Geospatial Crime Analytics: A GIS-Based Approach Towards Prediction of Crime Hotspots

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Abstract

GIS has proven its proficiency in many fields but still require some more observations. The spatial interpolation which has seen widespread used in diverse domains with multiple applicability. Currently, some commercial GIS or analytics program packages now provide spatial interpolation technique including inverse distance weighting (IDW), kriging, triangulated irregular networks (TIN) interpolation, kernel density interpolation (KDE). Further, the two spatial autocorrelation techniques i.e., also known as LISA indicators that comprised of Moran's I and Getis-Ord G_i^* techniques. Amalgamation of spatial interpolation and spatial autocorrelation are being shown in this paper. For the implementation, related enabling technologies are summarized. Further, this paper entailed the literature survey of multiple papers comprising the associated works carried out in the domain of spatial interpolation and spatial autocorrelation areas of GIS. The proposed framework is a generalized framework with four tiers to realize geospatial systems. This paper scrutinized geospatial crime dataset for understanding the proposed framework realistically. Numerous results are produced to prove the efficiency of the proposed model. The paper entailed weighted-overlay analysis, symbological heatmap analysis, choropleth analysis, kernel density interpolation, and Getis-Ord G_i^* spatial autocorrelation analysis implemented to practically realize the essence of geospatial crime an-

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alytics. Finally, future research directions are recapitulated, where the task of interpolation and autocorrelation might be merged with techniques of artificial intelligence, machine learning, and cloud computing paradigm, serverless computing framework and many such in order to enhance the proposed structure with lessened restrictions.

Keywords: Geographic Information Systems (GIS), Weighted-Overlay, Choropleth Analysis, Kernel Density interpolation, Getis-Ord G_i^* Autocorrelation.

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1. Introduction

With the use of GIS (geographic information system), we can open up our own custom maps on our personal computers, or add new data to existing maps, each of which would give us the freedom to display several different ways of seeing or create additional map features are just and important as critical as data storage and maintenance, for the proper expansion of the amount of geographic information and thus making it easier to use (Geographic data Systems). It might be very recent, coming into being during the 1970s, but GIS has expanded tremendously over the years will be available to only to certain businesses and colleges who can afford expensive equipment to provide computerized geographic information systems (GIS). Today, almost anyone who has a personal device is using geo-coding tools, whether it's a desktop or a home computer. More recently, GIS applications have been made simpler to use. There's no need for a huge amounts of training; in fact, it is comparatively simple even for a novice and beginner users. GIS is no longer just software: managing and processing geographic information; it may also include managing and handling any and/all geographic information. //

Geographic Information Systems (GIS) has emerged as a prime technology is diverse domains such as disaster management, susceptibility assessment, epidemiological analysis and many such. In a cartographic viewpoint, GIS plays a key role in designing maps and corresponding vector files [1, 2, 3]. The proficiency of spatial interpolation techniques as well as spatial autocorrelation techniques in identifying heatmaps, hotspots, and coldspots has led to immense rage these days [4, 5]. Interpolation is a widely used method to classify data points in order to identify dense and sparse regions based on pseudo-color intensities [6]. Further, spatial autocorrelation techniques are used to identify risk zones (hotspots and coldspots) [7, 8].

As is critical in designing and making charts, it also has a crucial tasks when it comes to making vector files. To make an interpolation, we have to presume that the information is available, or as long as there is no available information we can use some mathematical tool to make an approximation. A often used strategy in expanding strings is to draw on distinct data to provide a more continuous form. And we switch from a vector to a raster, for interpolation. And, thus, input data can be in the form of a point, line, or it can be in the form of a waveforms. If we have identified these specific shapes on the computer graphics programmers have open, it's simple to take those contour points and translate them to continuous coordinates. We will have to expand on the definition of contour because our point representation, whether discrete or continuous, is required.

In GIS, spatial interpolation can be used to measure any surface property at a specified point, to create contours for viewing data graphically, and it's widely used as a tool in spatial decision-making processes including terrain analysis, hydrology, resource prospecting, hydrocarbon discovery, and crime analysis. Until going through various interpolation strategies, it's important to go through the variations in surface representation methods; each representation is useful in a particular circumstance. Furthermore, A grid representation of a surface is called a functional surface since it holds only a single z value rather than multiple z values for every given x, y position, and the surface values are constant rather than discrete.

