DATA SCIENCE TOOLS FOR CRIME INVESTIDATION, ARCHIVAL, AND ANALYSIS

SEMINAR REPORT

Submitted by,

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ABSTRACT

Crime Tracking System (CTS) aims to facilitate the process by automating data entry, storage, and retrieval using a mobile interface and a database to efficiently store said data. The Emergence of the field of data science has opened new doors that have high potential in facilitating the process of criminal investigation. Data science enables criminal investigators to create tangible and quantifiable information on criminal social network profiles then analyzes crime concurrence based on location proximity.Aiming at availing the relevance of integrating data science analysis techniques in the criminal investigation, this study examines the suitability of **cluster graphs** and geolocation proximity (through **heat maps**) as two of the data science analysis techniques to facilitate criminal investigation processOn one hand, **cluster graph** analyses the social network of a suspect and examines its centrality, parallel betweenness and community affiliation. On the other hand, **geolocation proximity** provides an investigator with previous crime occurrences through the use of the heat map visualizing technique. These concepts are tested by embedding them in a mobile application developed to facilitate investigation process.

Keywords: Crime Tracking, Crime Analysis, Geolocation, Heat Map, Clustering, Data Mining.

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CHAPTER 1
INTRODUCTION

1.1 OVER VIEW

Artificial intelligence and algorithms are increasingly becoming commonplace in crime fighting efforts. For instance, predictive policing uses software to predetermine criminals and areas where crime is most likely to happen. Risk assessment software are employed in sentence determination and other courtroom decisions, and they are also being applied towards prison overpopulation by assessing which inmates can be released. Public opinion on the use of predictive software is divided: many police and state officials support it, crediting it with lowering crime rates and improving public safety. Others, however, have questioned its effectiveness, citing civil liberties concerns as well as the possibility of perpetuating systemic discrimination.

Fig 1.1 Crime Scene

1.2 Crime Tracking System (CTS)

The process of crime investigation involves gathering and analyzing vast amounts of data. For investigators who need to track the status of criminal cases and to get valuable suggestions on their potential suspects, the Criminal Tracking System (CTS) is an information system that will provide an anywhere/anytime single point of access to the criminal cases logs and their potential suspects. The system will store detailed information of every criminal case within online central repository, the Crime Date and Time, the case opening Date and Time, the location of every crime scene, the victims' names, the potential suspects and the evidence found. The system will save the investigator 25 percent time on criminal cases by providing the investigator with fast and easy access to crime cases logs, identifying serial crime case and listing all crimes committed by a suspect. Unlike the current human driven processes, our system will generate news feeds required to keep the investigator informed about recent crimes cases.

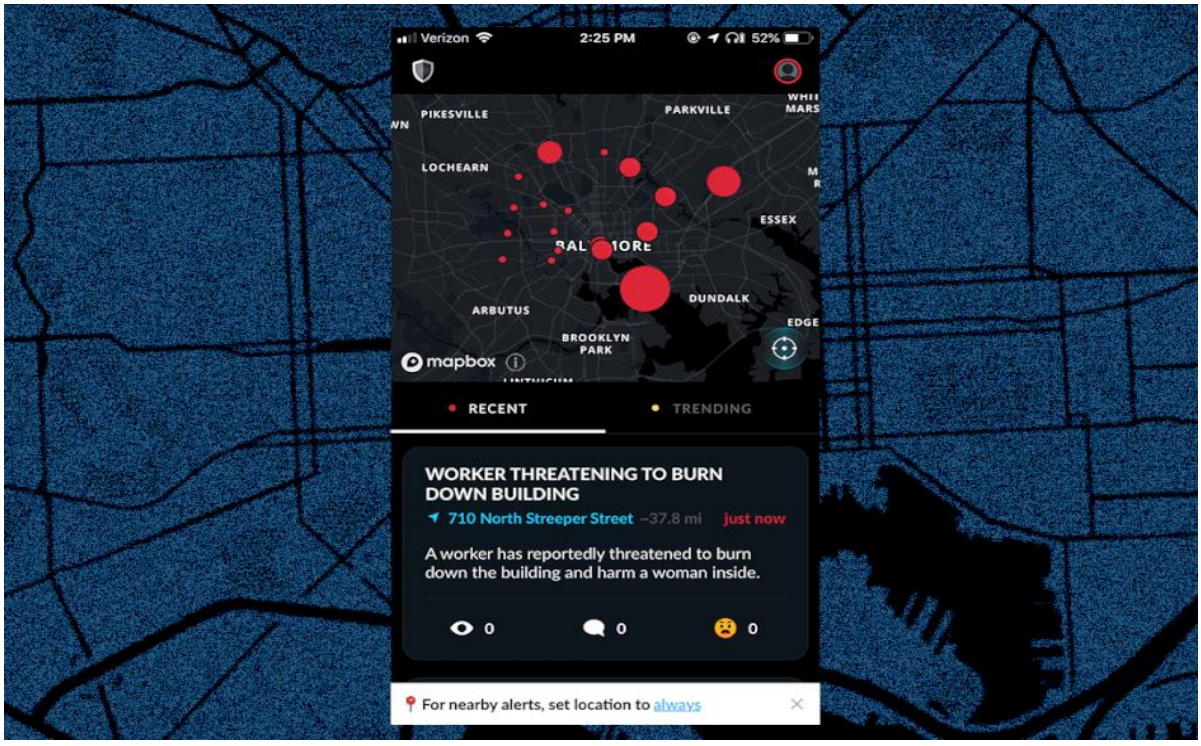


Fig 1.2 Heat Map

CHAPTER 2
LITERATURE SURVEY

The process of crime investigation involves gathering and analyzing vast amounts of data. In the past, gathering and analysis of crime data was all done manually. Therefore, investigation of a single crime took a lot of time and effort [4]. The emergence of data science has introduced new tools and techniques to automate and broaden the range of data collected for crime investigations. One such example is suspect profiling using social media platforms. It provides a summarized narrative about a suspect and their background details gathered from their social media profiles [5]. This section presents a summary of several academic publications related to applying data science concepts into crime investigation process. The review aims at categorizing related works into five features and data science tools, namely profiling, geographic profiling, structured and unstructured data mining, network analysis, and tracking techniques.

The first feature enumerates the crime and criminal profiling tools that have been introduced by several researchers in the literature; for example, the work carried by David J. Icove [1] is a similar concept to Serial Crime Detector of the CTS mobile application. Both operate by suspect profiling and crime pattern analysis to solve crimes. They both attempt to create a suspect profile based on crime details gathered by identifying particular patterns or behavior linked to other past crimes.

