Identifying Crime Hotspots in CAMANAVA by Geographic Information System using Spatio-Temporal Analysis

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Abstract – *Hotspots in crime analysis are regions that require attention from law enforcement, perhaps through increased allocation of resources or location-specific patrolling custom-made to hotspot features. The purpose of the study was to develop a graphical information system (GIS) which identifies the different hotspots of crimes that occurred in the year 2017 throughout the cities of Caloocan, Malabon, Navotas and Valenzuela (CAMANAVA) using MarkerClusterer clustering algorithm along with spatial and temporal analysis to cluster occurrence of crime together in certain areas and periods, and to provide a recommendation for that hotspot. The developmental research design was adopted by the proponents to satisfy the research problem, along with the Knowledge Discovery in Database (KDD) during the development of the system. Nine (9) crime types were observed, namely; car/motor-napping, drug-related incidents, homicide, murder, physical injuries, rape, robbery, theft and vehicular accidents. A total of 12,784 occurrences of crimes was observed, and vehicular traffic accident occurred the most which accounts for 63.97% of the total 12,639 crime occurrences in CAMANAVA during the year 2017. Hourly distribution varied depending on the crime observed, daily distribution did not show much variation but monthly distribution showed that August is the month when most crimes occurred. The proponents recommend that future research may include impact of socioeconomic and environmental factors in crimes, plus data mining techniques that could be able to forecast crime based on the hotspots that were generated.*

Keywords – *Crime Hotspots, Spatio-Temporal Analysis, Geographic Information System (GIS), MarkerClusterer Algorithm, CAMANAVA Crimes*

INTRODUCTION

Crime information analysis and mapping have progressed considerably throughout the years. It started as pins in city maps to visualize felonies and their incidences to computer systems that implements various algorithms and techniques to investigate, visualize and describe the occurrence of illegal activities. The use of a rational techniques to categorize these information based on the frequency, locality and period of incidence is a significant feature that have to be focused [1]. Basically, hotspots are regions that require attention from law enforcement, perhaps through increased allocation of resources or location-specific patrolling custom-made to hotspot features. For researchers, hotspots offer a view into the core risk aspects of crime and their associated theoretical perspectives. The identification of hotspots is helpful because most police departments are understaffed. As such, the capability to prioritize intermediation across a geographical view is pleasing. Agarwa, Nagpal and Seghal [2] stated that the core rationale of crime investigation are (1) obtaining of crime patterns by examination based on existing criminal data, (2) anticipation of crimes grounded on spatial distribution of available data and calculation of crime occurrence using data mining methods, and (3) lastly crime identification, while crime analysis is done mainly to inform law enforcers about general and specific crime trends in timely manner and to take advantage of the plenty of information existing in justice system and public domain.

In the Philippines, one of the priorities of local law enforcement is crime reduction and avoidance and as stated in the Philippine National Development Plan 2017 – 2022, national security and public order are essential elements in building the foundation for inclusive growth, a high trust and resilient society, and a globally competitive knowledge economy. Statistically, crime is those reported violations to authorities are covered.

Philippine National Police (PNP) has defined crime classification as an index and non-index crimes. Index crimes involve crimes against persons such as murder, homicide, physical injury and rape, and crimes against property such as robbery, theft, car-napping/carjacking and, cattle rustling while non-index crimes are violations of special and private laws such as local ordinance. Police awareness is the most relevant factor that may lead to reduction of crime rate or fast response to crimes. Police department cannot easily visualize where or what time certain crimes frequently happen [3], unless systems are implemented to aid and support them. Crime data contain a variety of spatial-temporal information and unless those data are computerized and examined using suitable software, statistical test and descriptive procedures, that information will remain largely unavailable to both researchers and practitioners [4]. Murray et al. [5] noted that the ability to combine spatial information with other data that makes geographic information system (GIS) so valuable. A GIS allows to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. A GIS helps answer questions and solve problems by looking at data in a way that is quickly understood and easily shared.

