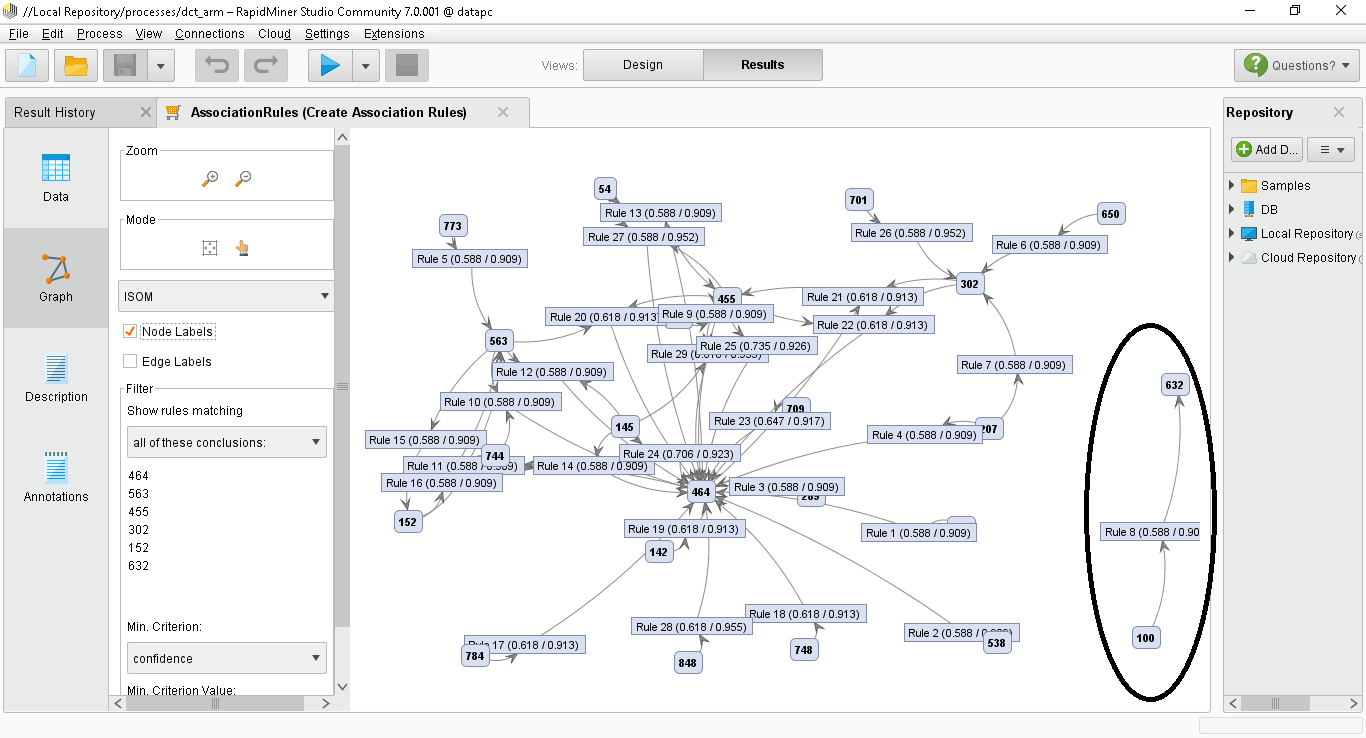


Figure 4: Graph View of Generated Association Rules (Ignored results)

* I will keep focus on following visitors during further analysis: 100, 632, 464, 145, 563, 455, 302, 709, 744, 207, 209, 152, 302 as these visitors has been present in relationship with most other visitors during theft day. (Ignore later)
* Now, it’s time to try another approach. I just wondered, why didn’t I took this problem as a classification problem? What about adding a new column with two possible classes, i.e., theft occurred or not. And then train the model to make prediction. This could have been a good approach to identify potential thieves. The problem is, all experiment of association rule mining will need to be re-run as I have to regenerate the visitor ids to accommodate visitors that I left out during previous generation of visitor ids. The good part is, we can always identify the new ids for old ones using joins, which means the problem can be solved. I just did as I discussed above, I took all data and converted it into columnar format as I did with my previous theft day only data set. Then the record for each visit of theft day is marked as 1 and each visit on non-theft day is marked as 0. The script for preparing the data as discussed above is made available as attachment with this document with name reformulatingasPrediction.sql.
* After preparation of the data, we attempted to identify highly correlated attributes, which for us means visitors. With 0.6 cutoff for correlation we got only four visitors of 330, 731, 745, 627 using R script given below:

#Loading initial data

train <- read.csv("C:/data/certi/mybiwork/freelancertask/visitor\_c.csv")

#Check that data is as it should be

#View(train)

set.seed(7)

library(mlbench)

library(caret)

train.visitors <- train[2:length(train) - 1]

myvisitors <- sapply(train.visitors, as.numeric)

corrmat <- cor(myvisitors)

hicorr <- findCorrelation(corrmat, cutoff=0.6)

print (hicorr)

* I used this script, because I had it with me. I wrote it using an internet resource. But beware, these are visitors that are correlated for both theft and non-theft visit. To ease up my problem, I will be re-generating my association rule mining results with new visitor’s id, so that I can myself keep track of visitor’s ids of interest. The good part is, my effort for re-generating my association mining results ended up in getting better rules as can be observed in Figure 5. I found out the visitors with above 70 % support and 100% confidence that they were present during the theft day. I have listed the identified association rules below with first row showing the visitor with highest support from data for rule.

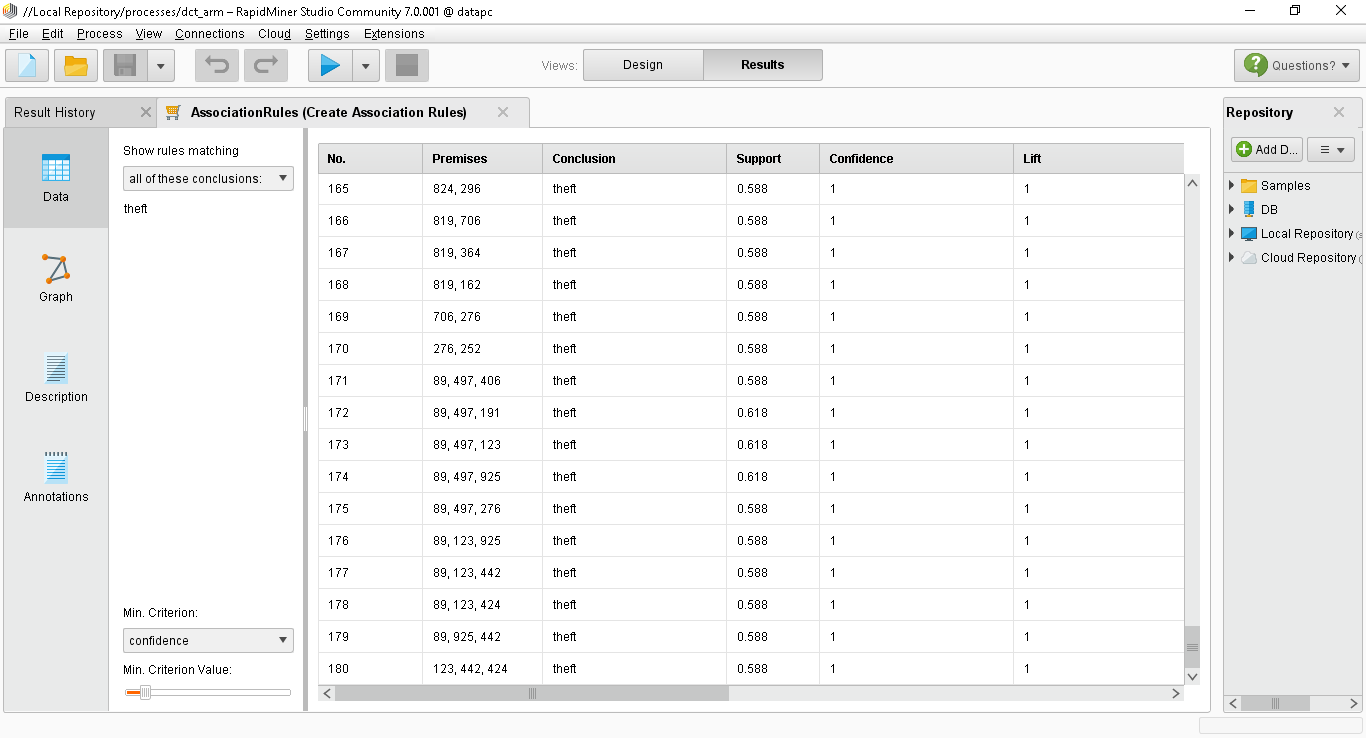


Figure 5: Group of Visitors During Theft Days

**Association Rules (Theft during presence)**

Association Rules

[89] --> [theft] (confidence: 1.000)

[523] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[497] --> [theft] (confidence: 1.000)

[406] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[191] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[123] --> [theft] (confidence: 1.000)

[925] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[442] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[424] --> [theft] (confidence: 1.000)

[234] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[824] --> [theft] (confidence: 1.000)

[819] --> [theft] (confidence: 1.000)

[706] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[364] --> [theft] (confidence: 1.000)

[276] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[886] --> [theft] (confidence: 1.000)

[809] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[612] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[252] --> [theft] (confidence: 1.000)

[239] --> [theft] (confidence: 1.000)

[212] --> [theft] (confidence: 1.000)

[176] --> [theft] (confidence: 1.000)

[89, 497] --> [theft] (confidence: 1.000)

[89, 123] --> [theft] (confidence: 1.000)

[89, 925] --> [theft] (confidence: 1.000)

Following added after reducing support to 65%, to reach 20 suspects

