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Clustering Crash Hotspots to Organize Police Dispatch Routes Using GIS

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Abstract: ***Traffic crashes events are known threats to public safety. Identifying high-crash-risk road segments provides safety specialists with an insight to better understanding of crash patterns and enhancing road safety management. In this work the main aim is to identify hotspots of severe crashes and reduce police dispatch time thereby reducing crash severity. In this crash monitoring and identifying approach, the objects and its positions tend to change periodically due to its dynamicity and mobility by which there should be a provision to monitor its behavior and position regularly. This will help to study the traffic flow and object behavior in the study locality. Based on the object movement in the region the position and time will be updated based on which the speed can be calculated. The frequency of speed will helps to identify the traffic situation of the region. Instead of monitoring individual node movement and speed the system will analyze the region based on multi-object speed analysis. It also defines the minimum and maximum speed and average speed flow of the object in a particular region. After a certain period of time, the object selects a new random path based on the distance and maximum speed path. In this process a novel Position-based speed updating process is proposed, in which several moving objects are recognized by the system. A dynamic segmentation is done to classify regions based on crash severity and minor clustering of hotspots is done. Finally kernel density is analyzed and frequency is calculated by which the data will be analyzed for further classification. ArcGIS was used for analyzing the data and displaying the results.***

Keywords: ANN, ArcGIS, Crash rate, hotspots, Dynamic Segmentation, Minor Clustering

1. Introduction

Road traffic safety mainly focuses on reducing the risk of people using a secured road network from either being killed or seriously injured. The first level is to prevent serious injury and death crashes, considering all key areas under study. The next level is risk reduction, which can be done by providing users at high risk with a specific indication to enable them to take immediate action, which is not possible due to dynamically varying environment. The final level is about reducing the crash risk by improving police enforcement. The proposed method involves identifying areas of higher crash severity and improving the existing dispatch pattern of police enforcement. A novel dynamic segmentation algorithm is performed, based on local density and path similarity information which includes vehicle lookup and path, speed and other factor analysis and monitoring. This helps to manage the crash details and in decision making. The density plays an important role in classification of hotspots based on severity strength. Path similarity can be used to identify the frequent patterns of crashes occurring in the study region. The density analysis can be used to find the gap between the vehicles and the related details which helps to gather information about severity of crashes in road network, which includes busy working towns , high metropolitan cities, and currently unmonitored motorway roadways. The route hierarchy and minor clustering helps to maintain the details about the route and objects by which police enforcement can be dispatched efficiently in order to reduce the crash rate to considerable amount. This paper studies or suggests ways of organizing the police enforcement in areas of high crash severity based on frequency calculation of crashes and time. The rest of the paper is organized as follows. In Section 2, related works are reviewed with summary. Section 3 gives the problem formulation. Section 4 describes the material and methods used such as location and density analysis, Estimating the Average Nearest Neighbor index, crash spots detection, Dynamic Segmentation and finally the Police patrol route selection. Section 5 discusses the algorithm of the work. Section 6 elaborates the classification and clustering of severe hotspots by estimating the effectiveness. Section 7 gives the result and discussions. Finally Section 8 concludes the work.

2. Literature Review

2.1 Collision patterns

Yonggang Wang et al. have evidently proved that the occurrence of a traffic crash is the result of multiple contributory factors. In this study, they have shown that driver's behavior, geometrics and environmental conditions all contribute to the traffic crashes and collisions. The study has evaluated the features of crashes in the city of Harbin, using the policy reported crash data over the period 2000_2010, and checked how the factors (e.g. time, location, number of lane, with or without divided median, mean speed, diversion of speed, etc.) have influenced the crashes to provide necessary insight into understanding and coupling with the safety performance of the roadway network effectively. The findings indicate that driver's behavior is an important factor in the occurrence of crashes than do vehicle, environmental or geometric factors.

2.2 GIS based methodology

Srinivas S. Pulugurtha et al. presented a methodology to identify high pedestrian crash zones and an evaluation of methods to rank these zones. This GIS based methodology helps quantify the severity of crashes, and thus reduce the degree of risk involved in identifying high crash zones. Crash concentration maps were created using the Kernel Method feature available in a commercial GIS software program. Thus, a study on statistical correlations between individual methods and composite methods was done.