Crimes have spatial patterns due to two reasons. First, crimes tend to cluster at or near crime generators and/or attractors [6] and Second, frequency of crimes is affected by certain environmental factors such as proximity to various services, land use mixes, issues of access, exposure, opportunity, and the availability of targets and temporal patterns due to routine activities of people (criminal or non-criminal) affect the temporal distribution of predatory crimes, which tend to cluster when there is an influx of people at a particular place [6]. Temporal data mining is a data mining method for temporal data primarily to find data patterns with respect to time [7]. To perform crime analysis, an appropriate data mining approach need to be chosen and as clustering is an method of data mining which groups a set of objects in such a way that object in the same group are more similar than those in other groups and involved various algorithms that differ significantly in their notion of what constitutes a cluster and how to efficiently find them.

The principal purpose of the study is to develop a graphical information system that can be able to identify the different hotspots of criminal activity throughout the Northern Manila District composed of the cities of Caloocan, Malabon, Navotas and Valenzuela (CAMANAVA) using MarkerClusterer clustering algorithm along with spatial and temporal analysis to cluster occurrence of crime together in a certain areas and periods after which providing a recommendation to users of the factors that causes the hotspot generation. The research field is abundant but in terms of the application in the local scope it is lacking, in which the proponents sees an opportunity to develop a system to address the gap in the research area within the scope of the Philippines, specifically in the area of CAMANAVA.

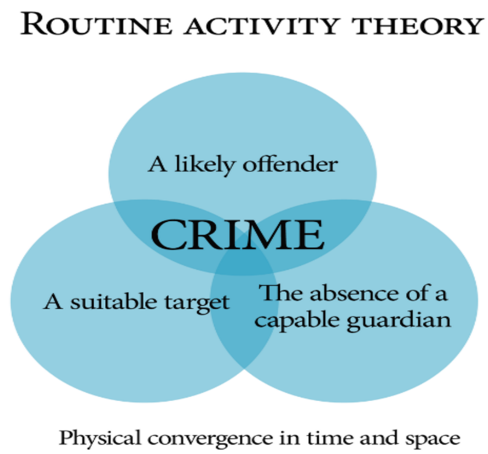

Fig. 1. Routine Activity Theory [8]

Figure 1 shows the routine activity theory which was adopted by the proponents as the theoretical framework to explain individual motivation and guardianship factors pertinent to crimes perpetrated in the CAMANAVA area. The empirical overview indicates that the convergence of motivated offender, suitable target and the lack of capable guardianship result to a criminal action [8].

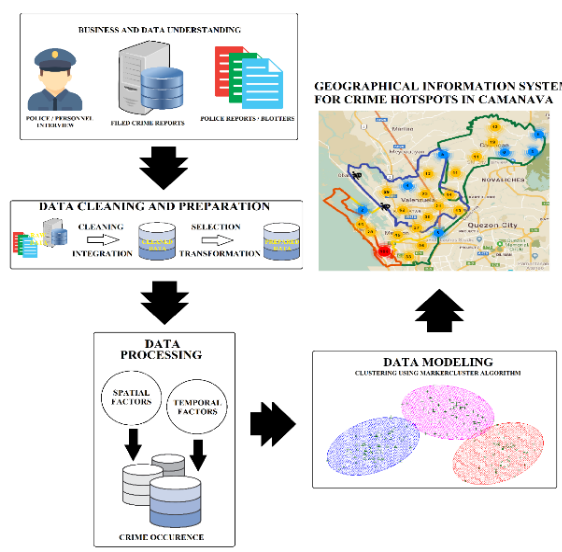

Fig. 2. Conceptual Framework

Figure 2 shows the conceptual framework of the system. The system applied spatial and temporal analysis along with MarkerClusterer clustering as the data mining technique to generate results for local law enforcement purposes. The development process of the system starts with the gathering of data ranging from paper documents such as blotters and incident reports, interviews with field officers and investigators and softcopy of document and files, the information will come from the different police stations in the Northern Manila District. The proponents gathered all of the needed files and the daily crime report that had occurred in the CAMANAVA within the period of January to December 2017. The data gathered was then cleaned and processed to be able to retrieve information that were usable for the purpose of developing the system. The process started by extracting relevant data from the records gathered such as crime, location, time, and date. The proponents extracted spatial and temporal properties of the records that are relevant to the study, then classified and segregated the extracted data to the different classification of crimes per time and location, after which the proponents using Google Maps API and Maps JavaScript API library plotted and clustered the data based on the spatial and temporal properties of each data points. The results will be presented using graphical design such as map, clusters and charts which will also include a recommendatory action to minimize or alleviate the crime hotspots in CAMANAVA.