The global expanders define a single feature which is applied to the entire field, for example, for trend surface illustration and example, for drawing an ascending or descending line trend. For example, the use of local interpolator's sample-weighted vectors is done repeatedly on a smaller subset of the total number of points, for instance, IDW. Exact interpolators preserve the input data while approximates allow for approximation. The more random approaches use the principle of non-fit surfaces (in several ways close to linear regression, including a best-fit plane) and the less random ones do not use probability theory. Other expanders allow for faults (such as those), and to appear inside the data, whereas the Smooth interpolators provide a smooth surface. Mathematical and numerical (and geometric) interpolation is two kinds of interpolation, one of which is linear and the other is non-linear. More importantly, interpolation strategies can be divided into the following five groups:

- Kriging is a geostatistical method for computing the magnitude of a random field (e.e. elevation, z) at an unknown position by interpolating between observed values. Daniel Krige's Master's thesis helped refine and improve the technique of interpolation and extrapolation, and was used by the French mathematician Georges Matheron in the analysis of their ideas. Global expansion is gradual, smooth, or sudden, or local; Kriging is stochastic, exact, or precise, or stochastic.

- Shortened inverse distance Point-weighted interpolation: This type of weighted average includes the weighting effect on the interpolation method: calculates cell values by combining the values in the neighborhood of the samples. To and subject cell value, an equal distance from the closer a point has in the cell, the formula, the more power or weight it has in the averaging.

- Spline Interpolation: This technique uses a mathematical function that avoids the effect of total curvature, and ensures that the input points lie on a smooth surface, allowing the calculated values to flow precisely through the points.

- Triangulated Irregular Network: The TIN (3D geodatabase) is a data structure that is used in GIS to illustrate a surface, meaning it's a distorted in shape and uses a geometric, equal-area Cartesian grid. or A, TINs can be produced by either by conversion of a functional surface data or by the application of a pattern recognition technique to another functional surface.

- Kernel Density Interpolation: Instead of using a parametric function for calculation of likelihood density and using it, K-nearest is an alternative that doesn't create a function for data smoothing. Spatial autocorrelation tests the association with its constituent values across the magnitude of the region under consideration.

The result of spatial autocorrelation can be either helpful or detrimental. While people are seeing the same experiences in the same locations, they appear to be in agreement; yet when circumstances are different, they tend to disagree.

- Moran's I: I believe that the most frequently employed strategy in spatial autocorrelation is I is ordinary world autocor (i.e. a unique combinations of events, each world, and native spatial autocor), Individuals of the American Indian descent, Native Americans may consider their quality of life to be good, may have higher cultural and financial standards than other people of the United States. Correlation coefficients in Moran arises from the whole universe of contrasts, which results in variances which are greater than those of the interaction between the 2 conjoint variables is measured in terms of their respective utility.

- Getis-Ord: In general Getis-Ord G can have a large value, which indicates a correlation for prime averages of the strength, while an occasional value indicates a correlation for low intensity values. It is important to provide spatial autocorrelation.

Since it's often interpreted as suggesting that there's anything of concern inside the distribution of map values that necessitates more analysis in order to comprehend the reasons for the discovered spatial variance, Furthermore, the existence of spatial autocorrelation means data redundancy, which has important repercussions for spatial knowledge processing methodology.

The rage of GIS technology in the domain of computer applications has led to immense applicability in sectors of disaster management, epidemiological analysis, susceptibility mapping and many such. This paper entails a novel strategy to converge spatial interpolation techniques with spatial autocorrelation methods in order to perform proper risk as well as zonal analysis. The proficiency of GIS technology has been recently proved in risk and zonal analysis of various prevailing epidemics as well as disasters and crime analysis. But, some lacunae still persists in providing predictive competency to the model. This paper tries to overcome such hurdles through a proposed framework on convergence of spatial interpolation and spatial autocorrelation. The outcome of the proposed framework is to provide appropriate risk analysis along with zonal analysis by identification of hotspots as well as coldspots.

This is a realistic representation of the system with geospatial analysis, or weighted overlay, weighted factors present the main challenge of measuring crime locations in the United States, particularly in the initial stage. In a region-specific way, a mapped weighted average shows crime per capita. To distinguish crime hotspots based on their severity, a symbological graded heat map was created where crime rate varies geographically few estimates are given. In addition, a choropleth map, which is simply a collection of evenly-spaced points joined to the vector dataset is shown. An obvious goal of geospatial crime analytics is to use kernel density to calculate the interpolation. The radius is set to 5 units and an interpolated map is created. Additional, Getis-Ord G_i^* , a local measure of spatial interaction, denotes spatial autocorrelation Spatially auto-correlated can be classified as hotspots and coldspots based on assigned zone scores. The findings reveal a well-grounded study of crime data on law enforcement procedures and other policies implemented in the U.S. in different areas. Often, the findings may be charted on a zone-based study of U.S. criminal statistics.

