International Journal of Remote Sensing & Geoscience (IJRSG)
www.ijrsg.com

GIS BASED CRIME HOTSPOT MAPPING AND ANALYSIS USING RADIAL BASIS FUNCTION (RBF) AND INTERPOLATION METHOD

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Abstract

Crime mapping has made rapid advances in recent years with regard to data availability and analytical techniques. One of the major actions that have to be performed by crime investigation department are mitigation of hot spot locations where the number of crimes happening more. Literature shows that Inverse Distance Weighted (IDW) interpolation method was used which does not consider the actual surface values of north south direction and the interpolated surface will reside outside the actual surface area .This method will lead to poor performance for analysing the hot spots. To overcome this problem Radial Basis Function (RBF) is used for considering actual surface values of all the four directions and then the interpolated surfaces will reside inside the bias (i.e within the actual surface area) and Triangulation with Linear interpolation method is to provide a flexible structure and also set of n points are computed in the plane. The experimental study by applying RBF proposes that the accuracy of crime mapping is being increased. In this work Quantum Geographic Information System (QGIS) tool is used to visualize, navigate, manipulate, and analyse geographic crime datasets.

Keywords: GIS, Crime Mapping, Crime Analysis, Interpolation method, QGIS tool

1. Introduction

The objective of this work is to design and implement the Geographic Information System (GIS) for crime mapping and to reduce the time factor in crime rate detection. The crime rate is increasing in all developing countries due to the poor socio, political, and environmental conditions. Police departments taking a preliminary action for safeguarding the citizen's and to extenuate the hotspot locations. It will take long time for the police department people to identify hotspot locations .For that crime prohibiting method was undertaken for reducing the criminal activity and to identify the hotspot location. In this work, combinations of Radial basis interpolation method and Triangular with linear interpolation method are used for crime analyzing and mapping using Geographic information system (GIS).The crime prediction is the first step for analyzing the present status of crime incidents and also identifies the highest incident areas of hotspots.

1.1. Geographic Information System (GIS)

Geographic Information System (GIS) uses geographical features and computer-generated maps as an interface for accessing enormous amount of locality based information. It allows police personnel in analyzing and mitigating the historical events to plan accordingly for emergency response, and to predict the future measures. It is used worldwide by police departments, both large and small, in providing visualized solutions for crime analysis and tracking criminals. Maps that displays the hot spot locations are very helpful in crime mapping for the police patrol to discover the places that they are most wanted.

2. Related Works

M.Ahmed and R.S.Salihu [1] proposed a geographical information system and spatial database of crime characteristics which was used to determine the hotspots. The crime was divided into four categories: offence against person, offence against property, offence against authority and offence against local act. ArcGIS version 9.3 was used for crime rate analysis. The buffer zones of 2Kms were analyzed in need of police stations.

Robert et al. [2] did survey across the domains of Criminology/Crime Analysis and GIScience/Cartography in order to characterize the current science of spatiotemporal crime analysis. The results of this study were used to design and implementation of spatiotemporal pattern of crime mapping called Geo VISTA Crime VIZ.

Dawei Wang et.al. [3] discussed the technique of Hotspot Mapping which is extensively used in analyzing the spatial characteristics of crimes. HOT is a use of spatial data mining to the field of hotspot mapping. The author recommended that the key component of HOT is meant for capturing the differences between two classes in a spatial dataset. Comparison studies with the Hot Spot Analysis tool implemented by EsriArcMap 10.1 validate that HOT is capable of precisely mapping crime hotspots.

Shahebaz M. Ansari and K.V.Kale [4] proposed a crime mapping and analyzing technique for various crimes such as Murder, Day House Break and Night House Break by using different classes of Hotspot detection such as Spatial Analysis, Interpolation and Spatial Autocorrelation for finding out the Crime Hotspot. The author made use of Kernel Density Estimation, Inverse Distance Weighted and Getis-OrdGi were used.

Toju Francis Balogun,[5] examined a crime situation in Benin metropolis using survey method to extract information from the public and the police. GIS was an effective management of crime in Nigeria. The study proves that GIS can give a better outlook for crime study, analysis of it, mapping, proactive decision making and prevention of crime. ILWIS, ArcGIS software and GPS were used for digital land use map screening the crime locations, crime geo-spatial database and spatial analysis.