OBJECTIVES OF THE STUDY

The main objective of the study is to develop a graphical information system that can be able to identify the different hotspots of criminal activity throughout the cities of CAMANAVA using MarkerClusterer clustering algorithm along with spatial and temporal analysis that can be able to assist law enforcement agencies in determining the spatial/temporal factors that causes these hotspots and mitigate them. Specifically, it aimed to understand how the MarkerClusterer clustering algorithm identify the crime clusters; to identify the spatial, temporal or spatio-temporal factors that have created those clusters; and to develop a system that can be able to generate recommendation to address the clusters of crime within the cities of CAMANAVA.

MATERIALS AND METHODS

Research Design

The design used by the proponents is the developmental research [9]. A developmental research is defined as the study of design, development, and evaluation of products, programs and processes that meet the criteria of effectiveness and consistency. The developmental research design was chosen because of the following reasons: support for development of prototypical projects which also include practical evidences of their effectiveness. Also, it is for purposes of generating methodological directions for the design and evaluation of such products. In this approach, the scientific contribution (knowledge growth) is seen as equally important as the practical contribution (product improvement). The product-development process is analysed and described, and the final product is evaluated [10]. It facilitates the study of new tools, models and procedures so that the researchers can anticipate the efficiency and effectiveness of the system.

Knowledge Discovery Methodology

The steps of the study adopted the Knowledge Discovery in Database (KDD) [11]. The KDD is a recursive process of operations from the raw input to high-level data that leads to interpretable and useful knowledge. The major steps in KDD process are typically: Selection, Pre-processing, Transformation, Data Mining, and Interpretation/Evaluation.

Selection. The proponents gathered data from the different police stations in CAMANAVA, understands the data quality and the data needed for the development of the system.

Pre-processing. The proponents removed unnecessary information that was gathered with the data and process the data in a way usable for the data mining technique to be used in the latter part of the methodology.

Transformation. The proponents converted the data into the final data set to be used and cleaning of data for modelling tools.

Data Mining. The proponents assessed and identified the modelling technique that is applied in the study which is data clustering. Data clustering is the process of grouping and analysing the list of objects which have similar characteristics. Wu [12] stated that the MarkerClusterer clustering algorithm is best suited for clustering data markers in maps. Hence, the proponents implemented MarkerClusterer as the clustering algorithm used by the developed system.

The MarkerCluster clustering algorithm [13] works on the following procedure:

1. Divide the given map into square grids of certain sizes based on users zoom level and grid size.
2. Place marker into map and create a cluster for that marker.

3. Repeat adding markers into the map and creating its own cluster.
4. If marker is within the bound of more than one existing cluster, Google Map API computes the marker distance and added to closest cluster.

Interpretation / Evaluation. The proponents checked the results of the model if it attained the desired results of the objectives of the study. The proponents produced a final report which included detailed findings, explanation of models, and discussed the results and the goals that was met.

The data gathering procedures implemented by the proponents included interviews to the police personnel's and officers, data analysis using the crime volume and occurrence reported and documented from January – December 2017 from different police stations in CAMANAVA and library research using books, journals, articles, magazines, online publications and unpublished theses and dissertation.

RESULTS AND DISCUSSION

Table 1. Crime occurrence, percentage and ranking

Crime Type	No. of occurrence	%	Rank
Vehicular Traffic Incidents	8085	63.97%	1
Drug-Related Cases	1529	12.10%	2
Murder	757	5.99%	3
Theft	651	5.15%	4
Physical Injuries	434	3.43%	5
Robbery	409	3.24%	6
Homicide	332	2.63%	7
Rape	236	1.87%	8
Car/Motor-napping	206	1.63%	9

Table 1 shows the distribution, percentage and ranking of the different crimes in the CAMANAVA area during the year of 2017. It shows that vehicular traffic incidents is the largest contributor of crime occurrences in the CAMANAVA area which is almost 2/3 of the total crimes recorded during the year of 2017. This large number of occurrence of vehicular traffic incidents is mainly because of the congested routes through-out the CAMANAVA area and the surge in the volume of vehicles in the metro.