2.3 Injury Patterns

Carlos Arregui-Dalmasesa et al. Presents an estimation of associated problems resulting from the study of accident related injuries. Details of crash avoidance methodologies, especially from the engineering side, should benefit from these results. It is somewhat impractical, for example, that the only legislation in place to project pedestrians in the EU uses a unique head injury predictor, the Head Injury Criterion, which takes into account only translational acceleration. It is very important to address the issue of vehicle design in this regard. However, their study points out that linear acceleration are only partially responsible of these very frequent, severe and disabling injuries.

2.4 Spatial Aggregation

Isabellethomas in this work illustrates one of the many problems arising when studying objects located in space which is called the scale problem. The is faced with the problem of choosing one spatial segmentation level from a set of available alternatives. In this paper, “classical” univariate descriptive statistics are systematically calculated for accident strength and ratio, using different roadway path lengths. The simple exploratory data analyses conducted in this paper also show that individual accidents are Poisson distributed, but the way they are measured (here: space intervals) makes it difficult to verify empirically.

2.5 Moran’s I and Getis-Ord Gi

V. Prasannakumar , H. Vijitha et al in their study investigated and compared different kinds of traffic accidents in terms of spatial and temporal aspects is the first attempt of its kind in the Thiruvananthapuram city corporation. The results of the spatial statistics and cluster analysis elicit the spatial and temporal variations of accident highs (hotspots) and lows (cold spots) in the area. The assessment of spatial characteristics of the accident data by Moran’s I method, derived Z score, Moran’s I index and critical value indicates that accident datasets, as a whole, are categorized as clustered in nature. The results can be effectively used for the successful management of traffic and reduction of accidents effectively to improve the efficiency or reduce the crash rate at expected accuracy rate or as desired.

2.6 Collision prediction models

Vicky Feng Wei et al. have reviewed the literature, presented empirical research findings, and highlighted emerging research on the global road safety problem. Initial research developed community-based, macro-level CPMs based on one of three main neighborhood data stratifications – land use, data sources, and design traits. Our theoretical research results suggest that the 3-way offset and fused grid community patterns can be reasonably expected to experience 60% fewer road collisions than similar neighborhoods using conventional road patterns.

2.7 extended fuzzy C-means (EFCM)

Ferdinando Di Martino et al. in their proposed work identified that usually hotspots in GIS environment are determined by using density clustering methods which have an elevated computational complexity. Indeed, in accordance to the previous our works, the usage of the EFCM method seems more successful because of its linear computational complexity and robustness to noises and outliers. It derives hotspots as hyper spheres which become circles in the case of bi-dimensional pattern data like in the case of fire point-events in the Santa Fè district (NM).

2.8 Black sites Identification

Becky P. Y. Loo illustrated that based on the analysis in the city of Hong Kong, the spatial nature of crash hotspots are likely to vary by road type and by district. Moreover, though the hot zone methodology supplements the black site methodology, it is superior and more flexible in many aspects, especially in the identification of hazardous road locations on expressways and in the rural areas. A big challenge ahead is to eliminate the spatial clusters of crashes at hot zones without causing accident migration.

2.9 Geographic information system

Kevin Austin studied that the GIS-based validation system has verified mistakes in the coding and locating of accidents not identified by the current system. . If all highway authorities adopt this GIS-based system, the variables discussed in this paper could be removed from the police form altogether as they would be added to the computer database automatically once an accident has been placed onto the digital map.

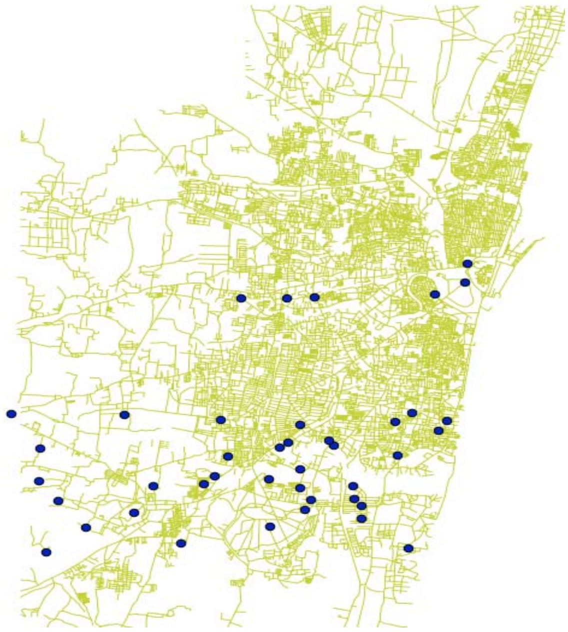

Figure 1: Map of Chennai with crash hotspot

3. Problem Formulation

In all the related works, both hotspots and cold spots of crash occurrences and possibilities were considered. The study focuses either reducing the crash rate by modifying the plan of the existing police route or changing the design of the police route. Due to the dynamic nature of police departments, establishing a standard and fixed dispatch route is impossible. Hence this study focuses on calculating the ANN index for each hotspot. Based on which it is also possible to decide the nearby hotspots that it covers. This can be done by location analysis and density analysis which is used to calculate the risk density and frequency of occurrences of each crash. Finally since there are no approximate results for the study, police routes can be established for each ANN index that has been calculated and the effectiveness can be estimated.