2. Related Works

2.1. Spatial Interpolation and Autocorrelation in Crime Hotspot Mapping

Ansari and Kale [9] discussed that Crime detection has been an important feature of GIS, where analysts utilized the geographical and temporal aspects of crime data for analysis and forecasting utilizing the Hotspot analysis method. A hotspot is a region where there is a high incidence of crime. There are many types of Hotspot detection techniques, including Spatial Analysis, Interpolation, and Spatial Autocorrelation, that can be used to locate a crime hotspot. The methods of Kernel Density Estimation, Inverse Distance Weighted, and Getis-Ord G_i^* from each class are explored in this article. These techniques were used in Aurangabad, Maharashtra, India, to identify hotspots for crime. Recent crimes indicate that the requirement for a massive expansion of facilities to detain criminals. Cops have an obligation to stay in a step ahead of the suspects, who are perpetually re-veining the field with police by trying to keep ahead of the lawbreakers, who always want to surpass their efforts. This paper proved that KDE (Kernel Density Estimation) and IDW (Inverse Distance Weighting) for spatial interpolation and Getis-Ord G_i^* for spatial autocorrelation are more precise than other techniques.

Kennao et al. [10] summed up that Policing authorities aren't good at forecasting where specific crimes will arise in the future; As a result, geography plays an important part in law enforcement and criminal justice. The author significantly highlighted the most identified crime in the police stations of Allahabad city via a thematic chart that police departments may use in this analysis. Author and the group decided by an interpolation process that a crime hotspot analysis chart would include information on offences. The police force must identify and describe sources of crimes for the information they want in order to stay ahead of criminal behavior patterns. The interpolation process (IDW) was used to create a hotspot chart to show the concentration of crime (both crimes against life and crimes against property) in each police station. The police department's crime problems necessitate the use of computerized crime mapping for research. Crime analysis plays a crucial role in devising solutions in formulating crime preventions strategies and crime problems. For the form of crime investigated in this paper, the jurisdictions of Doomanganj Police Station and Kernal Ganj Police Station need increased patrolling and successful steps.

Jakobi and podor [11] analysis aimed to determine whether human characteristics such as gender or age have an impact on crime fear, suggesting, for instances, that aged people are more fearful of things that young people are less afraid of, or that women might experience fear in different places than men. Using visual sketch maps and predictive GIS tools, this analysis analyses apprehension of crime experience and social crime statistics in a spatial sense. By analyzing the outcomes of selected big, medium, and small sized Hungarian towns, the research aimed to assess causal reasons for fear of crime. There was a web-application where people could identify locations on a chart where they felt secure, allowing them to track crime information that was available. To make these interactive maps comparable, GIS technology was used to process the results. Such items and others were mirrored by the grid-based model. According to the findings, there were papers of both coincidences and reverse associations between crime rates and perceptions of dangerous locations, demonstrating the role of location in crime fear study. Furthermore, the findings revealed that while the scale of the area or the gender of the respondent had no substantial impact on total judgments of locations, the absolute amount of protected markings and the local number of recorded crime incidents can have an impact on local outcomes.

Hu et al. [12] epitomized in the paper to track geographic distributions of historical crime cases and forecast possible crime trends, various spatial analysis approaches have been used. The first approach counts crime cases and then measures statistics based on regional areas including census units. The multivariate regression approach is then used to investigate the association between crime rates and a variety of crime attraction and inhibition factors, including social circumstances, community populations, land use types, cultural beliefs, and drug misuse records. In hotspot policing, predictive hotspot analysis is important. Existing techniques, such as the often used kernel density estimation (KDE), do not take the temporal component of crime into account. The article suggested a spatio-temporal system for predictive hotspot mapping and assessment, building on previous studies in related fields. In comparison to previous work in this area, the proposed structure has four significant characteristics:

- A spatio-temporal kernel density estimation (STKDE) technique is used to incorporate the temporal component into predictive hotspot mapping,
- a data-driven optimization technique called likelihood cross-validation is used to choose the most appropriate bandwidths,
- a statistical significance test is used to exclude false positives in the density estimates, and
- a brand new benchmark was commenced to project precision inventory .