MarkerClusterer clustering algorithm in identifying crime clusters

The MarkerClusterer is a clustering algorithm that uses a grid-based clustering method which is probably the most common approach for clustering markers. It divides the map into a grid and group all markers within each square/grid into a cluster, which makes it ideal for a fast solution to the many-markers problem. The clustering algorithm is simple; for each new marker it sees, it either puts it inside a pre-existing cluster, or it creates a new cluster if the marker doesn't lie within the bounds of any current cluster. In the developed system, the process starts by creating an object that holds all the markers. By plotting hem one by one, each of these markers are placed into their specific geo-location in the map provided by Google, then dividing the given map into grid with a grid size of forty (40) and clustering all crimes inside the grid that is visible within the zoom level of twelve (12). All clustered crimes are shown using marker symbol along with the cluster value. By default, clusters are displayed as colored circles with size depending on the number of markers they contain: a blue circle indicates less than ten (10) markers, a yellow circle indicates ten (10) to ninety nine (99) markers, a red circle indicates one hundred (100) to nine hundred ninety nine (999) markers, a pink circle indicates one thousand (1000) to nine thousand nine hundred ninety nine (9999) markers, and a violet circle indicates ten thousand (10000) markers or more. It is a utility library of the Google Maps API that is used for marker management.

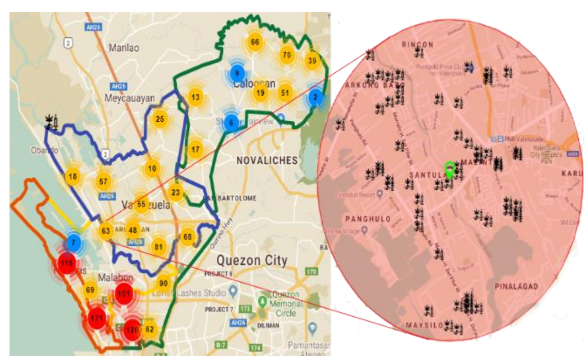

Fig. 3. Implementation of MarkerClusterer Algorithm

Figure 3 shows how the cluster of each crime was created and the markers inside a specific cluster that created the cluster. The figure also shows the center point of the cluster which is the average center point of all the crime incidences in that specific cluster.

Spatio-Temporal factors of the crime clusters

Adopting the hotspot matrix developed by Ratcliffe (2004), the proponents identifies the spatial features (*Dispersed, Clustered, and Hotpoint*) of the crime patterns within the hotspot, along with aoristic signature (Diffused, Focused, and Acute) for that hotspot.

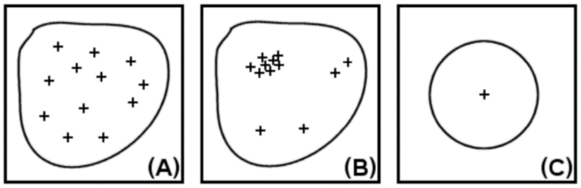

Fig. 4. Spatial Feature of a hotspot [14]

Figure 4 shows the spatial features of a hotspot, (A) Dispersed is a type of crime hotspot where the points that generate the hotspot are spread throughout the hotspot area. (B) Clustered is a type of hotspot where the events that make the hotspot tend to cluster at one or more particular areas within the hotspot region. (C) Hotpoint is a particular type of crime hotspot generated by one single criminogenic feature. This feature would no doubt be considered a crime attractor or generator [14].

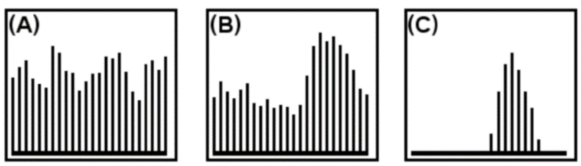

Fig. 5. Temporal Feature of a hotspot [14]

Figure 5 shows the temporal features of a hotspot, (A) Diffused are crime hotspots where the crime events could happen at any time over the 24-hour period of a day, or because the time span of events is so large that it is not possible to determine any significant peaks of activity. (B) Focused is a type of crime hotspot that may have crime happening throughout the day, but there are times when there is significantly more activity than at other times. (C) Acute is a rare group of hotspots where the temporal activity is confined to a small period of time, or where the aoristic signature almost negates the possibility of criminal activity at some time periods [14].