[923] --> [theft] (confidence: 1.000)

[743] --> [theft] (confidence: 1.000)

[611] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[438] --> [theft] (confidence: 1.000)

[17] --> [theft] (confidence: 1.000)

[162] --> [theft] (confidence: 1.000)

[89, 523] --> [theft] (confidence: 1.000)

[89, 406] --> [theft] (confidence: 1.000)

[89, 191] --> [theft] (confidence: 1.000)

[89, 442] --> [theft] (confidence: 1.000)

[89, 234] --> [theft] (confidence: 1.000)

[497, 191] --> [theft] (confidence: 1.000)

[497, 123] --> [theft] (confidence: 1.000)

[123, 424] --> [theft] (confidence: 1.000)

Following added after reducing support to 60%, to reach 20 suspects

[892] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[868] --> [theft] (confidence: 1.000)

[82] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[677] --> [theft] (confidence: 1.000)

[587] --> [theft] (confidence: 1.000) (Also present on non-theft days)

[296] --> [theft] (confidence: 1.000)

[262] --> [theft] (confidence: 1.000)

[157] --> [theft] (confidence: 1.000)

[133] --> [theft] (confidence: 1.000)

* I will also like to identify those individuals who were always absent on the day when no theft occurred as this will increase their suspicion if they were always present when theft was occurred (This is my weak assumption: I Know). For this purpose, I also changed the positive value to false for FP Growth algorithm, which means when certain visitors were absent no theft occurred. I select 100% support and confidence for rules generation. We also want to omit the most loyal customers. The generated association rules are listed below. The good part is, none of them are in our suspicious visitors list.

# Association Rules (No Theft During Absence)

Association Rules (None were found to be present on theft day with 100% conf)

[theft] --> [690] (confidence: 1.000)

[690] --> [theft] (confidence: 1.000)

[theft] --> [660] (confidence: 1.000)

[660] --> [theft] (confidence: 1.000)

[theft] --> [544] (confidence: 1.000)

[544] --> [theft] (confidence: 1.000)

[theft] --> [521] (confidence: 1.000)

[521] --> [theft] (confidence: 1.000)

[690] --> [660] (confidence: 1.000)

[660] --> [690] (confidence: 1.000)

[690] --> [544] (confidence: 1.000)

[544] --> [690] (confidence: 1.000)

[690] --> [521] (confidence: 1.000)

[521] --> [690] (confidence: 1.000)

[660] --> [544] (confidence: 1.000)

[544] --> [660] (confidence: 1.000)

[660] --> [521] (confidence: 1.000)

[521] --> [660] (confidence: 1.000)