Ristea et al. [13] have shown that society's level of real and suspected violence in metropolitan environments is critical and that of crime is crucial in maintaining a healthy community. It turns out the, that fear of crime occurs at a greater pace than recorded incidents of crime. Urban decay describes the issue where a neighbor-hood declines due to poverty and related issues. Geographic Information Science (GISc) and the use of geospatial technologies have greatly benefited spatial crime detection and perceived (crime) protection analysis. This paper used an innovative analytical methodology to chart the usage of new geospatial technology to investigate perceived community protection in Baton Rouge, Louisiana, through the lenses of fear of crime and crime interpretation. A survey, spatial video geonarrative (SVG) in the field with research subjects, and the extraction of moments of tension (MOS) from bio sensing wristbands are among the mixed techniques used. The participants in this research were 46 people who completed geonarratives and MOS identification. Here is a selection of ten of these geonarratives, Each participant was driven along a predetermined route in a car fitted with audio recording and spatial video while wearing Empatica E4 wristbands that measured three physiological variables, all of which were connected by timestamp. The findings reveal gender-based disparities in participants emotions (positive or negative) and MOS in the area. This mixed-methods approaches are promising for establishing links between real crime occurrences and neighborhood perceptions of crime in urban communities.

Yang [14] asked for four spatial trends in violent crime to travel to be analyzed:

- Analyses of street violence and learning environment patterns across schools since the safe passage program was established,
- creating a web-enabled mobile application to allow researchers and resi-

dents to collect and share GIS data on the situation,

- enhancing a research network of shared information about it, and using it to drive robotic vehicles to patrol these locations (to search for specific patterns and locations),
- undertaking a process to gather and analyze geo-referenced-maps of areas that will provide them with these findings.

Via this study the author discovered that, while the amount of secure routes have risen in these regions, hotspot rates for gun violence have also become worse over the years. GIS has then serves as a great foundation for community-based study initiatives. In his paper, Yang looked at gun-related shootings in each of the four communities. To that purpose, ArcGIS Online, a cloud-based visualization tool, was used to build maps for gun-related crime counts. It's important to communicate scientific findings or geospatial data with the general public because it allows them to engage in current studies in their communities. As a result of this study, an interactive map was created that included neighborhood services as well as the results of the spatial analysis and statistics. The author illustrated Numeric data with region details is transformed into spatial data with geographic coordinates using GIS-based charts. GIS is an excellent forum for both urban populations and academics, since it offers a geographic overview of group partnerships and hotspots, along with local infrastructure and crime statistics.

Ristea and Leitner [15] highlighted few research articles having devoted discussions to approaches that can address the question known police patrol route problems, the two main ones being traffic enforcement (the issue here) and population monitoring (the issue being ignored). Crime prevention and law enforcement are also needed because the police would make sure that no criminals are found, but can tend to crimes if they happen. They laid out the points, from the street (or neighborhood) down to the city of Milwaukee, arguing that if broken windows are not cleaned up, crime would increase (US). It is proposed that further study of this hypothesis is required for many factors that include:

- violent broken window enforcement against marginalized populations;
- disparities in crime intensity,
- disturbance styles and their dominance in crime; and ,
- the ethnic stratification in neighborhoods.

This study explored the question of whether there is a relationship between crime and disorder, as other studies in the authors have studied in the near past, but has focused on the different details, and found it to be only partly applicable. However, it seems that the result is to be restricted to public area disturbance, with a more powerful bearing on the second category of offences, which correlates with less severe violence in the community as a result, relationships with the city should resolve problems with neighborhood incivility are commonly practiced. The authors developed online and interactive maps,that be used to survey a variety of the communities that include these medium and small cities in Hungary, as well as Hungary's larger and smaller municipalities. The aim of this analysis was to find out why people perceive the safety in lab studies as important. Overall, the results are only quite mixed because of the similarities and disparities within studied metropolitan environments. It appears to be the residents opinions about safety and how often criminal activities happenings are happening which shape their beliefs about the security of a particular area. The cities and the scale do not seem to affect the judgment is insignificant in relation to the population size; on the other hand, gender is considered important for the total number of respondents Expanding on this, the findings show the significance of the local view in interpretation of protection testing. The author were studying the improvement in spatial precision for predicting crime in the case of burglaries in Wuhan Houkao involves analyzing an extension of related concepts. They put forward a more multidimensional crime model, as the standard one only accounts for temporal and spatial aspects, anisotropic diffusion (AnisDM), since it contains external variables, which are able to vary in location.