locx	locy	distance
333	351	2826.027069934...
364	246	2830.437775327...
311	351	2831.184027928...
294	246	2833.537012286...
295	246	2835.905146509...

Figure 2: ANN index

4. Proposed Work

4.1 Location analysis

Collected Raw datasets represent time stamped geographical locations. Apart from storing raw data in the moving object database it needs to reconstruct the datasets. Raw points arrive in bulk sets, it needs a filter that decides if the new series of data is to be appended to an existing trajectory or not. The frequent users of road too need good quality information about traffic design in order to plan and build their routes accordingly. Traffic information has often been collected with induction based loop like detectors. Location updates may help to monitor accurate location analysis. This will helps to gather all relevant information's about the analysis.

4.2 Crash spot detection

The system visualizes the crash spots in the map from the collected data sets. This indicates the serious hotspots in a particular region where crash severity is the highest or above the threshold value. This module utilizes the dynamic segmentation process to differentiate the study locality into segments based on the frequency of crash occurrences as high, medium and low. Then the segments with 'high' value are selected for clustering where police routes can be applied to reduce the rate of crash severity in the region.

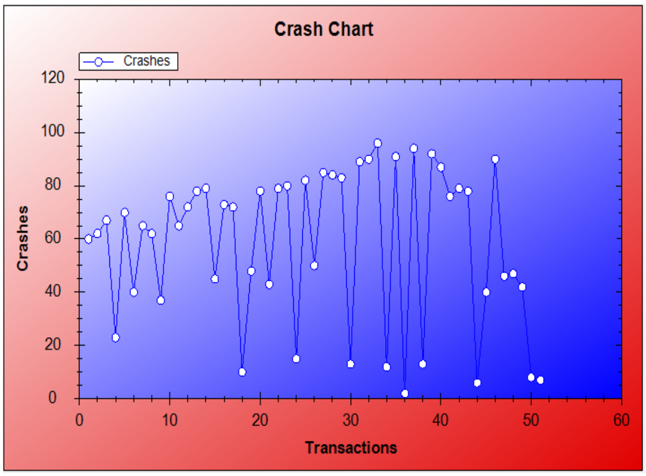

Figure 3: Crash hotspots

4.3 Density evaluation

The density analysis can be used to find the gap between the vehicles and the related details. The average density gap can be found out for deciding the movement of the. All the details can be clustered by using 'ANN' clustering. The data that has been collected from the vehicles is immediately communicated or sent to a central repository like facility for further manipulation. This method permits the composition of crash data across the whole segments of road , including growing towns, busy cities, rural pathways and currently unmonitored motorway segments. The object will be identified by object search (ANN search).

4.4 Dynamicity based segmentation

A novel dynamic segmentation algorithm is performed, based on local density and path similarity information. This method is applied for each part or segment of the section under study, forming a local path descriptor that represents various line segment representativeness. This line sequence of this path over a trajectory gives the voting signal of the trajectory or path, where huge values subject to the most representative parts. It involves two steps:

Step 1: Segmentation algorithm: It is applied on the signal that automatically estimates the number of partitions and the partition margins, identifying similar partitions based on their representativeness.
Step 2: Crash detection method: It is applied over the resulting dynamic segments yields the most representative sub paths in the database.
The analysis includes vehicle lookup and path, speed and other factor analysis and monitoring. The developed crash detection concept developed as a hierarchical sub networks which will helps to manage the crash details and decision making. Each and every object will be identified by the object Id and the distance will be measured by spatial, temporal distance, speed of an object, and distance between two objects.

4.5 Minor clustering

The route hierarchy and minor clustering helps to maintain the details about the route and objects. Through the route hierarchy there are two kinds of additional information gathered. The first one is selective (shortest) paths across an route network that enable any traversal to bypass the route if it has no object of interest, and the second one is the existence and/ or contents of objects that are inside the Route network to provide quick traversal guidelines.