[544] --> [521] (confidence: 1.000)

[521] --> [544] (confidence: 1.000)

[theft] --> [690, 660] (confidence: 1.000)

[690] --> [theft, 660] (confidence: 1.000)

[theft, 690] --> [660] (confidence: 1.000)

[660] --> [theft, 690] (confidence: 1.000)

[theft, 660] --> [690] (confidence: 1.000)

[690, 660] --> [theft] (confidence: 1.000)

[theft] --> [690, 544] (confidence: 1.000)

[690] --> [theft, 544] (confidence: 1.000)

[theft, 690] --> [544] (confidence: 1.000)

[544] --> [theft, 690] (confidence: 1.000)

[theft, 544] --> [690] (confidence: 1.000)

[690, 544] --> [theft] (confidence: 1.000)

[theft] --> [690, 521] (confidence: 1.000)

[690] --> [theft, 521] (confidence: 1.000)

[theft, 690] --> [521] (confidence: 1.000)

[521] --> [theft, 690] (confidence: 1.000)

[theft, 521] --> [690] (confidence: 1.000)

[690, 521] --> [theft] (confidence: 1.000)

[theft] --> [660, 544] (confidence: 1.000)

[660] --> [theft, 544] (confidence: 1.000)

[theft, 660] --> [544] (confidence: 1.000)

[544] --> [theft, 660] (confidence: 1.000)

[theft, 544] --> [660] (confidence: 1.000)

[660, 544] --> [theft] (confidence: 1.000)

[theft] --> [660, 521] (confidence: 1.000)

[660] --> [theft, 521] (confidence: 1.000)

[theft, 660] --> [521] (confidence: 1.000)

[521] --> [theft, 660] (confidence: 1.000)

[theft, 521] --> [660] (confidence: 1.000)

[660, 521] --> [theft] (confidence: 1.000)

[theft] --> [544, 521] (confidence: 1.000)

[544] --> [theft, 521] (confidence: 1.000)

[theft, 544] --> [521] (confidence: 1.000)

[521] --> [theft, 544] (confidence: 1.000)

[theft, 521] --> [544] (confidence: 1.000)

[544, 521] --> [theft] (confidence: 1.000)

[690] --> [660, 544] (confidence: 1.000)

[660] --> [690, 544] (confidence: 1.000)

[690, 660] --> [544] (confidence: 1.000)

[544] --> [690, 660] (confidence: 1.000)

[690, 544] --> [660] (confidence: 1.000)

[660, 544] --> [690] (confidence: 1.000)

[690] --> [660, 521] (confidence: 1.000)

[660] --> [690, 521] (confidence: 1.000)

[690, 660] --> [521] (confidence: 1.000)

[521] --> [690, 660] (confidence: 1.000)

[690, 521] --> [660] (confidence: 1.000)

[660, 521] --> [690] (confidence: 1.000)

[690] --> [544, 521] (confidence: 1.000)

[544] --> [690, 521] (confidence: 1.000)

[690, 544] --> [521] (confidence: 1.000)

[521] --> [690, 544] (confidence: 1.000)

[690, 521] --> [544] (confidence: 1.000)

[544, 521] --> [690] (confidence: 1.000)

[660] --> [544, 521] (confidence: 1.000)

[544] --> [660, 521] (confidence: 1.000)

[660, 544] --> [521] (confidence: 1.000)

[521] --> [660, 544] (confidence: 1.000)

[660, 521] --> [544] (confidence: 1.000)

[544, 521] --> [660] (confidence: 1.000)

* I just realized that I must complete the confusion box. So far, we have identified visitors who were present and theft has occurred and who were not present and theft haven’t occurred. Now we should also identify those who were present and theft didn’t occur and those who were absent and theft occurred.