The second feature involves the concept of geographical profiling which has been utilized by many researchers in the literature. The work by D. Kim Rossmo et al [2] is essentially the same idea as the CTS HeatMap system. Both concepts make use of a geographical map to analyze and predict the occurrence of crimes in particular areas of concentration. Furthermore, the paper by Rui LI, Kin Hou Lei, Ravi Khadiwala, Kevin Chen-Chuan Chang called ”Twitter Based Event Detection and Analysis System” [3] extract location data such as GPS coordinates longitude and latitude from a tweet to detect, analyze and anticipate events such as criminal activities.

The third feature is concerned with structured and unstructured data mining. For example, the paper “Crime Data Mining: An Overview and Case Studies” [6] contains a string

comparator that examines crime records for deceptive information. Also, the work by Yuen-Hsien Tseng et al [7] mines for text from official criminal records and news to identify relationship hidden in unstructured text. Moreover, the paper by Mohammad Reza Keyvanpour et al [8] detects and explores the relationship between crimes and criminals using data mining to perform a crime matching operation. They are all fundamentally similar to the CTS Serial Crime Detector system which also compares crime records against one another to detect behavioural characteristics of criminals.

The fourth feature is focused on the concept of network analysis, the social network connection in particular. The paper [9] by Jennifer Xu and Hsinchun Chen delves deep into the approach of using cluster graphs to create a visual representation of the relationship between individuals to uncover non-obvious patterns. Furthermore, the work by Rabeah Al-Zaidy et al takes information that is potentially useful for investigation, and then create a visual representation of a suspect's criminal network. These papers are essentially similar to the CTS Social Network Analysis system that creates a cluster graph to visually present a suspects social network connection to draw a conclusion about the suspect's relation to organized criminal networks. The work [11] by Floris Bex et al uses the concept of automated forming of a narrative about a crime based on gathered facts. This is similar to the storytelling feature of the CTS Social Network Analysis which bases it narrative on information gathered from a potential suspects Facebook profile.

The fifth feature contains the concept of using tracking systems. In this research, [12] describes a tracking system as an Android mobile application to detect or prevent child kidnappings. This system automatically detects the GPS coordinates of an Android phone associated with a child. It is similar to the CTS mobile application which has an automated geographic location update function that displays the phones current location in term of longitude and latitude.

CHAPTER 3

PROPOSED SYSTEM

The proposed solution is a Mobile application for criminal investigation tracking system that tracks the investigation status of criminal cases with logs and also predicts primary suspects, as shown in Figure 3.1. The system will help the investigators to speed up the investigation process and track status of multiple cases at a time. The system keeps logs of a case which includes case summary, people involved, disputes, past criminal history of those involved, Items recovered on scene and other details. All the information added by the investigator will be uploaded to the online database to be accessed everywhere, the investigator will have a unique username and password to upload/access all the information required.

Fig.3.1 Mobile Interface

In addition to the CTS mobile application, we also have the Facebook Data Mining System and the HeatMap System. Firstly, the Facebook Data Mining System is used to extract a suspect name from the CTS database and inspect through Facebook website for similar names that could potentially be the suspect's account. This system will then extract data such as suspect profile photo and their 2 degrees of separation (friends of friends) to apprehend any criminal communities that may exist within their network of friends. The system is able to produce a visual representation in a form of a cluster graph of their friends' network to uncover any parallel betweeness and community detection (as shown in Figure 3.2). The initial plan is that the system will only capable of probing through Facebook but in the future we would like to have a broader perspective by combining data from a variety of Social Media such Instagram, Twitter or YouTube and extract valuable information that could facilitate the investigation process. The proposed plan is that we develop a software agent that gathers relevant information from these Social Media platforms. This existing system acts as a proof of concept and once proven to produce valuable results, we will continue developing it by adding the other platforms. Moreover, the systems conceptual design is modular and thus, is capable of integrating several other social media platforms.

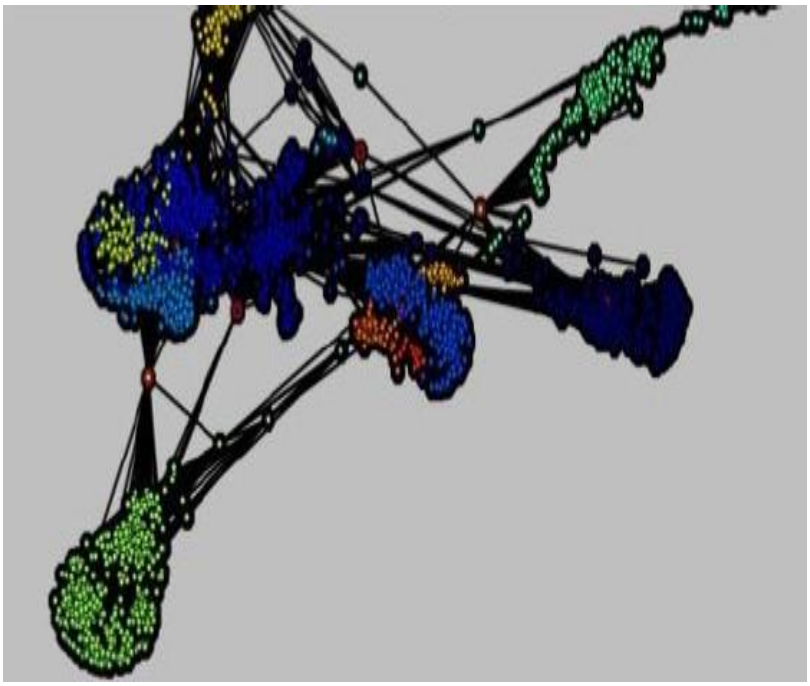


Fig. 3.2 Community Detection

Secondly, the HeatMap System is used to identify the occurrence of specific crime types according to location details such as longitude and latitude values. The system is able to identify crime “hotspots” as they occur in a specific proximity of area in a map, as shown in Figure 3.3. With this system, law enforcement is able to allocate resources better when police officers are sent out for patrolling in specific areas.

