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A Framework for Visual Representation of Crime Information

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Abstract

Objectives: This paper proposes a framework that transforms the structural crime related data into effective visual reports to strengthen the pro-active activities of law enforcement agencies. **Methods/Statistical Analysis:** The information visualization depends on the input data. The visualization engine, as proposed in this research work, processes all the data to produce crime information instrumental for the law-enforcing agencies and present it in three different formats: 1) Statistically summarized reports in graphical formats, 2) Heat-maps of crimes and 3) Clusters of crime patterns based on geo-locations. **Findings:** The visual crime analysis information may also help the policy-makers to gain depth knowledge about crime types, their timings at certain regions. This insight knowledge may improve the performance of law enforcement agencies in reducing crime rate and utilizing resources efficiently. Especially, it performs comprehensive processing of crime information to detecting heat-maps of crimes, clustering crime patterns and presenting it by means of information visualization techniques. **Application/Improvements:** Law enforcement agencies can use the system to have comprehensive, consolidated and chronologically view of all types of reported criminal activities.

Keywords: Crime Information, Data Visualization, Heat Maps, Information Visualization

1. Introduction

The growing need of technological solutions and usage of web map services have increased data analysis much popular[1]. Several application domains, such as water management, crime mapping, traffic analysis and disease analysis, use Geographic Information System (GIS) applications. Modern GIS systems embedded with web-based map services are essential to wide range of users for data exploration[1].

Crime analysis is among the major activities of intelligence and law enforcement agencies all over the world[2,14]. To prevent crimes and optimum usage of resources is the prime concerned of the agencies[2]. This enquires the need of analytical systems that can provide knowledge to the law enforcing agencies. The extracted knowledge from the available data regarding crime can assist in controlling the crime and finding out the sensitive regions in certain locality where vigilance is required. In order to mitigate crime, the criminal activities and related data must be stored and visually represented in such a way so that the concerned authorities may take actions pro-actively.

Analyzing huge crime data and finding accurate results with efficient methods is an open and challenging task. The diversity in the geo-location and complex series of crime patterns has made it more challenging and difficult. Knowledge discovery helps to cope with such challenges by extracting desired analytical results from large databases. The primary need is the crime data on which knowledge discovery algorithms can work to provide suitable and relevant information. Eventually, the analytical reports generated by knowledge discovery system will help authorities to take decisive or preventive approach for any unwanted situation.

This research aims to provide a framework for analysis of crime data. It proposes a framework that records all the criminal activities and crime reports on geographical locations. Mapping crimes on maps according to the

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geographical locations of their occurrence is called crime mapping. Crime mapping is a comprehensive and effective approach to illustrate the criminal offenses[5]. This research takes it to the next level where the geographical locations and details of crime are processed to produce knowledge for law-enforcement agencies.

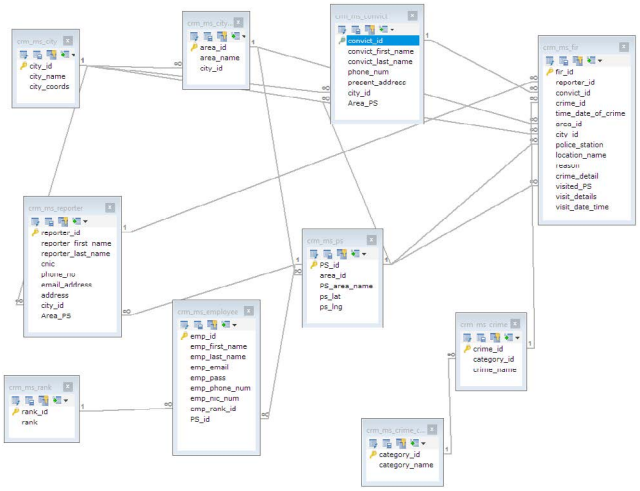

Figure 1. Database Schema.

Crime maps are a common practice and these frequently show crime incidents as a point distribution on a map. Each incident indicates where a crime occurred and very often these locations are the victims' home addresses. The proposed framework is a web-based system, which aims at bridging the structured crime related data with information visualization techniques. In particular, the proposed framework allows storing crime related data into structural format i.e., database. Later, the data has been processed to produce visual results in order to analyze crimes, crime patterns. Besides, the framework detects the crime heat-maps and also clusters the similar crime patterns using information visualization techniques. By exploring the current status of private geo-information disclosure, a basis has been created to achieve the second aim of this research, which is to offer cartographic display guidelines when crime data are presented on public maps or disseminated among stakeholders. The research outputs shed light on the disclosure risks and current practices and also assist potential "maskers" regarding the practical steps that are required to ensure that data are accurately visualized.