Figure 6 shows the different spatial maps of the different crime that occurred in CAMANAVA. Upon investigation the following are spatial features are identified: (A) Vehicular traffic incident hotspots showed clustered spatial signature due to the large number of occurrences. (B) Drug-related hotspots showed a combination of clustered and diffused spatial feature. (C) Murder hotspots showed a dispersed spatial signature. (D) Theft hotspots has a combination of dispersed and clustered spatial signature. (E) Physical Injury hotspots showed a combination of dispersed and clustered attribute. (F) Robbery hotspots showed a combination of dispersed and clustered feature. (G) Homicide hotspots showed a combination dispersed and clustered spatial distribution. (H) Rape hotspots showed a combination of dispersed and clustered spatial distribution. (I) Car/Motor-napping hotspots showed a dispersed spatial distribution. As seen in the different spatial maps, most crime types have a combination of dispersed and clustered. This is because some clusters have a large number of occurrences while others have lower values. The recommendation of the system for law enforcers and policy makers is based on type of crimes committed. A cluster with a clustered spatial distribution will show a recommendation near or within the area of the crimes that are clustered. A dispersed will show a recommendation within the average area of all the crimes within the cluster.

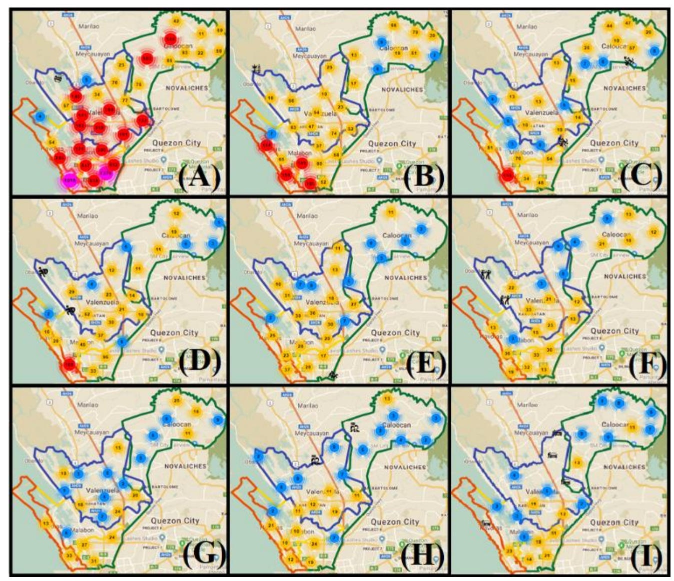

Fig. 6. Spatial Map of crime clusters

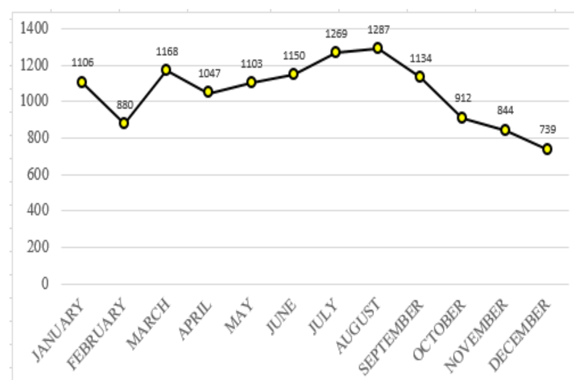

Fig. 7. Overall Monthly Summary of all crime distributions in CAMANAVA

Figure 7 shows that there is no important trend overall on the different crime categories during the monthly distribution that shows the relationship of the crime occurrence with certain months. It shows that overall crime peaks during the month of August in 2017 and goes down to its lowest point during the month of