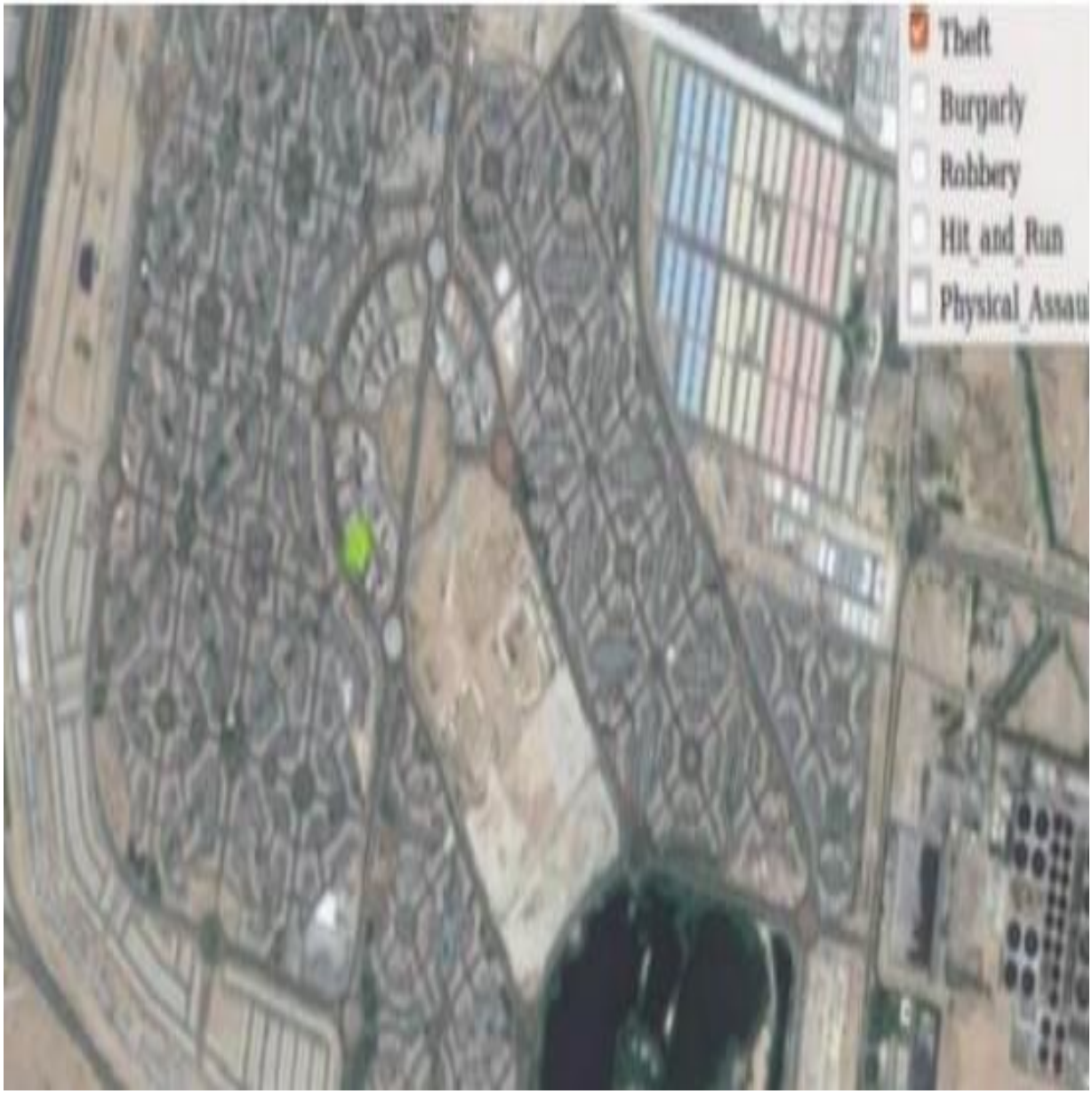


Fig.3.3 Heat Map Crime “Hotspot”

The basic objective of these systems are to extend the investigation process beyond the scope of the police database and push it further to the Web and publicly available data. Figure 3.4 below shows the basic infrastructure of the CTS project as a whole.

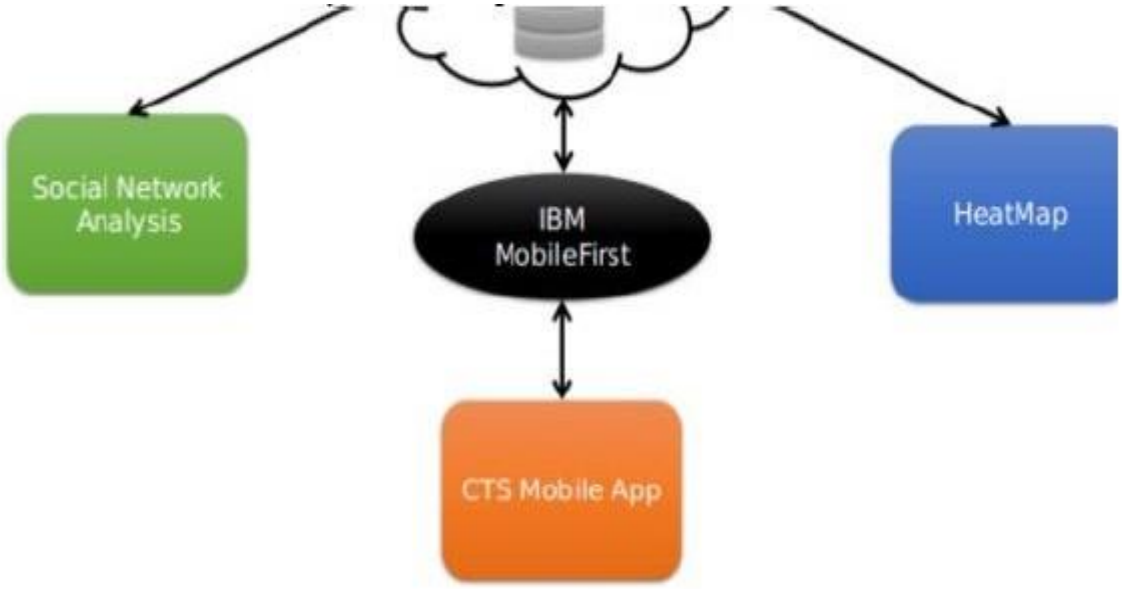


Fig. 3.4 System Architecture

CHAPTER 4

TECHNOLOGY USED

4.1 HEAT MAPS

Heat map is a data visualization technique that shows magnitude of a phenomenon as color in two dimensions. It is founded by Weinstein (2008) It is a graphical representation of data (data visualization) and is implemented using the libraries such as Matplotlib and Seaborn in python. The variation in color may be by hue or intensity, giving obvious visual cues to the reader about how the phenomenon is clustered or varies over space. There are two fundamentally different categories of heat maps: the cluster heat map and the spatial heat map. In a cluster heat map, magnitudes are laid out into a matrix of fixed cell size whose rows and columns are discrete phenomena and categories, and the sorting of rows and columns is intentional and somewhat arbitrary, with the goal of suggesting clusters or portraying them as discovered via statistical analysis. The position of a magnitude in a spatial heat map is forced by the location of the magnitude in that space, and there is no notion of cells; the phenomenon is considered to vary continuously.