The rest of the paper is organized as follows. Section 2 reports the related existing literature for crime analysis and visual representation of crime analysis. Section 3 presents visualization techniques that can be used for crime analysis. The proposed framework has been comprehensively described in section 4. The research assumptions and constraints are reported in section 5. The detailed discussion of the outcomes of the proposed framework is reported in section 6 and finally section 6 draws conclusions.

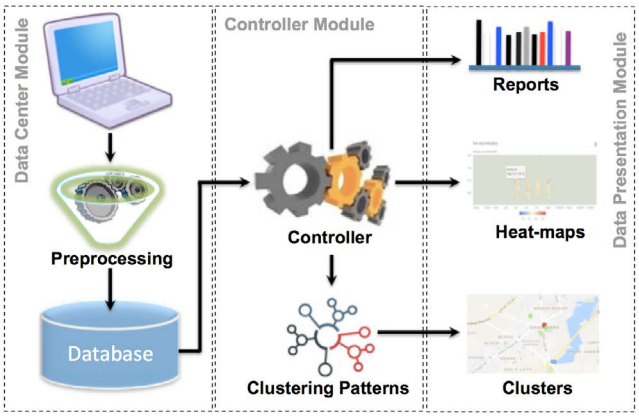

Figure 2. Proposed Framework.

2. Literature

The information representation, assisting crime analysis and decision-making, has become an important activity for law enforcement agencies. There is a need of effective implementation of the systems that can reveal the rate and type of crime based on geographical locations in an interactive and concise manner. The existing literature reports different aspects and parameters for preventing crimes. For example, the study[12] presented a project to prevent the crime through efficient environmental design. The study[13] reviewed 14 articles related to crime places and suggested mutually supportive three perspectives in understanding the crime: 1) Rational choice, 2) Routine activity and 3) Crime pattern.

Crime maps are a common practice and they frequently show crime incidents as a point distribution on a map. Each incident indicates where a crime occurred and very often these locations are the victims' home addresses. Having such geolocations of crime occurrences, the task of analyzing crime becomes more demanding as more accuracy and precision is expected in the outcome. The further relevant research work accomplished in crime analysis is given below.

- Hotspot temporal pattern detection method is used to identify high, medium and low crime areas[7]. The work provides information about what is the rea-

son behind the level of different crime rates in two different locations.

- Much research work has been done on crime analysis, which highlights the importance of this area. Crime detection and criminal identification in India using data mining techniques is proposed[10]. The approach to detect criminals and crimes has been addressed using different data mining techniques.
- Finding intensity level of crime from minimum to high scale and presenting that information on geo-map in shape of clusters is reported[8]. The study uses five spatio-temporal pattern analysis techniques.
- Aoristic signatures and the Spatio-Temporal analysis of high volume crime patterns[11] is used to identify the patterns of crimes based on time-stamp in order to predict the times of crimes.

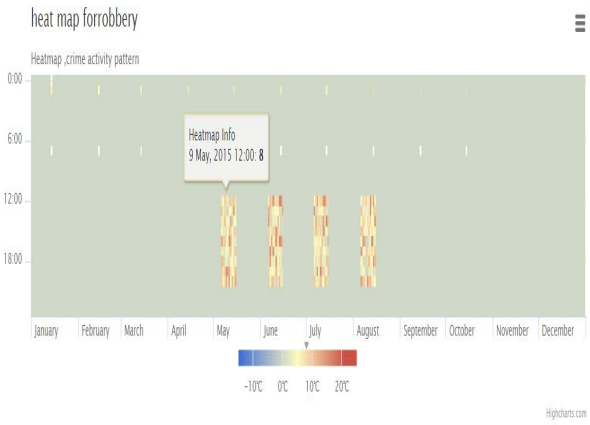

Figure 3. Heat map for robbery.

3. Visualization Techniques

Visualization is the backbone of the crime analysis system. The visual techniques offer insight and depth knowledge for the decision-making strategies. Therefore, the visual representation of facts and figure about crime is the major focus of this research work. The visualization is considered an effective approach when it can improve or increase the knowledge of the end user[4,15,16].

The different visualization techniques are described as follows.