4.5.1 Shortcuts
4.5.2 Summary about the route and crashes.

4.6 Police Patrol Location Selection

The aim of police patrol is to provide the public with a sense of security and discourage potential crashes. One good approach is to adopt a randomized patrol prediction strategy so that crashes can never be sure when a patrol might arrive on the scene. The use of randomized police patrols has been one of the key factors in the significant fall in the crash rate of a city. The proposed system performs the prediction system, which will help to identify the optimal location of police patrol. The existing system performs the comparison only after the placement of police patrol. But the current system provides a prediction model with the probability based data analysis. The scheme performs the ANN algorithm for the nearest and average distance of neighbor nodes in the location. When a particular region is selected the ANN algorithm suggests the nearest locate theons of high crash rate also covering the surrounding locality. When police is dispatched to that region it approximately suggests the rate by which crash could be reduced.

Algorithm

Step 1: Analyze the spatial distribution of accidents
Step 2: Identify the crash hotspots
Step 3: Calculate distance between the police location(x) & crashes(y)
Step 4: Calculates the Euclidean Distance between x and y
D = sqroot[(x1–x2)2.0 + (y1–y2)**2.0] (1)**

- D – horizontal distance
- x1,x2 – co-ordinates of x
- y1,y2 – co-ordinates of y

Step 5: Calculates the Minkowski Distance between x and y
Step 6: Calculates the Manhattan Distance between x and y

D=abs(x1–x2)+ abs(y1–y2) (2)

- D – vertical & horizontal distance
- x1,x2 – co-ordinates of x
- y1,y2 – co-ordinates of y

Step 5: Compare the distances to estimate the length.
Step 6: Copy input feature class and integrate points to map
Step 7: Cluster the hotspots based on ANN index
Step 8: Based on the distance organize the police route.

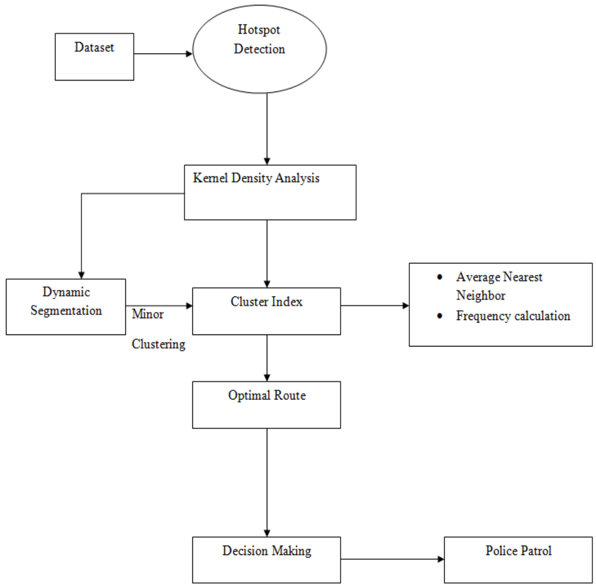

Figure 4: Flow chart of the work

5. Measurement of Effectiveness

The effectiveness of the overall result was estimated. Few assumptions were made on the data,

- Based on an assumption that crash rates were reduced to few percent in the study area. Minor clustering and density analysis were performed to calculate the effectiveness in different crash conditions.
- The next is to assume that crash hotspots also cover the regions with cold spots of crashes which can improve reducing the crash rates in the study region.
- The third assumption is that the police routes are first established in and nearby the regions where crash severity is extremely high or in the pathway that cover the maximum crashes.

The percentage of effectiveness (Δ) can be given by,

$\Delta=(p-q)/q$ **(3)**

Where Δ is the effectiveness of the police route, p is the number of crashes before police dispatch and q is the number of crashes after dispatch. The study assumes the effectiveness for the entire study area.

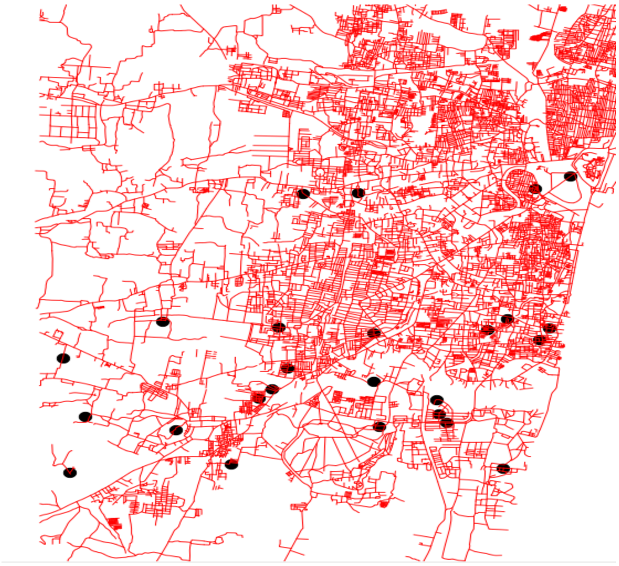

Figure 5(a): crash hotspots (high severity)