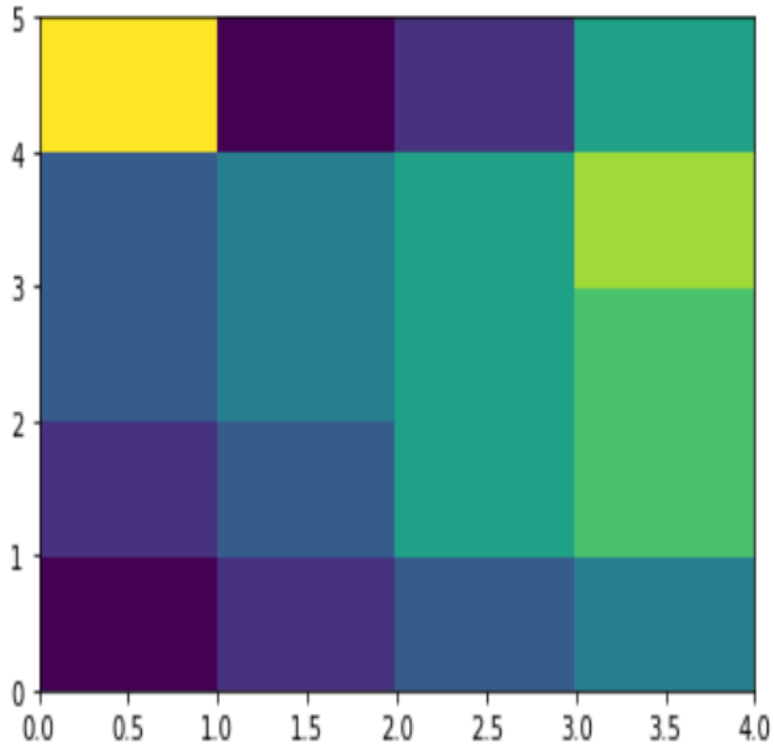


Fig 4.1 Heat Map Graph

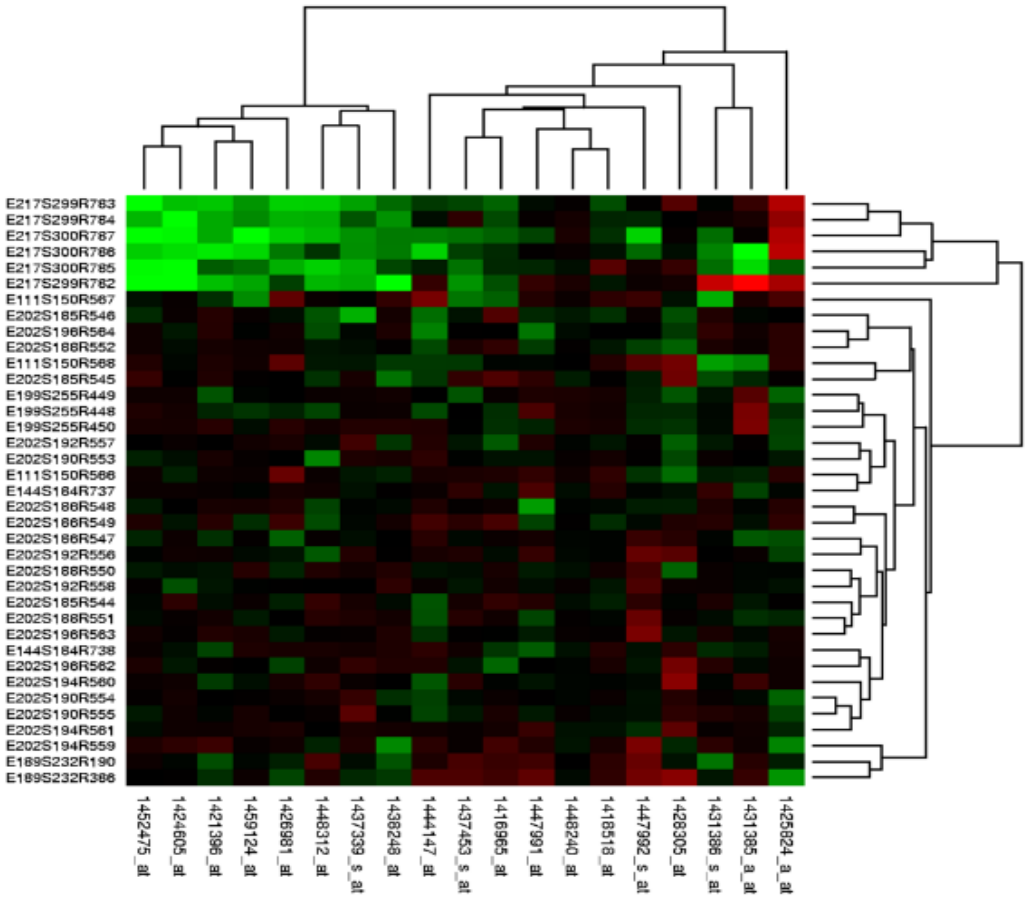


Fig 4.2 Heat map upon data

4.2 Color schemes

Many different color schemes can be used to illustrate the heat map, with perceptual advantages and disadvantages for each. Rainbow color maps are often used, as humans can perceive more shades of color than they can of gray, and this would purportedly increase the amount of detail perceivable in the image. However, this is discouraged by many in the scientific community, for the following reasons:

- The colors lack the natural perceptual ordering found in grayscale or blackbody spectrum color maps.
- Common colormaps (like the "jet" colormap used as the default in many visualization software packages) have uncontrolled changes in luminance that prevent meaningful conversion to grayscale for display or printing. This also distracts from the actual data,

arbitrarily making yellow and cyan regions appear more prominent than the regions of the data that are actually most important.