***Data Visualization*:** Data visualization is the representation of raw or unprocessed data. There are several data visualization methods available. This research work uses tables, line charts, pie charts, bar charts and area charts. Data represented in this format can be viewed statically, since data is organized presenting it to end-user.

Information Visualization: Information visualization is the representation of processed form of data. Information visualization usually consists of the ways, where interactivity with the information, can be ensured. The interaction allows transforming the look & feel of the overall representation of the information. This research work uses data maps and clustering techniques for representation of information.

Concept Visualization: The representation of qualitative concepts, ideas, plans analyses is called concept visualization. This technique comprises of mind maps, layer charts, cause-effect chain and others.

Strategy Visualization: The systematic use of complementary visual representations to improve the analysis, development, formulation, communication, and implementation of strategies in organizations is called Strategy Visualization[17]. Strategy maps, failure tree and Ishikawa diagram are some the frequently used strategy visualization methods[17,18].

Metaphor Visualization: The metaphor visualization technique positions the information using graphical components that metaphorically structures the information. Graphic metaphors provide a visual means to assure mutual understanding by making basic assumptions explicit[17].

Compound Visualization: The usage of several graphical methods of information representation in one single schema is called the compound visualization. Examples of compound visualization are cartoons, rich pictures, knowledge map and learning map.

Visualization Technique for Crime Analysis

The cornerstone of the crime analysis system is its information visualization capabilities. The information presentation is a fundamental feature for decision support and analysis. The use of both, data and information visualization techniques make the better representation of facts. Thus, the information visualization plays essential role in gaining in-depth knowledge about facts and

figures. The aim of this research is to provide a more readable, comprehensible and customizable crime patterns. Especially, line charts, bar charts, pie charts and area charts have been considered to illustrate the information in this research. Besides, data maps with clustering are applied for in-depth knowledge to better understand the crime patterns.

4. The Proposed Framework

The architecture of the proposed framework is presented in Figure 2. The major components of the framework are 1) Data Center Module, 2) Controller Module and 3) Data Presentation Module.
The details of each component are reported in the following.

1) Data Center Module
This module is responsible for the creation of the database. The module allows law enforcement officials to store the First Information Reports (FIRs) (i.e., crime reports). The FIR contains information about the crime containing the location and area where the crime has taken place, data and time of occurrence of crime, date and time of crime report and the type of crime. Though the FIRs are in the unstructured data format (*Data format that does not have certain schema e.g., textual data*), this module preprocesses the data and transforms into the structural data format. For instance, crime related data such as crime type, timestamp, date, longitudes and latitudes that represent certain location of crimes are transformed into structural format. Finally, it stores the processed data into relational database. The schema of the database is illustrated in Figure 1 .

2) Controller Module
This module is the heart of the proposed framework, which performs the following tasks: a) Extracting structured data from database, b) Transforming structured data into statistically visual graphs, c) Detecting hotspots (i.e., heat-maps) of crimes and d) Injecting clustering approach to identify the clusters of crime patterns.

The detection of heat-maps is carried out based on timestamp of the stored crime related data in the database. The data is fetched from database and is processed to produce heat-maps presenting the intensity of the crime within certain region. The region selection, timestamp and crime types are the provisions of the prototype application, which has been developed implementing the proposed framework.

Furthermore, the longitude and latitude for geo-locations are unavailable in the structural database as shown in Figure 1. Therefore, clustering crime patterns over Google-Maps needs to be done using additional processing to achieve the longitude and latitude of the regions reporting crimes in the database. In particular, reported addresses of the crimes are fetched from database and are processed in order to obtain their longitude and latitude using Google-Maps API (Application Programming Interface). The clustering patterns component group together the similar crime types with their intensities and convert the processed data into JSON (i.e. JavaScript Object Notation) object for visualizing the crime patterns at geo-locations. Thus, three different formats: i) statistically summarized information in graphs, ii) heat-maps of the crimes and iii) clusters of crime patterns located at certain regions are sent to Data Presentation Module.

3) Data Presentation Module
Data presentation module is the front-end for end-user in order to visualize the crime related information in interactive and effective manner. Statistically summarized information is presented in the form of line chart, pie chart, bar chart (see Figure 6-12). The heat-maps for the crimes at certain timestamp are reported in hotspots (see Figure 3 and Figure 4). Similarly, clusters at certain location of crime patterns are visually presented (see Figure 5).