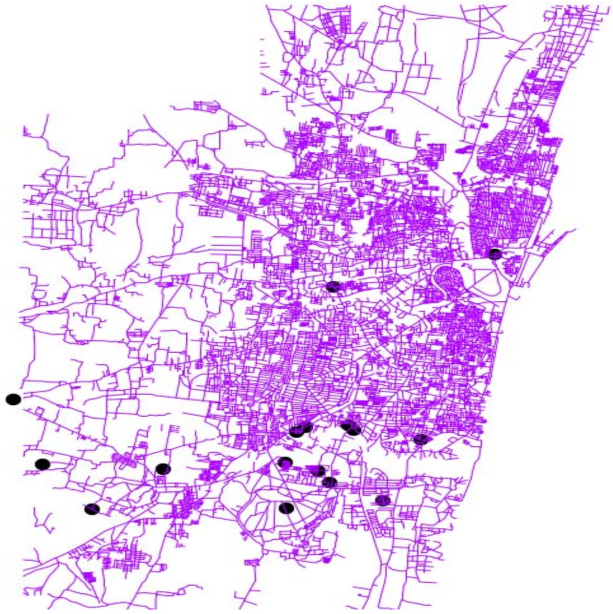

Figure 5(b): crash hotspots (low severity)

Figure 5(c): Police dispatch (approx.)

6. Results and Discussions

The major process in this work is to geocode the crash data. Fig.1. shows the geocoded crash data displayed on the map of Chennai. It is difficult to analyze the severity between the crashes and the frequency of occurances of the crashes since the vehicle lookup, path, speed and other factors may overlap. Hence dynamic segmentation identifies the unique partitions between the clusters of crashes and also identifies the homogeneous characteristics of the crash spots. Fig.5 (a) and Fig.5 (b). Illustrates the hotspots and Cold spots of the crashes in the study region. Furthermore the results from the ANN index can help us to identify the severity rate of the crash hotspots so that the maximum rate of severity can be included as necessary paths that must be covered during police dispatch. This study also discusses the possible police routes that can be established based on the results obtained from the ANN index results. Fig. 5 (c) depicts one of the results obtained from ArcGIS. The study resulted in reducing the crash rate to a considerable amount. A better approach of applying any form of genetic algorithm like best fit calculation which includes concepts of mutation and crossover and also considering the primary direction in future could help improve dispatching the police more efficiently and reducing the crashes to an even better rate.

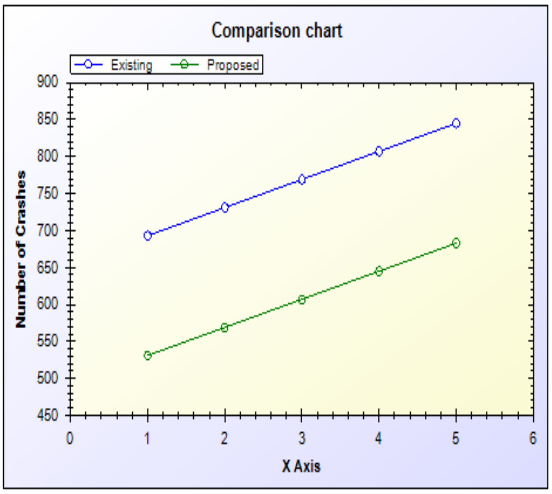

Figure 6 : Effectiveness Comparison

7. Conclusion and Suggestions

Most of the approaches employed in reducing crash rates only aimed at only reducing the dispatch time of the police enforcement to the areas of high crash severity. But the problem lies in the dynamic nature of the road characteristics, speed of the vehicle etc. Hence it would be difficult to establish a fixed and an optimal police route. To overcome this problem dynamic segmentation was used. But calculating the ANN values for each crash spot to identify the severity would be a tedious process. Future studies must take a note of this problem. In addition to this the time required to dispatch police exactly to the effect region should be notably considered. The driver's characteristics, small details such as traffic flow, speed limit, presence of lanes, pavement type, hit runs should also be considered to further examine the possible cause for occurrence of crashes to yield more efficient results.

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