- The changes between colors also lead to perception of gradients that aren't actually present, making actual gradients less prominent, meaning that rainbow colormaps can actually *obscure* detail in many cases rather than enhancing it.
- Not all colors in a rainbow color map can be differentiated by color-vision deficient readers, which makes figures using these color schemes inaccessible to a significant proportion of the population

4.3 Software Implementation

- MAPTIVE

  Heat can be also generated by software called **Maptive.** Geographic heat maps can help you identify trends in data that would otherwise be hard to see. You can quickly see areas that might already be saturated and other areas where there is still a market opportunity.

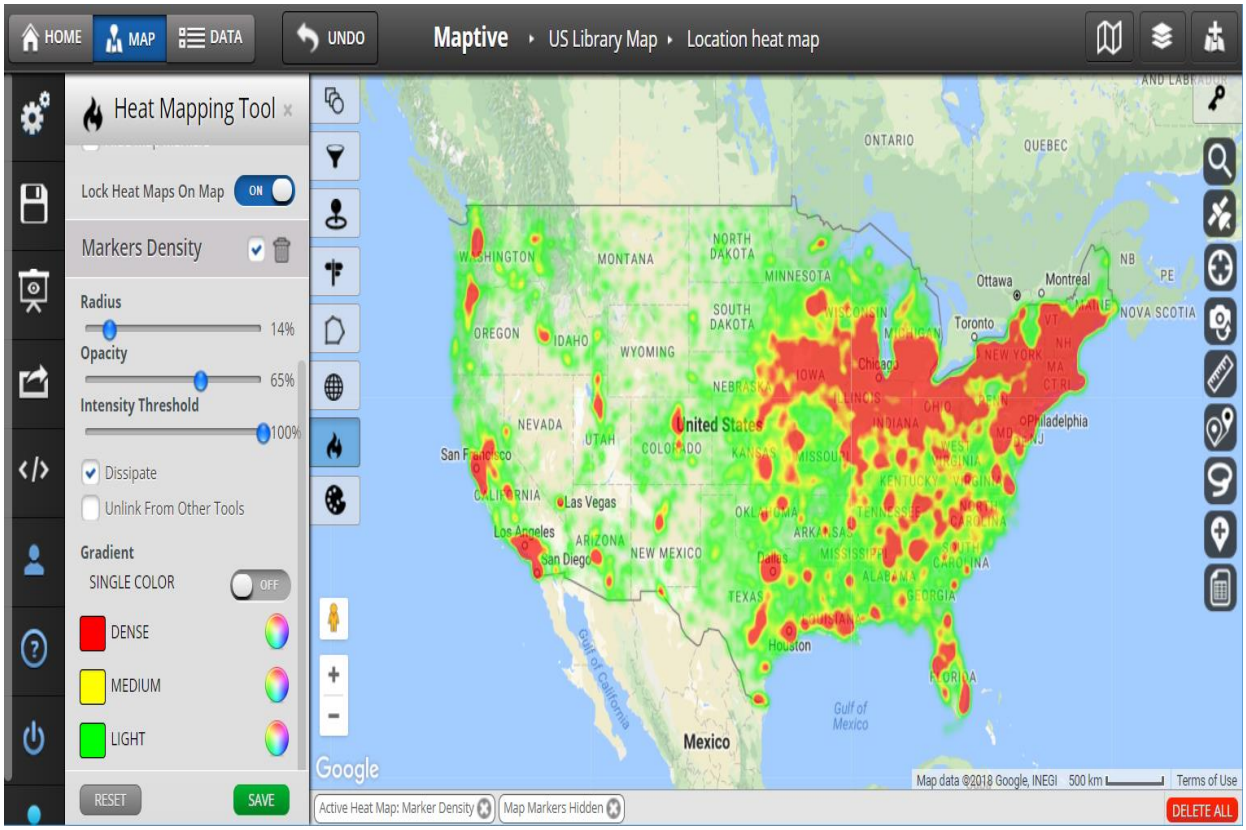


Fig 4.3 Maptive Heat Map Generate

- R, a free software environment for statistical computing and graphics, contains several functions to trace heat maps,[13][14] including interactive cluster heat maps (via the heatmaply R package).
- GNUPLOT, a universal and free command-line plotting program, can trace 2D and 3D heat maps.
- GOOGLE FUSION TABLES can generate a heat map from a Google Sheets spreadsheet limited to 1000 points of geographic data.
- Dave Green's 'CUBEHELIX' colour scheme provides resources for a colour scheme that prints as a monotonically increasing greyscale on black and white postscript devices.
- OPENLAYER3 can render a heat map layer of a selected property of all geographic features in a vector layer.[
- D3.js, AnyChart and Highcharts are JavaScript libraries for data visualization that provide the ability to create interactive heat map charts, from basic to highly customized, as part of their solutions.
- QLIK Sense allows displaying comparative data as color patterns in a heat map which is included in its visualization bundle.
- MATLAB provides the capability of the heat map visualization with a wide variety of configuration options.

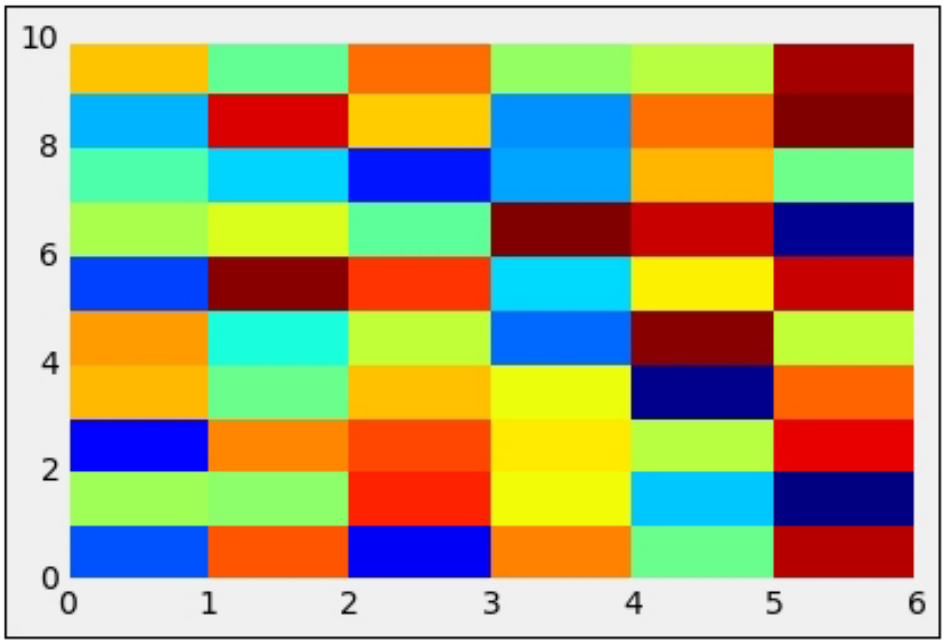
4.4 SAMPLE CODE IMPLEMENTATION

A basic heatmap between two dimensions. We'll create a 10 x 6 matrix of random values and visualize it as a heatmap:

```
>>> # Generate Data
>>> data = np.random.rand(10,6)
>>> rows = list('ZYXWVUTSRQ')  #Ylabel
>>> columns = list('ABCDEF')  #Xlabel

>>> #Basic Heat Map plot
>>> plt.pcolor(data)
>>> plt.show()
```

Output:



CHAPTER 5
ADVANTAGES

- For many years now, detectives, investigators and police officers have always relied on simple pen and paper to record their crime reports during crime scene investigations. So This approach of solving the crime cases will be simple and time effective.