Mohammed and Baiee [16] explored that there are so many places where crime must be researched and studied for someone to examine and analyze it carefully in just one place. For the past few years, there has been an increased social, socioeconomic, and person dysfunction, which is having a measurable impact on crime rates. This has made the collection of information regarding crime more challenging than it was used to be as a result of modern practices and procedures being brought in to bear. Crime prevention can be aided by a great advancements in our day, including GIS and can be a helpful in providing alternative solutions to locate better solutions. The paper illustated an increase in crime rates in developed countries is mostly attributable to the uneven distribution of psychological and economic hardship. This study seeks to classify the crime-probation areas and examine the historical crime data to ascertain where criminal activity may concentrate during the next four years, with the goal of gauging their tendency to create crime patterns and predicting them spatially. Both of the author have put forward their efforts in Examination of crime data using GIS enables law enforcement to recognize and monitor trends that allow for flexibility in implementing spatial crime control strategies and makes it simple to visualize crime clusters and move the crimes from one area to another. The most helpful method of localizing the location of criminal incidents for crime trend identification is through means of GIS; a viable approaches to finding criminal hotspots include spatially expanding one's boundaries in order to criminal pattern details and crime correlation; detection of potential patterns is done by examining criminal incidents from a geographic perspective. Using spatial correlation, the Getis-Ord G_i^* resulted in the conclusion that the crime data are used to plot statistically relevant crime hotspots to find locations with high and low concentrations as well as identified less dense areas of criminal activity for increased detail with more effectiveness using a GIS. This study, with the help of the Grid network, was used to identify the danger locations of violence like Shooting, Homicide, and Assault as well as crime hotspots in the state of Baltimore, Maryland. The article explored that GIS is capable of visualizing and temporal relations including violence, such as incidence, in addition to spatial features, is often capable of being used to forecast events based on the method by which the areas are used. Ensconced with delivering understandable, real-life-world data in the decisions that enable multi-application comprehension, even those inside Defense, and in disaster scenarios, the foundation provides users with focused, practical applications. While dynamic or expandable Hotspot and zone maps can also be represented using Getis-Ord G_i^* these are generally considered dangerous.

Through this research Hashim et al. [17] attempted to identify high-risk areas for opioid activity hotspots to avoid accidents and improve emergency response times. When we use "hotspot" to describe a location with a higher density of information and it occurs in the geographic system, we use the term "geo". The first phase in the analyst's search for problems associated with drug distribution is locating these hotspots, when each area can or may be different from others. Use of visualization and statistical analysis of illicit drug use patterns can assist in locating the high concentration of users of illicit drugs in regional areas. In this research authors emphasized the drug use is much stronger and is affecting the population's well-being. people have a habit of concluding that approximately 133,684 to 1/4 (or 20,684 individuals) of the population in Malaysia is addicted to drugs. Furthermore, the federal prison population of 56% consists of individuals who are serving sentences for drug-connected crimes. This research is intended to classify the parts of Selor, Malaysia that are particularly problematic for opioid users. Using three separate statistical methods, kernel density (KDE), Getis-Ord Gi, and IDW mapping, the researchers aimed to illustrate the concentrations of opioid usage among the various addicts. The hotspot algorithm calculates density-depth curves using the Gaussian kernel density estimate (KDE), and Getis-Ord G_i^* and IDW. The findings indicated that there are eight statistically important areas with high rates of opioid use in the subdistricts (99% certain and p-value is less than 0.001). Although the investigation of drug hotspots utilising GIS methods has not yet concluded, the preliminary data already indicates that this is a very promising solution. The present research has implemented multi-dimensional GIS mapping on the hotspots for opioid use in an in order to elucidate a more complex geographic picture of them.