System Security Mechanism
The proposed framework ensures the security of the data, since crime related data are always key concerns of law enforcement agencies. The system security has been ensured with implementing the state of the art technology of Intranet Security Mechanism. The system offers custom security layers and Intranet Security Mechanism is a closed network.

Further, private Internet Protocols (IPs) of certain Class (Class A, Class B, and Class C) have been allowed to communicate with the Data Center Module. Thus, creating a private Hub of connectives. This mechanism secures the system from World Wide Web.

The three-layer security is described as follows.
Layer 1: In this layer, the system allows only authorized private request and denies all requests for accessing the system from other networks.

Layer 2: This layer deploys firewall on the computer machine where database is stored. Thus denying access of all IPs other than the IPs of authorized system's class.

Layer 3: An additional custom design firewall has been deployed on the data center machine, which compares all local IPs, private IPs and physical addresses of all incoming requests of users. In case any mismatch occurs, the request is turned down and physical address of the user is blacklisted. Thus this layer ensures extra-security measures to keep the data secure.

5. Research Assumptions

To acquire the authentic data about registered criminal activities, law enforcement agencies were contacted. Due to security and confidentiality of the data, officials refused to share such data in any form (print or electronic). However, they cooperated informally to build mechanism of synthetic data generation. The data has been manually entered in the system based on the statistics informally shared by law enforcement officials. Therefore, the reports presented in this research are based on hypothetical data but illustrates the figures in exactly the same way it would represent when provided with the actual data about crime. Since the main objective of this paper is presenting an idea about how to represent crime data in the form of live statistics and graphical components. Thus, the presence of actual data is not the main requirement for this paper. The dummy data serves well to show overall working and concept of this paper.

6. Discussion

6.1 Crime Analysis

The attempts made in crime analysis by individuals are limited to few methods and approaches. For instance, study[1] rendered there results in three different ways and studies[2,3] have used spatio-temporal method to render the maps with hotspots on it which indicates the intensity of crime in form of cluster. Line chart and cluster data of crimes occurred in Sydney are reported[9].

This research comprises most of the rendering methods that are proposed by papers[6-9] with much effective graph formats and unit based clustering technique. In the cluster technique, each unit of cluster shows intensity count of crimes on the map along with heat count of crimes categorically. For the pattern analysis of crime, a 2-dimension model is condensed to analyze patterns of crimes by day-hour. The research contribution is discussed in the following.

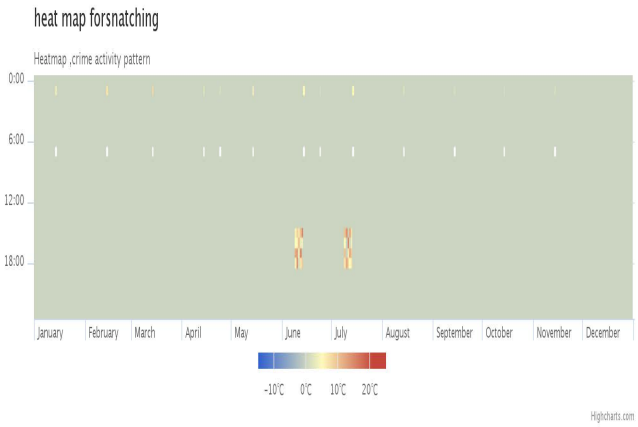

Figure 4. Heat map for snatching.

6.2 Live Heat Map

Crime can take place anywhere at any time. Changing rate of crime affects the crime analysis eventually resulting in wrong decision-making. Therefore, live heat maps show the exclusive and live details about the current situation of criminal activities. Figure 3 illustrates the heat map for robbery. Whenever any robbery takes place, provided that the robbery has been registered timely.

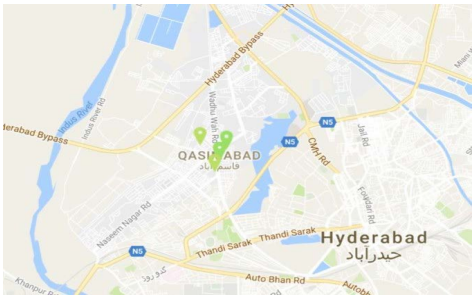

Figure 5. Live crime location clustering.