- As the conventional method of reporting will always cause some sort of delay as detectives will have to go back to the office and rewrite a formal report into the computer. This delay can lead to inaccuracies in the detective's report because what might be written in their pad paper may not precisely reflect what was on the scene. This is because an individual's memory may be subject to change. The longer the duration of holding the memory, the more substantial the memory of an incident can change. These inaccuracies may ultimately cause the innocent to be convicted or the guilty to roam free. Designing and developing a mobile application that can enable detectives and investigators to submit detailed and precise crime reports in real time.

- The app is capable of taking the actual date and time of the crime because its clocks and calendars are synchronized in real time. It is also capable of recording the location name as well as the exact coordinates of the crime scene because the app has a geo-location capture feature. The application records other basic information such victim's involved, potential suspects and evidence found.

CHAPTER 6
METHODOLOGY

The Crime Tracking System mobile application is created primarily using four programming languages which are Java, XML, JavaScript and SQL. Java was used entirely for the Android Studio IDE to develop the Android functionality and all its features. In this project's context, the Android java development is considered to be in the client side. XML was used to create the Android layout of each page of the app. Layout properties such as background color and layout theme is programmed here. In this project's context, the Android XML development is considered to be in the client side. JavaScript was used to program the server side which consisted mainly of the external functions that are considered as heavy on the process such as the Serial Crime Detector and Search algorithm. In this project's context, the JavaScript development is considered to be in the server side. SQL was used to create necessary tables needed in the application. Tables such as investigators table and crimes table are generated using SQL language. In this project's context, the SQL development is considered to be in the server side. Having requirements is a main part of developing a software; however, these requirements aren't always clear from the beginning. This is why this Prototyping Methodology is followed; which create a prototype that is basically an early version of the final system that can be developed. Hence, building a testing prototype and then getting it validated through several iterations until the acceptable result is satisfied. This is a trial and error based methodology, which allows us to work on any flaws and build upon it until necessary

6.1. Data Collection

Enormous amount of crime data is collected at the end of year at police records. This data is made available by National Crime Bureau of Records. This data is in the form of number of cases recorded all over the nation throughout the year. The data is in raw form and also contains some wrong as well as missing values. Hence preprocessing of data becomes very necessary in order to bring the data in proper and clean form. Pre-processing of data includes data cleansing and PreProcessing.

6.2 Data Classification.

We classify the data set into various groups based on certain characteristics of the data object here we group crimes according to states & cities. Classification of the crime is done on the basis of different types of crime .Kmeans algorithm can be used to group data with similar characteristics.

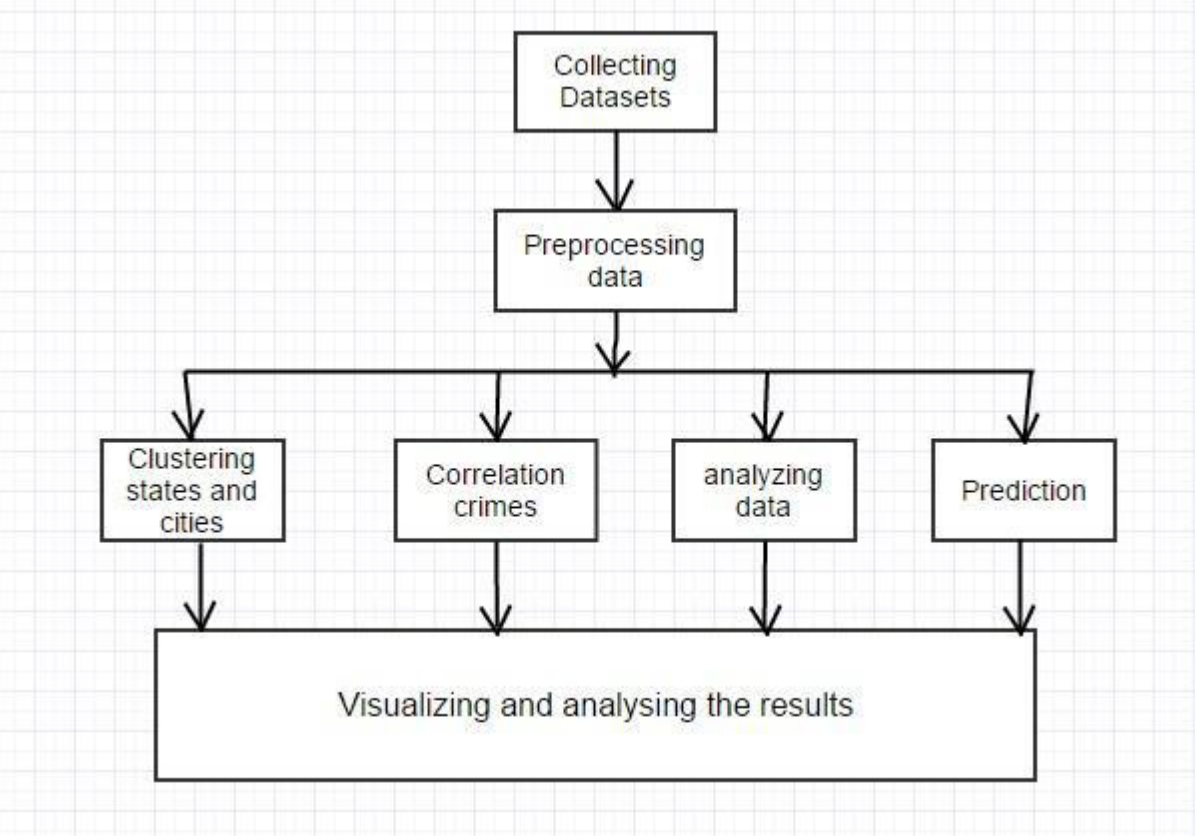


Fig:6.1 Methodology for crime pattern analysis

6.3 K-Means Algorithm.

K-means algorithm mainly used to partition the clusters based on their means. Initially number of objects are grouped and specified as „k" clusters. The mean value is calculated as the mean distance between the objects.