# Association Rules (No theft During Presence)

Association Rules (All found on theft days except those mentioned)

[191] --> [notheft] (confidence: 1.000)

[523] --> [notheft] (confidence: 1.000)

[925] --> [notheft] (confidence: 1.000)

[234] --> [notheft] (confidence: 1.000)

[406] --> [notheft] (confidence: 1.000)

[706] --> [notheft] (confidence: 1.000)

[82] --> [notheft] (confidence: 1.000)

[442] --> [notheft] (confidence: 1.000)

[276] --> [notheft] (confidence: 1.000)

[133] --> [notheft] (confidence: 1.000)

[612] --> [notheft] (confidence: 1.000)

[611] --> [notheft] (confidence: 1.000) (Was never present on theft days)

[809] --> [notheft] (confidence: 1.000)

[587] --> [notheft] (confidence: 1.000)

[892] --> [notheft] (confidence: 1.000)

[604] --> [notheft] (confidence: 1.000) (Was never present on theft days)

[191, 523] --> [notheft] (confidence: 1.000)

[191, 925] --> [notheft] (confidence: 1.000)

* I found many visitors who were absent during theft day with 100% support and confidence. The list of these visitors has been saved as a separate file with name theft\_absence\_visitors.txt. Now we have 12 suspects after analyzing the all four possibilities of visitors present/absent during theft/non-theft days. To increase the list to 20, I will again run the first experiment for visitors present during theft day to meet the 20 requirements. Only matching the additional 8 to be added with other lists.
* *Here 24 hours of my task time is completed. Only 24 hours left.*
* Now we have our 20 initial suspects list. It is time to explain/show our results before moving forward to get more insight. Below is the list of suspects that we identified, placed according to their rank based on the support from data.

89 Karen Keeney 1993-12-25

497 Judith Sanders 1993-08-26

123 Lynn Bernhart 1995-11-13

424 Daniel Laster 1995-12-31

824 Michael Mcbride 1993-04-26

819 Luz Connelly 1995-03-26

364 Kathleen Benzi 1995-09-15

886 Raymond Shannon 1997-08-06

252 Johnie Johnson 1995-12-28

239 John Davis 1996-02-05

212 Cheryl Robinson 1996-04-05

176 Florine Kim 1996-07-14

923 Sharon Barton 1997-09-08

743 Wes Carlson 1996-01-13

438 Charles Crandall 1997-05-12

17 Cynthia Allen 1996-08-29

162 Cynthia Dominquez 1996-05-16

868 Thomas Vanderwal 1997-05-06

677 Linda Gomez 1996-03-08

296 Charles Betts 1997-07-18

176 Florine Kim 1996-07-14

* What we claim about this list is as follows. With 70-60% support and 100% confidence from data we found that these visitors were present every time theft occurred. We also didn’t found these visitors in list of visitors who were absent during non-theft days with 100% support and from data. They were also not found in the list of visitors who were present on non-theft days with 100% support and confidence from data. They were also not found in the list of visitors who were absent on theft day with 100% support and confidence from data. The ranking of the customer is from first towards last considering their decreasing support from data during rules generation.

## My Crude Model

* I want to work out on the same problem using my custom-made point-scoring based greedy algorithm. It will be a very simple algorithm. For every visitor, it will score it positively if visitor was present on the day theft occurred and negatively if visitor was absent on the day or if visitor was present on the day when no theft occurred. We obtained the list of 20 visitors using this technique, from this list, 2 visitors were already on our existing list. The source code of the initial approach with identified visitors is provided as source with name dct\_freq\_tdv.py.
* I wanted to improve my crude approach. I just imagined, how humans will behave in similar scenario. I found that continuity of visitor presence during theft or absence of visitor presence during theft will affect how we rank each visitor. My implementation of this approach is available with name dct\_freq\_tdv\_con.py. However, the results are not what I expected. Rather the results are matching more with visitors identified in Absent on Non-Theft Day findings.
* I just got alarmed with my approach as it was not validating my initial list at all. Then I realized, that non-theft days don’t really add value to my calculation. So, I only focused on theft days for identifying suspicious visitors. And then, “**Yes**”, I felt back home. At-least updated results are validating my existing results and my approach, giving me confidence that I am moving in the right direction. The source code for updated approach is available with filename dct\_freq\_tdv\_con\_ana.py. The 20 most suspicious visitors using my crude model are as given below:

**""" Most vulnerable visitors under perceptions  
(191, 802) #Also present on non-theft days, skipped  
(89, 793) # This is also part of our initial list  
(497, 766) # This is also part of our initial list  
(276, 712) #Also present on non-theft days, skipped  
(523, 702) #Also present on non-theft days, skipped  
(706, 700) #Also present on non-theft days, skipped  
(442, 694) #Also present on non-theft days, skipped  
(123, 679) # This is also part of our initial list  
(234, 677) #Also present on non-theft days, skipped  
(886, 673) # This is also part of our initial list  
(925, 668) #Also present on non-theft days, skipped  
(406, 667) #Also present on non-theft days, skipped  
(824, 653) # This is also part of our initial list  
(967, 643)  
(819, 642) # This is also part of our initial list  
(364, 622) # This is also part of our initial list  
(424, 613) # This is also part of our initial list  
(176, 612) # This is also part of our initial list  
(743, 606) # This is also part of our initial list  
(612, 606) #Also present on non-theft days  
"""**

* Above results are quite optimistic in terms that it does validate our existing results. I want to continue with custom-made modeling using the dynamic programming approach for identifying longest-common sub-sequence. The concept will be take theft days as a sequence and find the visitors with most similar days/sequence. This could also be a good approach for ranking the suspicious visitors. However, I will attempt it given that I get time after attempting to use the known data mining/machine learning techniques
* *Before moving forward, I must backup my work on GIT. I have version controlled all my work at:* <https://bitbucket.org/saif137/mybi> *in freelancertask folder.*

## Well-known General Models

* The next approach will be to make use of Naïve Bayes. The approach will be to generate a model and to identify the attributes/visitors in the model that have high probability for theft given that they were present on the theft day. The model give us following 20 visitors with highest probability of theft given that they were present:

VID Visited Prob\_Theft\_Occured Prob\_Theft\_NotOccured

89 value=true 0.674667952 0.882110833 # This is also part of our initial list

497 value=true 0.674667952 0.79391445 # This is also part of our initial list

123 value=true 0.69876216 0.79391445 # This is also part of our initial list

406 value=true 0.758997681 0.79391445 #Also present on non-theft days, skipped

523 value=true 0.837303858 0.79391445 #Also present on non-theft days, skipped

191 value=true 0.855374514 0.79391445 #Also present on non-theft days, skipped

424 value=true 0.656597295 0.764515655 # This is also part of our initial list

442 value=true 0.740927025 0.764515655 #Also present on non-theft days, skipped

234 value=true 0.807186098 0.764515655 #Also present on non-theft days, skipped

925 value=true 0.831280306 0.764515655 #Also present on non-theft days, skipped

824 value=true 0.445772972 0.73511686 # This is also part of our initial list

364 value=true 0.608408879 0.73511686 # This is also part of our initial list

819 value=true 0.644550191 0.73511686 # This is also part of our initial list

276 value=true 0.740927025 0.73511686 #Also present on non-theft days, skipped

706 value=true 0.746950577 0.73511686 #Also present on non-theft days, skipped

212 value=true 0.55419691 0.705718066 # This is also part of our initial list

252 value=true 0.560220462 0.705718066 # This is also part of our initial list

176 value=true 0.566244014 0.705718066 # This is also part of our initial list

239 value=true 0.632503087 0.705718066 # This is also part of our initial list

886 value=true 0.632503087 0.705718066 # This is also part of our initial list

* The naïve bayes probabilities strongly supported our existing results. But it also increased my suspicion about skipped visitors, i.e., the ones that I skipped when they were also present on non-theft days. Well, I will continue with few more approaches to validate my results and then I will decide what is needed to be done.
* I updated this document and in parallel attempted to make use of Neural Network for generating a model on my data. Good part was I was able to update the document to make it readable, the bad part was Neural Network took more time in building the model than what I expected.
* I create the model using Decision Tree, however, I could not find any significant result/pattern in the constructed tree. Furthermore, I could not find the option in my tool to enforce the decision tree to only create significant rules for the causes of theft, as was possible for me in case of Association Rules. I also created the model using Logistic Regression. Again, the support vectors identified by logistic regression cannot be used to identify potential suspects. For example, both of them picked 660 as most important suspect. If we analyze the 660 then it is true that every time 660 was present, theft occurred, but there were many instances where theft occurred and 660 was not present.