The heat map shows as a colored spot according to frequency of the crime at certain time. Similarly, the colored spot is visible on the heat map for snatching as indicated in Figure 4. The colored spots represent the crime being registered as well as count of the crime. The higher number of crimes at certain time, the darker the color spot is represented. Thus, the heat maps serves effectively to cater the crime rates and ensure security timely. Live heat maps for different registered rates also provide the performance measures of the security and law enforcement agencies.

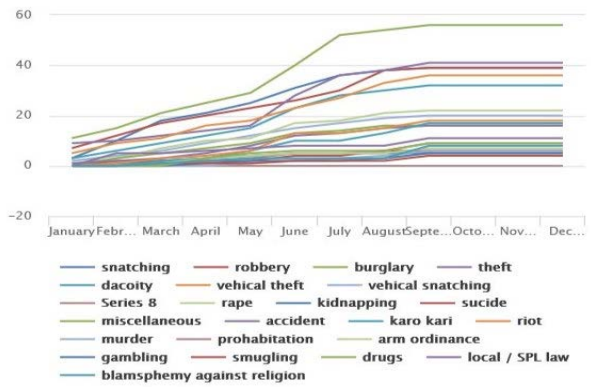

Figure 6. Consolidated categorical yearly report of crime.

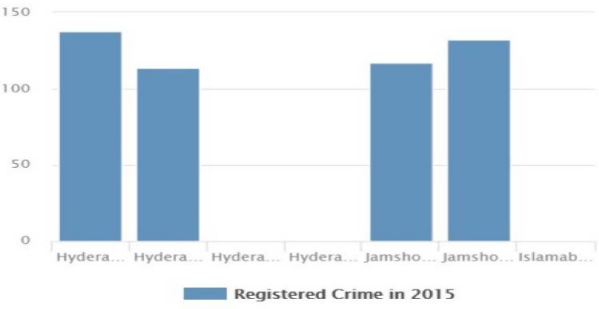

Figure 7. Bar chart illustrating consolidated categorical yearly report of crime.

Time based live heat maps may also help the administration to make better decision and take necessary actions based on identified times at certain regions; for example, deployment of higher number of patrolling officers at certain regions at specific time.

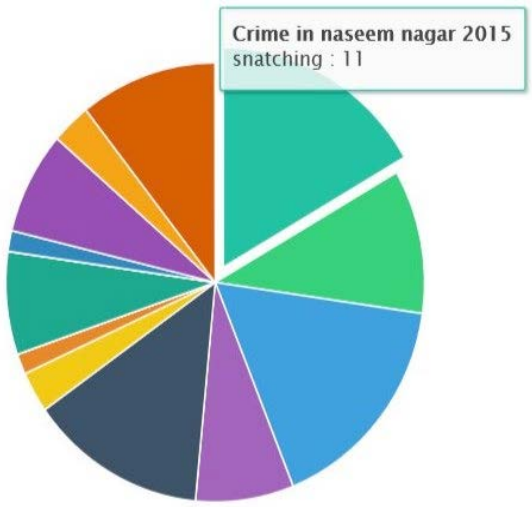

Figure 8. Pie chart showing region wise crime summary.

6.3 Live Geolocations Clustering

Live crime patterns in terms of clusters at certain geo-locations can be viewed, which provides insight knowledge of crimes and the criminals within certain locality. For example, Figure 5 illustrates live geolocation clustering proposed in this research. For instance, in Figure 5 there are four indicators, which represent the locations where certain crime occurred. In case, higher number of crime happens, the clusters are represented with darker colors to distinguish between higher crime rates and lower crime rates.

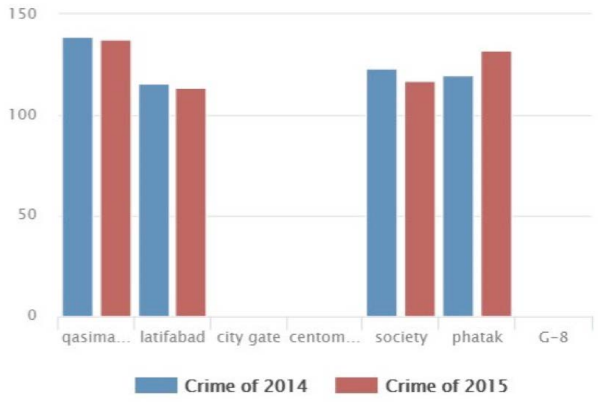

Figure 9. Region wise comparative crime report.