Achu and Rose [18] explored GIS analysis tells, the current level of crime , as well as its history and likely future trends. By using this study both the author enlightened that the incidence of crime is rising in developed countries owing to poverty and inequality. This research would look at the temporal and spatial variation in crime in Thiruvanthapuram over the time span of 2010 to 2014 to learn more about crime occurrence. Computer aided Geographic information tools like GIS, in addition to providing an increased level of detail for law enforcement, have the potential to draw up maps that enable them to find areas of criminal activity and papering, geographic correlation, is applied to the resulting hotspot patterns to determine the origin of crime hotspots, and interpolation is used to further pinpoint the location of criminal events among the others. Spatial auto-correlation has been conducted before in order to discover Getis-Ord G_i^* space anomalies and outlier phenomena previous to Getis-Ord G_i^* detecting trend analysis of spatial auto-correlation. Crime analysis utilises four key components, which include venue, timing, rates, factors, and types, in identifying areas where statistically important crimes are more likely to occur, then makes use of IDW interpolation to provide a stronger visualisation. One of the uses of this methods on the data from Thiruvanthapuram in Kerala is for the areas of high crime prevalence including manslaughter, robbery, stealing, and petty theft cases in that jurisdiction.

Rastogi et al. [19] signified the applications of GIS in crime visualization and crime detection and investigation are indispensable response capabilities are more commonly implemented using a combination of data from many organizations and outlets. Via an internet search of cases in police records, both through past observation, investigators may identify the suspects that have been recently been detained in certain areas and determine the crime's hot spots. The group explored that due to both a spike in violence and the social problems, there is a need for new ways to be developed to deal with this many measures have been put in place to lower the amount of crimes against women in towns, but many of these cities are also considered dangerous. The proposed study seeks to consider the socio-economic issues contributing to an increase in the risk of violence against women. Inverse-Weighted (IDW), Kriging, and Spline, and even, in order to explore the relationship between socio-economic characteristics and socio-emotional parameters on these maps more comprehensively. This is the best interpolation method: by using the best selected interpolation methodology, the thematic maps are generated to forecast the trend of criminal activity. Once the proposed architecture has been built using GIS and big data technologies, it can be implemented as a real-time decision-making method for helping those in need. True evidence is used to test the study's methods in the Jhunjhunu district of Rajasthan, India, and a case study is conducted to analyze it. It is captured by the group of authors that there is an increasing need for an atmosphere of safety in Indian cities.

Zahrane et al. [20] signified in studying the use of three distinct types of hotspot analysis to define and classify RTA hot spots and measure their impact on road traffic congestion, in order to arrive at reliable metrics for the resolution of congestion issues. We have three available approaches at our disposal: the Density (KDE) approach, which was recently endorsed by the Getis-Ord G_i^* , and the recently introduced cost-based Getis-Ord G_i^* , system (STA) approach, and the Getis- Ord G_i^* , procedure for calculating cost-related risk, as proposed in an expanding, both of integrating social risks in the model. Until analyzing the RTA data using any of these different approaches, they were first prepared in digital form in ArcGIS, and then imported into ESRI ArcSDE programme. Then, the actual safety measures (those listed above) are evaluated in relation to the places, the number, region, and value of the locations where the RTA is installed to find out the priority and cost/benefit of each measure has with each resulting metric. This article identified that in order to examine and determine the reason for these very long-term market fluctuations, a micro-level study might be needed. Thus, the methods presented above, especially in regard to stopping quickly with RTA expansion, have great value, but should not be pursued if an RTA expansion is detected. Immediately once they have identified a probable hotspot, the findings should be checked and subsequently, they can map out all the possible dangers that will lead to further collisions, so they can discover what will have the greatest impact.

Butt et al. [21] explored that many traffic-related incidents, the issue of present times, are the result of human error, rather than bad weather or hazardous conditions. The author Butt and group manifested in knowing where the worst locations for car accidents and taking preventative measures to ensure they do not occur is vital for traffic protection in the following year. The RTA wanted to create a list of places with increased traffic risk and then monitor it over time in order to identify areas that were more prone to accidents for five years in Rawindi, in this case the GIS was utilized to research the extent of the potential areas with greater danger of road mishaps. The method was utilized for the aforementioned reason was the one established by Morans I and Getis-Ord G_i^* method on the data gathered from the Punjab Emergency Department. Most places marked for expansion and significant to the analysis in terms of spatial clusters were concentrated in the northern and northeastern portions of the city neighborhoods, which often included both industrial and residential areas, although most hotspots representing an accident were found in locations near colleges, airports and highways. This paper pronounced that an Early warning system (or early detection system) using geographic information systems can help to reduce the amount of resources needed to respond to a crisis.