The relocation iterative technique which is used to improve the partitions by moving objects from one group to other. Then number of iterations is done until the convergence occurs. K-means algorithm steps are given as

Input: Number of clusters.

Step1: Arbitrarily choose k objects from a dataset D of N objects as the initial cluster centers.

Step 2: reassign each object which distributed to a cluster based on a cluster center which it is the most similar or
the nearer.

Step 3: Update the cluster means, i.e. calculate the mean value of the object for each cluster.

Output: A set of k clusters. K-means algorithm is a base for all other clustering algorithms to find the mean values.

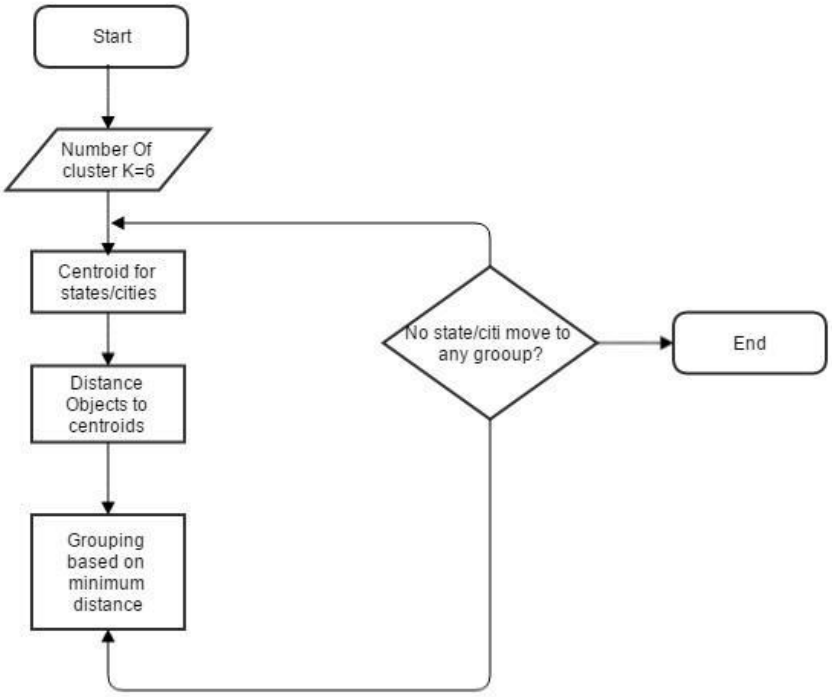


Fig:6.2. K-Mean Algorithm

6.4 Correlating Crime

Many crimes are related to other crime or criminal. Finding this correlation can be of great help in finding missing clues. Correlations can be used to help make predictions. If two variables have been known in the past to correlate, then we can assume they will continue to correlate in the future. We can use the value of one variable that is known now to predict the value that the other variable will take on in the future. Pearson's correlation coefficient between two variables is defined as the covariance of the two variables divided by the product of their standard deviations. The form of the definition involves a "product moment", that is, the mean (the first moment about the origin) of the product of the mean-adjusted random variables; hence the modifier product-moment in the name.

$\boldsymbol{\rho X, Y = CO\vartheta(X, Y)/\sigma X\sigma Y}$

where: co is covariance and σX is the standard deviation of X. Pearson product-moment correlation coefficient is a measure of the linear correlation or dependence between two variables X and Y, giving a value between +1and -1 , where 1 is called total positive correlation, 0 is no correlation, and -1 is called total negative correlation

.Figure 6.3 explains how correlation between X and Y depending on value of r.