Zhou et al. [6] proposed a web based crime analysis and mapping using geographical information system. The main objective of this work was to design and implement a Web-based crime mapping using four hotspot mapping techniques i.e., choropleth mapping, grid mapping, spatial ellipse mapping and kernel density mapping, were implemented in the system.

Francis Fajemirokun et al. [9] made use of Geographic Information System (GIS),an effective tool for crime mapping and management of crimes in Nigeria. GIS can be a very useful tool to display and apply spatial analysis to data, which reside in large databases, in order to obtain a strong visual appreciation of the patterns of crimes.

Kallum Dhillon, [10] developed several innovative methods and used them to geo-reference archival sources, in the quest to create a spatial picture of crime/criminality in Edwardian. The result illustrate that the historical GIS can be used to analyze crime/criminal interactions and provide researchers with an improved understanding of this social phenomena.

3. Spatio Temporal Databases

A spatiotemporal database is defined as a database which manages both time and space information of the object. A spatiotemporal object can be defined as an object that has at least one spatial and one temporal property. The spatial properties which includes location and geometry of the object. The temporal property is depicted as time interval of that object. The spatiotemporal object generally contains spatial, temporal and thematic or non-spatial attributes. Spatiotemporal data sets essentially confine changing values of spatial and thematic attributes over a period of time.

4. Crime Mapping

Maps offer crime analysts graphic representations of crime-related issues. An overview perspective of where and why the crimes take place and what type of crimes occurred can improve the process of tracking the crime hotspots. Mapping crime can help police personnel to protect people more effectively. Crime maps that display the high concentration of crimes can help in directing patrols to places they are most wanted. Policy makers in police departments might use more complex maps to monitor trends in criminal activity.

Display spatial patterns of events: Digital maps are the quickest means of visualizing the entire crime scenario. The locations of crime events can be routinely displayed on maps. This provides an easy method of viewing activities in an area rather than searching through a listing of events. Maps can also be used to convey more than one type of information at a time. Crime locations can be symbolized according to the day of week, type of crime, modus operandi (a particular suspect's method of operation when committing a crime) or frequency.

Integrate community characteristics: Community characteristics (for e.g., slums, markets, colleges, parks, alcohol permit locations, red light area, etc.) can be routinely displayed on maps while analyzing crime patterns to interpret relationship between these characteristics and the crime. For example, the locations of aggravated assaults, robberies and alcohol permits can be displayed to see if crime is clustering around locations that sell alcohol. Other mapping data such as bus routes and public housing can also be displayed at the same time to analyze relationships between neighborhood characteristics and crime.

Produce thematic maps: Maps can be produced at any geographic level (e.g. Police stations, divisions, or zones) to aid in the analysis of crime patterns. Each response area can be shaded to represent the number of crimes that occurred in that area during a specific time frame. The darker the shade, the more events that occurred within the response area. These thematic maps can also be used to show the change in an area's crime rate. The percent change in the number of crime incidents can be displayed by shading each area according to whether there was an increase, decrease or no change.

5. Crime Analysis

Crime Analysis is defined as a set of analytical processes which aims at providing timely information relative to crime patterns and trend correlations to aid the administrative personnel in planning the exploitation of resources for the prevention and control of criminal activities, aiding the investi-

gative process etc., It supports a number of police department functions in providing a best support for crime prevention and to carry out the investigations [13]. Crime analysis can be broadly divided into three categories as follows:

Tactical: This type of analysis can aid the police personnel in providing information that helps to assist operations personnel in identifying the crime trends and patterns, series of crimes, sprees and hotspots. This method generally associates the criminal activity with the information like date of crime, exact location of it along with the time of occurrence.

Strategic: This type of analysis is essentially used for the preparation of crime reports statistically. Hence this method is concerned with the crimes that are being handled for long time of investigation.

Administrative: This type of analysis which consider economic, geographic, or social information to administration.

6. Methodology

To implement the Hotspot detection method, the work flow employed as shown in the Figure1. In the first step dataset collection is the basic steps for implementation .The latitude and longitudinal values of the area fed in to the excel file .In the third step files are transformed to the GIS environment and the data are digitized and crimes are analyzed and mapped using interpolation method.