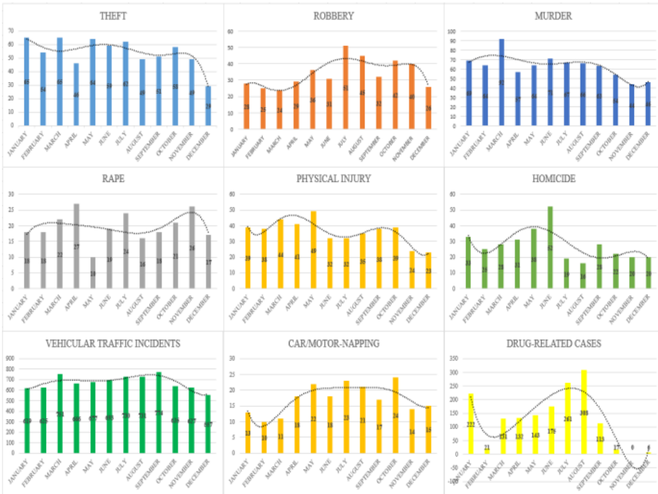

Fig. 8. Monthly distribution of individual crime types fitted with a polynomial trend line

December which may be attributed to crimes that are predicated to susceptible targets in which during the latter part of the year they are with their families or within the confines of their homes.

Figure 8 shows each individual crime associated with a 6th-order polynomial trend line to indicate the approximate trend of crimes across the monthly temporal components. As shown, each crime varies throughout the months of the year. Aside from drug-related cases that have a slight focused aoristic characteristic, the remaining crime types have a diffused aoristic characteristic. It showed that offenders of this crimes do not necessarily choose a specific month to perpetrate these crimes and may be attributed to the lack of guardianship and a number of suitable targets.

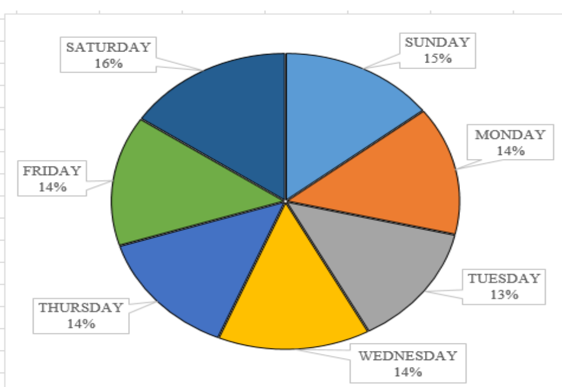

Fig. 9. Overall Daily Summary of all crime distributions in CAMANAVA

Figure 9 shows the distribution of the all of crimes on the different days of the week. As shown, each day has

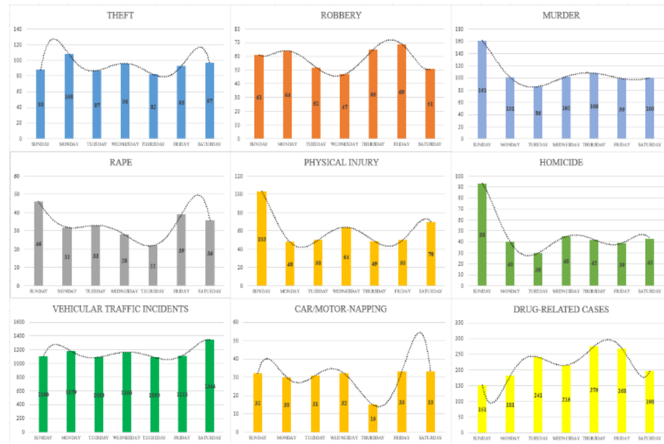

Fig. 10. Daily distribution of individual crime types fitted with a polynomial trend line

almost an equal number of percentage in terms of crime occurrences. It showed that overall, no specific day is attributed to the perpetration of the different crime in CAMANAVA, and perpetration of crimes may be attributed to social or economic factors and also to exposure of targets to motivated offenders during scenarios where there is no capable guardian.

Figure 10 shows each individual crime associated with a 6th-order polynomial trend line to indicate the approximate trend of crimes across the daily temporal components. As shown, each crime varies throughout the days of the week. Murder, Homicide and Physical Injury have a focused aoristic signature and are focused during Sundays, while the crime types have a diffused aoristic characteristic, but overall, it shows that lawbreakers does not necessarily choose a specific day to commit these crimes and may be attributed to the opportunities provided due to the routinely activities done by citizens of CAMANAVA.