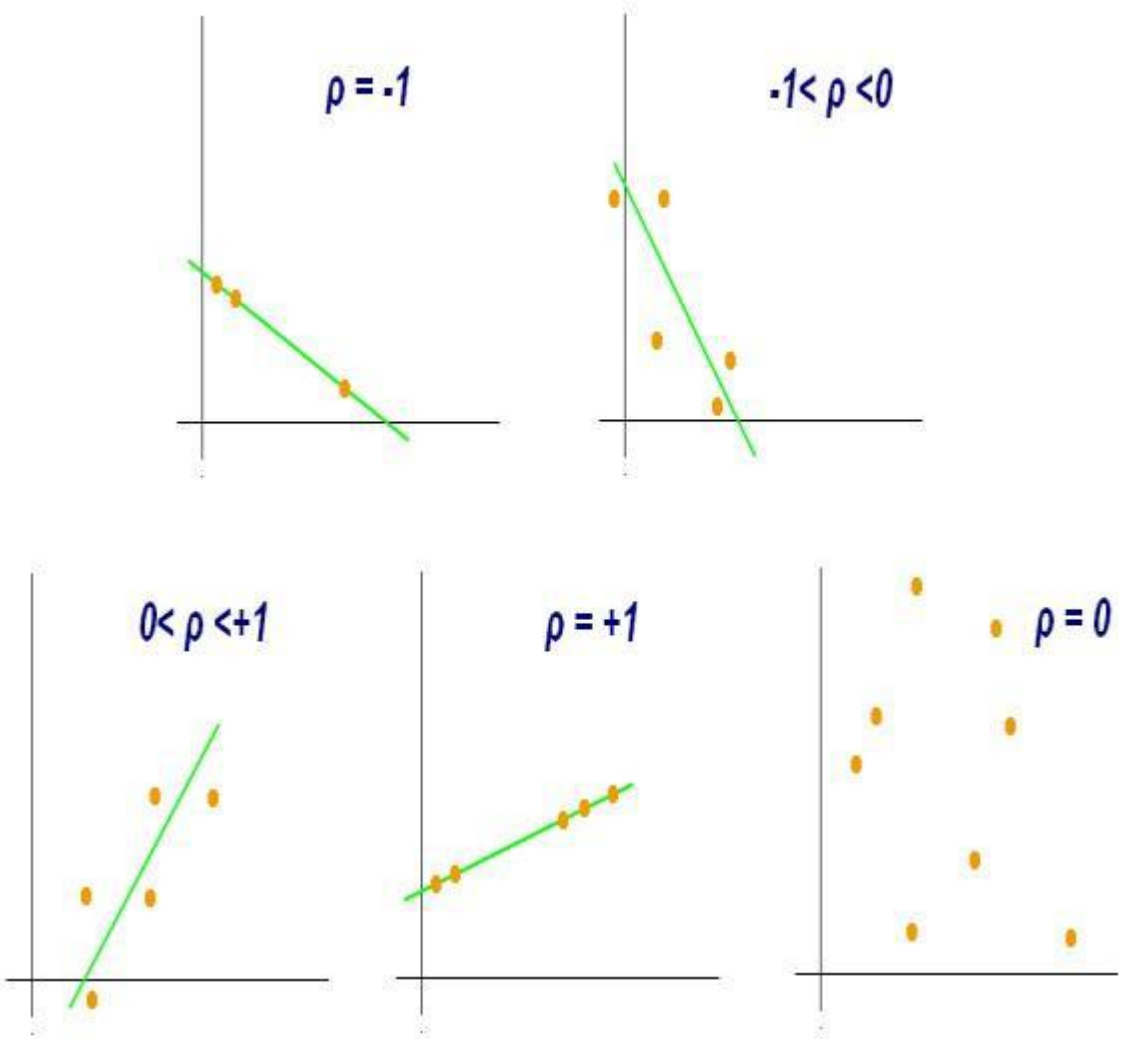


Fig:6.3. Correlation example of person

6.4 Predicting Crime

P5ediction of crime is a great aid to the administration in order to curb the crime incidences. Prediction is stating probability of an event in future period time. In this case crime against women can be predicted using linear regression. Prediction about various types of crimes and most probable places of occurrences of crime will be

predicted linear regression is an approach for modelling the relationship between a scalar dependent variable y and one or more explanatory variables (or independent variable) denoted X. The case of one explanatory variable is called simple linear regression. In simple linear regression, we predict value of one variable from the value of a second variable. The variable we are predicting is called the criterion variable and is referred to as Y. The variable we are basing our predictions on is called the predictor variable and is referred to as X. When there is only one predictor variable, the prediction method is called simple regression. In simple linear regression, the predictions of Y when plotted as a function of X form a straight line. Line a regression consists of finding the best-fitting straight line through the points. The bestfitting line is called a regression line. The most commonly used criterion for the best-fitting line is the line that minimizes the sum of the squared errors of prediction.

The formula for a regression line is

Y = aX + b where, Y is the predicted score, b is the slope of the line, and A is the Y intercept.

The slope (b) can be calculated as follows:

$$b = r\frac{Sx}{Sy}$$

And the intercept (A) can be calculated as

$A = MY - bMX$.

Where, MX is the mean of, My is the mean of, Sx is the standard deviation of X, Sy is the standard deviation of, and is the correlation between X and Y.

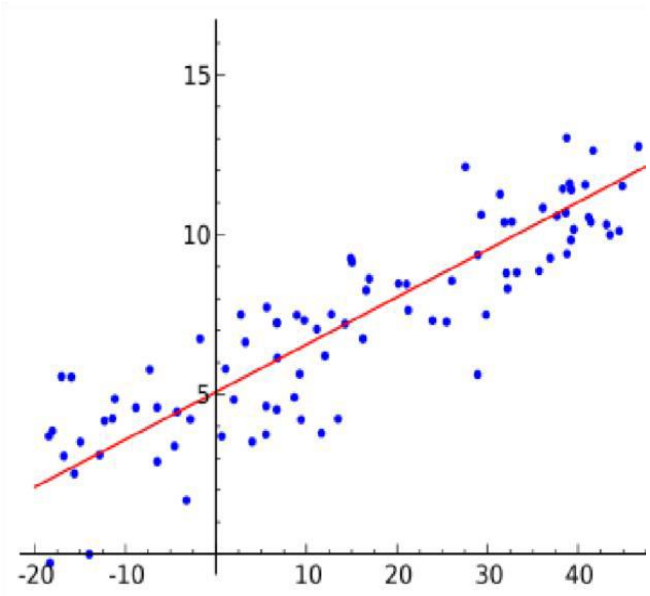


Fig6.4: Linear regression

4. Result

Result of this research will be to analyse, correlate and predict the crimes from huge data set available. Results will be in the form of correlation between various crime and location of crime i.e. state/city. Crime can also be correlated on the basis of age group, location of crime & type of crime. Prediction of the crime will be displayed using various diagrams pie charts, heat maps, spikes and graphs.

CHAPTER 7

CONCLUSION

The CTS mobile application is only designed for Blue Collar crimes. Crime detail entries were made to fit these type of crimes. White Collar crimes naturally needed more parameters for analysis. Thus, the focus was narrowed to solving Blue Collar crimes only. The Social Network Analysis System of CTS is limited to analysing public Facebook accounts only. Gathering information from private Facebook accounts could be limited. Thus, the reach of the cluster graph provided by the Social Network Analysis of CTS could be massively narrowed.

The Heat Map System is limited to analyse longitude and latitude only. Altitude was excluded because its significance in geographic analysis in terms of crime occurrence was relatively low. The current CTS mobile application run solely on Android mobile phones. Thus, future work could involve expanding to other platforms (ie, iOS) and devices (ie, Tablets). The future improvement plan for the Social Network Analysis System is to expand its analysis capabilities from text to images and/or videos. Currently, the system operates on text analysis based on the textual data gathered from Facebook. Image and video analysis will be a big leap forward for this project.

This report outlines how data science could be used to aid criminal investigation process. With technology such as the Social Network Analysis system, criminal or terrorist organizations could be crippled by targeting the leaders or prominent members.

Therefore, improving crime-fighting efforts. Also, a Heat Map system has a high potential for subduing concentration of crime occurrence in particular crime infested areas. Furthermore, with a Serial Crime Detection system, the crime investigation process could now be automated to become more efficient and effective. Ultimately, this report aims to create a safer modern society by equipping law enforcement agencies such as the Police with the technology and systems that could improve their overall policing performance.

CHAPTER 8

FUTURE SCOPE

- The Idea of data science for Crime Investigation is been implemented in many countries such as US, Canada, UK, Colombo etc.

- Data Science for Crime Investigation can be extended for Predicting Future Crime Spots, Pretrial Release and Parole, who all likely to commit a crime etc...

- In India, many metro cities like Bangalore, Hyderabad, Mumbai, Pune etc… are trying to implement the same for their easiness as well for fast Crime Solving.

- Either the idea has been still under testing or is implemented by many states with their Cyber Cell and Developer teams.

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