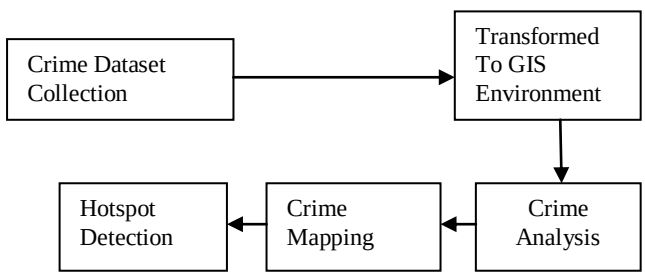

Figure 1. Hotspot detection

6.1 Data Acquisition

Crime data from any GIS could be computed in spatial and attribute or non-spatial data and there are various methods for obtaining these data.

6.1.1 Spatial and Non Spatial Data Acquisition

In Data acquisition crime mapping and analysis based GIS environment can be done by using Interpolation Method. The data were created in the form of latitude and longitudinal values of the given area and it was fed in to an excel file (Windows 2007). Later, the file was imported and transformed to GIS environment. In this work QGIS tool is used for crime mapping and analysis.

6.2 Interpolation Method

Interpolation methods are used to calculate the unknown distance of interested points by referring to higher distance information of neighboring points. Among various interpolation methods, Radial basis interpolation method and Triangular with linear interpolation method are used in combination [7] as shown in Figure 2.

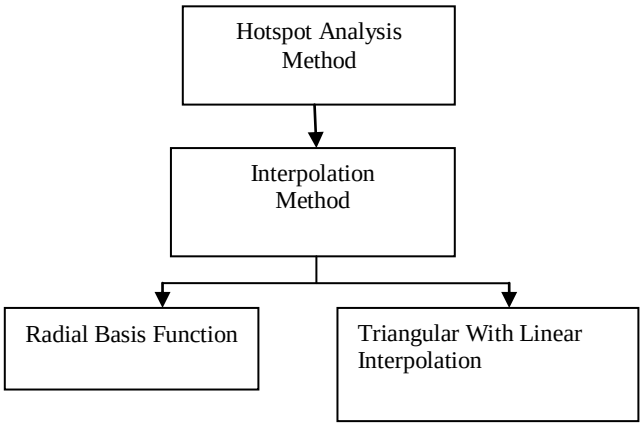

Figure 2. Hotspot analysis method

6.2 .1 Radial Basis Function and Triangular With Linear Interpolation Method

Radial Basis Functions (RBF) is one of the five deterministic interpolation techniques: An interpolator is one which predicts similar values with those values which is used to measure the similar point. RBF method estimates values that can vary above the maximum level or below the minimum of the estimated values and also it covers all the surface values of the direction (north south and east west) and it was interpolated surface will reside inside the bias [17].

In radial basis interpolation method, there is a framework that controls the smoothness of the effective surface. The result of this method that reduces the overall surface curvature, generating fully smooth surfaces.

The dissimilarity among them is slight, so the generated surfaces are almost same. A formula *f*, which minimizes the following factor, is an example of RBF technique and more specifically of the exact spline method:

$$A(f) + \sum_{i=1}^{n} W_i^2 [f(X_i) - Y(X_i)]^2 \quad (1)$$

Where, $y(xi)=z(xi)+\varepsilon(xi)$ is the source of stochastical error, where z is the measured value of an non spatial at point

xi and epsilon is the associated stochastical error. *A*(*f*) represents the flatten surface of the function *f* and the second term represents its proximity to the data .

Radial basis function approximation

Radial basis functions are normally used to build up function approximations is of the form

$$y(x) = \sum_{i=0}^{n} wi\emptyset(x - xi) \quad (2)$$

where the approximating function $y(x)$ is represented as a sum of N radial basis functions, each associated with a different center $_{xi}$, and weighted by an appropriate coefficient w_i. The weights w_i can be estimated by using the matrix methods of linear least squares, because the function is linear in the weights. Approximation schemes of this kind have been predominantly used in time series prediction and control of nonlinear systems exhibiting sufficiently simple chaotic behavior, 3D reconstruction in computer graphics (for example, hierarchical RBF and Pose Space Deformation).

Radial basis function mapping

Radial Basis Function (RBF) Mapping are working in the standard regression framework of function approximation, with a set of N training data points in a D dimensional input space, such that each input vector xp = {xi p : i =1,..., D} has a corresponding K dimensional target output t p = {tk p : k = 1,...,K}. The target outputs will generally be generated by some underlying functions gk (x) plus random noise. The goal is to approximate the gk (x) with functions yk (x) of the form

$$yk\ (x) = wkj\varphi\ j(x)$$

Concentrating on the case of Gaussian basis functions

$$\varphi\ j(x) = \exp -(\ x - \mu\ j\ )^2 / (2\sigma\ j)^{\ 2}$$

which have centers {μj} and widths {σj }. Naturally, the way to proceed is to develop a process for finding the appropriate values for M, {wkj}, {μij} and {σ j}.