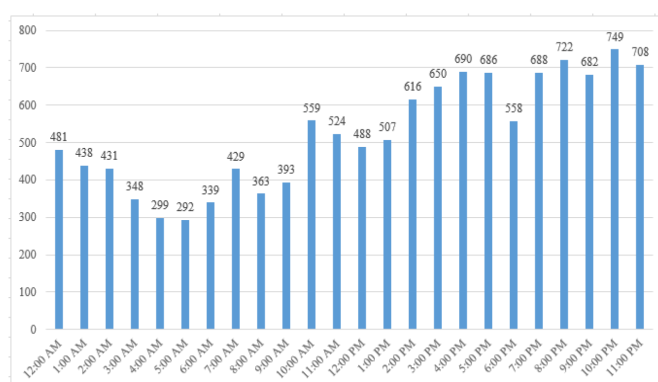

Fig. 11. Overall hourly summary of all crime distributions in CAMANAVA

Figure 11 shows the distribution of the all of crimes on the different hours of the day. As shown, mornings between 3 a.m. – 7 a.m. have low number of occurrence as compared to latter part of the evening 7 p.m. – 11 p.m. which almost double the occurrence of different crimes. This shows that criminals mostly perpetrate crimes during late hours of the evening and even during the wee hours when most police officers are off-duty and when possible witnesses are also at rest or asleep. Moreover, these are the hours of partying and other nightcaps which would lead to committing certain crimes.

Fig. 12. Hourly distribution of individual crime types fitted with a polynomial trend line

Figure 12 shows each individual crimes associated with a 6th-order polynomial trend line to indicate the approximate trend of crimes across the temporal components. As shown, theft crimes have a trend of occurrence during lunch hours to early evenings. Except for vehicular-traffic incidents and car/motor-napping cases, the remaining crimes have a trend of occurring during the late evenings and the early mornings. This can be attributed to the different routinary activities habitual of CAMANAVA resident.

Recommendation generation to address the clusters of crime in CAMANAVA.

The system generates the recommendation based on the chosen parameters of location, crime type, year, month, day and time after which a hotspot was created based on the different parameters provided into the system.

There are three levels of intensity that are classified in a hotspot as shown in Figure 12. A crime prone area is classified if a given hotspot has been generated with a marker count of between 2 to 10. A high crime prone area is classified if a given hotspot has been generated with a marker count of 11 to 17. A very high crime prone area is classified if a given hotspot has been generated with marker count of greater than 17.

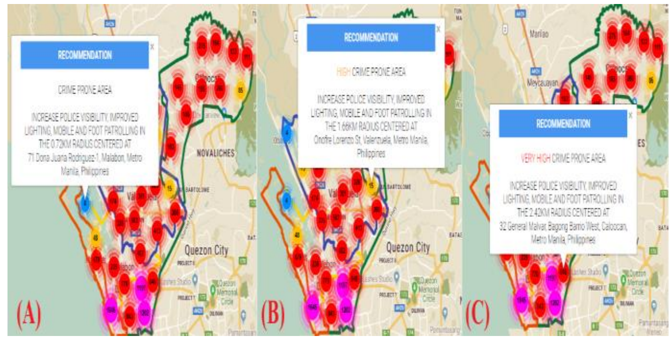

Fig. 12. Hotspot with intensity classification

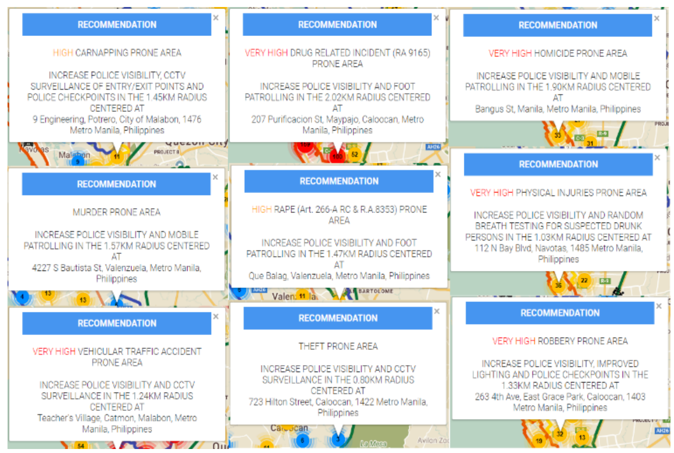

Fig. 13. Hotspot with intensity classification

A corrective / preventive measure is also provided by the system that may be able to mitigate and lower the occurrence of the crime incidences in the hotspot. The corrective measure provided varies depending on the type of crime, as the proponents learned during interviews with police investigators, depending on what is the crime being committed the preventive measures of the police force may vary. Figure 13 shows the different recommendations for preventive/corrective measures on the different crime categories.