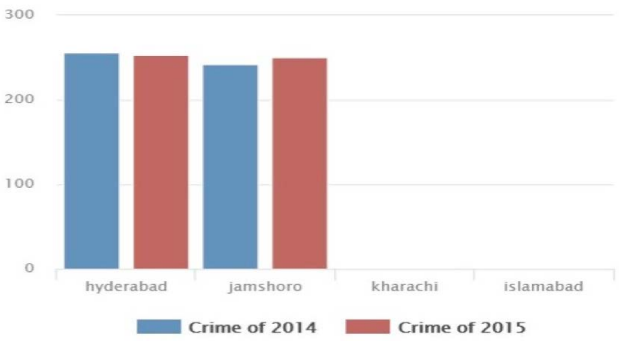

Figure 10. City wise comparative crime report 2014-2015.

Thus, this information helps indicating types of crimes, crime rates at certain locality. It may help to determine the areas of the city where more crimes take place. The decision about crime preventative and mitigation measures may be taken to improve the law and order situation. The clustering of crime according to geolocation indicated on maps makes crime information more readable and understandable. The visualization provides a compact and integrated view of overall crime activities in a region.

6.4 Consolidation of Structured Data about Crime

In addition to live crime reporting and heat maps, the proposed research presents the crime reports in single coherent interface. These consolidated reports provide the summary of all the criminal activities over the year according to the number of their occurrences (frequencies). The crime reports show the annual crime rate of certain region as shown in Figure 6. Similarly, Figure 7 represents annual crime report in bar chart.

6.5 Annual and Regional Crime Summary Reports

Aggregation of annual data provides a generalized view of all crimes. Security officials require a number of reports for all the criminal activities over the year. Consequently, such summary reports help them to get insight knowledge about crimes, crime rates and targeted regions. The summary reports must be designed and should address several dimensions to project facts and figures clearly and effectively.

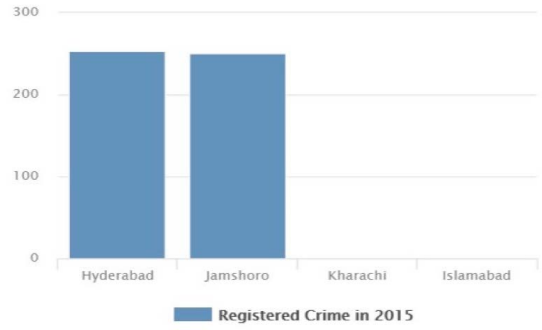

Figure 11. City wise annual crime summary report 2015.

Figure 12. Annual crime summary report of 2015.

Summary reports such as area/region wise crimes, inter-city comparison of crime rate, aggregation monthly of crime etc. are some of the useful aspects from which data can be organized to increase the knowledge of decision makers. Thus, this will result in effective and beneficial decision-making approaches.

The proposed system provides the summary reports covering numerous dimensions, as mentioned. The pie chart in Figure 8 illustrates summary reports obtained in the proposed framework. Likewise, Figure 9 to Figure 12 present the summary reports in bar chart format for region-wise comparative, city-wise comparisons, city-based annual, per anum and monthly comparative reports respectively.

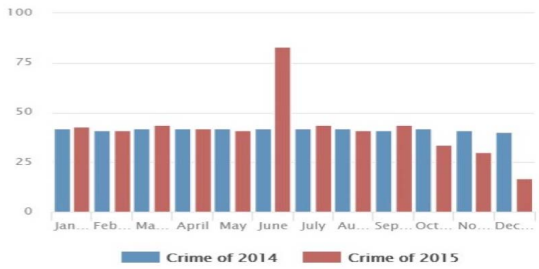

Figure 13. Monthly comparative crime summary report.

7. Conclusions

This digital-age experience criminal activities with diverse criminal patterns and methods. There is a dire need of adopting up-to-date technology by law enforcement agencies to cope with the crime rates and their diverse patterns.

A framework has been proposed for crime analysis to illustrate facts and figures about live heat maps of crimes, crime patterns and their clusters. The representation of crime data has been presented by applying data and information visualization techniques. The goal of this research is to provide an integrated solution to process real time crime related data and provide the effective illustration of criminal information to reduce crime rates and ensure security.

The proposed framework comprising of a rich and simplified environment may assist the law enforcing agencies and policy makers in taking preventive measure against crimes. In particular, live heat maps and clusters representing crime patterns may help security officials in taking pro-active measures in crime rate reduction. The consolidated reports may further help officials to deploy human resources more efficiently as per crime rate.

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