Triangular with linear interpolation method

The Triangulation with Linear Interpolation method provides a flexible structure that can be computed set of n points in the plane. This method creates triangles by drawing line between the specified points. Triangulation with Linear Interpolation works best when the data are uniformly scattered over the grid area.

In this work, RBF and Triangular with linear interpolation method were combined for computing of two data points which are close to each other even if the crimes were extremely different , also it covers the actual surface values of all the four direction and then the interpolated surfaces will be plotted inside the actual surface area where the crime has been approximately done.

7. Experiment and Analysis

7.1 Performance evaluation

The performance evaluation is done to compare the effect of hot spot mitigation by both existing work and the proposed work. The comparison will be done based on some performance metrics called as precision, accuracy and recall.

Accuracy

Accuracy is defined as the percentage of correct prediction of hot spots which are happened in the different crime locations.

Accuracy is evaluated as,

$$\text{Accuracy} = \frac{(\text{True positive} + \text{True negative})}{(\text{True positive} + \text{True negative} + \text{False positive} + \text{False negative})}$$

Precision

Precision value is determined based on the retrieval of information at true positive prediction, false positive.

Precision =True Positive/ (True Positive + False Positive)

Recall

The Recall value is determined based on the retrieval of information at true positive prediction, false negative. Recall in this perspective is also referred to as the True Positive Rate. In that process the fraction of relevant instances that are retrieved.

Recall =True Positive / (True Positive + False Negative)

The performance evaluation graph of Precision, accuracy and Recall for Inverse Distance weighted and combination of Radial basis Function and triangular with linear interpolation method for each crime like cybercrime, dacoity, kidnap, rape, dowry death was shown below.

The precision comparison value of inverse distance weighted and the combined work of RBF and Triangular with linear interpolation method for crimes like cyber crime dacoity, kidnap, rape, dowrydeath is given in the below table 1, which shows the percentage for each crimes for both the Inverse Distance Weighted and combined work of Radial basis Function and Triangular with Linear interpolation method.

Table 1. Precision comparison

Crimes	Inverse Distance Weighted	RBF and Triangular With linear Interpolation method
Kidnap	81%	84%
Dowry death	83%	87%

Cybercrime	76%	96%
Dacoity	68%	91%
Rapes	67%	84%

The Figure 3 shows the overall precision comparison for IDW and combined work of RBF and Triangular with linear interpolation method. The precision comparison is compared from this graph RBF shows higher performance than IDW.

Figure 3. Precision comparison

The overall percentage for Precision value in IDW is 75% and RBF is 88% when comparing IDW and RBF. The Radial Basis Function shows better than approximation than the Inverse Distance Weighted Method.

The Recall comparison value of inverse distance weighted and the combined work of RBF and Triangular with linear interpolation method for crimes like cyber crime dacoity,kidnap,rape,dowrydeath is given table 2 which shows the percentage for each crimes for both the Inverse Distance Weighted and combined work of Radial basis Function and Triangular with Linear interpolation method.

Table 2 Recall comparison

Crimes	Inverse Distance Weighted	RBF and Triangular With linear Interpolation method
Kidnap	81%	84%
Dowry death	83%	87%
Cybercrime	68%	91%
Dacoity	76%	96%
Rapes	67%	84%

The Figure 4 shows the overall recall comparison for IDW and combined work of RBF and Triangular with linear interpolation method. The recall comparison is compared, from this graph RBF shows higher performance than IDW.

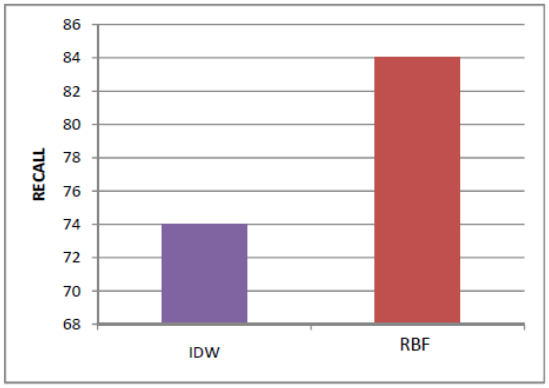

Figure 4. Recall comparison

The overall percentage for Recall value in IDW is 74% and RBF is 84% when comparing IDW and RBF .The Radial Basis Function shows better than approximation than the Inverse Distance Weighted Method.