Figure 13 also shows that the developed system also provides the radius in which the investigators/police personnel must implement the corrective measures generated by the system. The computation uses the average circular distance of all the markers of all of the given crimes in the hotspot and lastly, the developed system provides the central position of the cluster to be able to implement the corrective measures. This is also computed by the Average Center function, by using the values returned by the Average Center function the Google Map API geocoded the location to provide a specific location for that given center.

A report generated by the system. It displays the search criteria chosen by the user first, then displays the total number of crime occurrences, the total clusters generated and the recommendatory corrective/preventive action to be taken by the police personnel. It also shows the total crimes per cluster, the radius size of each cluster, and the center of the cluster providing the latitude, longitude and the actual geo-coded location provided by the Google Map API. The actual speed of retrieving the geo-coded location was deliberately slowed down in order to retrieve all the needed information from the API. A table in the last part of the report shows information regarding each of the crime occurrence shown in the system.

CONCLUSION

The focus of the study is to develop a geographic information system that can identify crime hotspots throughout the Northern Manila District and provide recommendations for the hotspots that are created. The following objectives were attained:

1. Implementing MarkerClustering algorithm to be able to identify crime clusters.
   The MarkerClustering algorithm is a grid-based clustering algorithm that divides that map into grids of certain sizes at certain zoom level and then plots each markers into the grids to develop the cluster. Each cluster created provides a specific value and contains all the markers of the different crime occurrence in that hotspot
2. Identifying the spatial, temporal or spatial-temporal features of each crime clusters.
   Routine activity theory discusses that crime happens if the different factors converges (presence of a likely offender and suitable target factors while absence for the capable guardian factors) during a particular moment in space and time. Based on the result of the research it shows that most of the crime occurred during times in which a capable guardian factor is lacking, as shown in the temporal results of the research. Based on the hotspot matrix, spatial features that were created were either clustered, dispersed or a combination of both. The temporal feature were created were either focused or diffused. Based on this information, law enforcers and policy makers can develop preventive / corrective measures to mitigate and lower the crime hotspots.
3. Developing a recommendation system to provide preventive / corrective measures to the hotspots.
   The recommendation was based on the different parameters provided by the user on the different clusters that were created. A specific radius was provided on the range of the implementation of the recommendation. A report was provided for police officers and investigators to be used in the mitigation of the different hotspots in CAMANAVA. Using this information, PNP and other crime preventing organization can re-allocate their resources to flexibly react to the different temporal and spatial signatures of crimes, while, LGU's and communities can use this information to be more alert and observant on their surrounding especially on hotspot areas of CAMANAVA.

RECOMMENDATION

The development of the GIS for CAMANA crime hotspots is open for further improvements. From the foregoing findings, and from the conclusion drawn, and within the scope and limitations of study, the following recommendations are proposed:

1. Based on the literature review conducted by the proponent, future researches can be directed to include not only the Routine Activity Theory but also the impact of socioeconomic and environmental factors, specifically, such as residential location, individual characteristics and neighbourhoods' subculture.
2. Inasmuch as the study proved to be successful in identifying crime hotspots in CAMANAVA, a modification on the system inclined towards crime investigation, analysis and mitigation should implement a data mining technique that could be able to forecast crime occurrences.
3. The proponent implemented MarkerClusterer algorithm in developing the clusters of the system, hence, the proponent recommends other clustering algorithm can be implemented for comparison on the performance of the current clustering algorithm to those other algorithms that are available.
4. The proponent deliberately slowed down the system due to the constraint of free license Google API, therefore, the proponent recommends purchase of premium Google API license to mitigate the degradation of speed during the reverse geo-coding of the coordinates.

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