The Table 3 shows the accuracy value of inverse distance weighted and the combined work of RBF and Triangular with linear interpolation method for crimes like cyber crime, dacoity, kidnap, rape, dowry death.

Table 3. Accuracy comparison

Crimes	Inverse Distance Weighted	RBF and Triangular With linear Interpolation method
Kidnap	76%	82%
Dowry death	72%	86%
Cybercrime	70%	84%
Dacoity	72%	84%
Rapes	78%	82%

The Figure 5 shows the overall accuracy value for IDW and combined work of RBF and Triangular with linear interpolation method. The horizontal and vertical line represents the accuracy value of each crime and methods. The accuracy is compared, from this graph RBF shows higher performance than IDW.

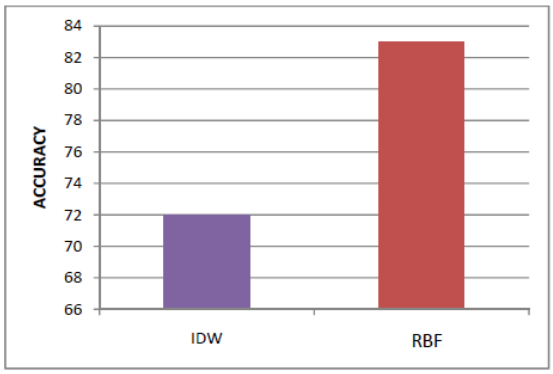

Figure 5. Accuracy Comparison

The overall percentage for accuracy value in IDW is 72% and RBF is 83%.when compared with IDW , RBF shows better approximation.

7.2. Result and Analysis

The data set consists of crimes likes kidnap, dowry death, cybercrime, dacoity and rape. Reports which are collected from crime info India for a period of 2 years. In the existing methodology IDW method does not consider the actual surface values of north south direction and then the interpolated surface mostly plotted outside the surface area where the crime was not committed and it is shown in the Figure 6.

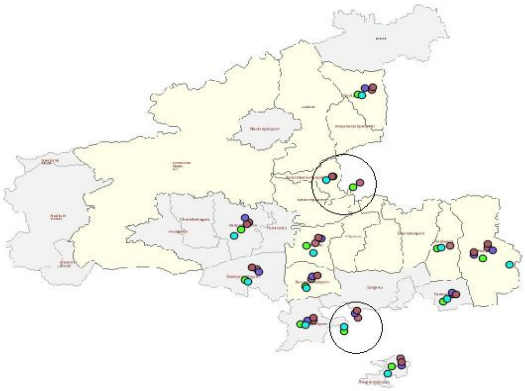

Figure 6. IDW in QGIS

From the above Figure 6, the circles mention the given crimes which were plotted outside the bias (actual surface area) where crime actually did not happen. By using combination of RBF and Triangular with linear interpolation method most of crimes were plotted within the actual surface area as shown in the below Figure 7.

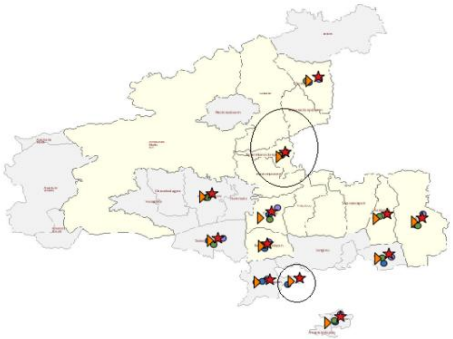

Figure 7. RBF and Triangular with linear interpolation method in QGIS

The Inverse Distance Weighted and combination of Radial basis Function and Triangular with linear interpolation method has been implemented in Quantum Geographical Information System (QGIS) plotted in Coimbatore north map using latitude and longitudinal values for the given areas of crime for efficient mapping and analysis.

8. Conclusion and Future Work

Crime mapping and analysis techniques are used to find crime hotspot locations. Implementations of Radial Basis function and Triangular with Linear interpolation method are combined to analyze the Hot spot location more approximately. This combined approach helps the police personnel to easily analyze the hotspots in a computerized form by which the frequent crime occurring areas can be protected more efficiently .In future work, Latent Dirichlet Analysis method may be used for analyzing most recent criminal Hotspots in an effective manner.

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