2.2. Geo-spatial Operations For Crime Visualization

Dede et al. [22] conducted a research project with the researchers and computer programmers in Bandung hopes of gaining different knowledge on crime location and then exploring the possibilities of identifying danger distribution by means of GIS. A number of statistical methods are used to quantitatively determine the factor values and/ from that, under which of the above quantitative tests, a set of deciles, the law is drawn to figure out the value distribution By applying GIS program, a formula needs to calculate crime rate (or score) and meaning (or weight) to various factors, such as the dispersion and population density, Eastman would be able to obtain overlay results for Bandung. The author and group analyzed that any of the factors contributing to Bandung's crime rates include history, public services, the availability of property, the amount of roads, as well as the density of the community, along with issues concerning the inequality of the poverty distribution using of GIS means that the location of most criminal activity. This puts a crime-risk at the agglomeration in the centre and western Bandung, because the region has been prioritized as a police concern.

Lee et al. [23] the aim of the research was to understand the existing criminal population's habits and behavior patterns in order to allow new solutions to be proposed; it commenced by studying and understanding the criminological patterns that had already been established in other cities, later on conducted some research in this area to determine where the root causes of crime can be found; it developed methods to classify the current CCTV-based causes of crime for solution; and at the same time, provided diagnostic recommendations. Looking at the crime features, aquatic and stationary populations, as well as crime locations, it was discovered that the floating population had the greatest density of all in and of the places where it occurs. This paper explored that the need for Korean people to feel secure and protected has increased, resulting in the nation pursuing long-long-term strategies for constructing safe cities as a matter of priority. In order to deter urban crime, it is essential to learn as much as possible about the everyday life of urban citizens, as well as about the locations and features of the city where they live. According to this paper this result supports the idea that floating population data should be used in lieu of actual population data, as the difficulties in collecting such data has previously been cited as a problem. One big arterial roadway expansion after another and City A's new residential developments focused on them, resulting in the rapid growth of a floating community along these arteries. these places, as a hotspot for violence, are the crime areas in these cities being associated with people who stay by the water or in flotation's, as well as the frequent place "anchor" points for criminals, which could be reason for installing CCTVs and other crime-prevention tactics including increased police patrols Instead, however, places prone to violence seem to concentrate further such where it is most visible as a direct results of individual events, with most of the changes in the people's everyday lives (i.e. over the course of time while they're working, socializing, or shopping).

Faisal and Shaker [24] turn inside out that socially speaking, urban environmental quality can be described as a description of how urban, environmentally, the climate, and in terms of socio-economic factors are doing. A few partial attempts have been tried with a multi-temporal and multi-resolution data in the past, as these datasets give a clear picture of both visual and understand land cover (to) water coverage and vegetation patterns in urban areas which helps identify further patterns and patterns of usage and develop more extensive detail in the Urban EQ assessment does so, as well, being thus more beneficial to sustainable development and urban planning. They signified into that the United Nations has predicted that the world population would double in the planet within the next forty years, and have an effect on the atmosphere and human well-being. The goal of this research was to use GIS and remote sensing to analyze the UEQ with an in the case of Toronto, to gain a better understanding of the impact of various natural, urban, and socioeconomic conditions on data-related trends. There was then a need to gather and monitor natural, urban, and socioeconomic data, as well as geography information using remote sensing, and GIS technology. To measure the effects, they collected comparison data and examined the UEQ relationship to see how that it affects the quality of the test's outcomes. More precisions and accuracies, at 71% and 65%, are recorded by the GIS technique. This project would provide the municipality with a generic metric to assist with preparing with regard to all educational, environmental, and urban requirements where you might have a few other kinds of results to monitor. Both the authors explored that via the use of two different methods:

- GIS overlay (on a map) and,
- PCA, the results of this research aimed to evaluate the correlation of UEQ with the study location in the city of Toronto, Canada.

Srivas and Khot [25] discussed a variety of tools and methods for multi-dimensional database and visualizations that are available for complex data sets. In this article they mainly covered the popular open source Quantum GIS (QGIS) visualization tool which works well with several different visualization functions, as well as complex data types and data models. They are mostly used for obtaining several representations of records, unions and combination of numbers, but can also be used for data extraction and numerous other processes. A bonus aspect that the consumer may take advantage of is the greater precision of the software is Edit Spatial Information and exporting maps to and diagrams. The software application of GIS is well suited for creating geospatial decision support systems (DSS). The process of collecting a vast volume of spatial data takes a lot of time and resources. Research has resulted in different techniques for spatially enhanced research which are quicker and provide improved analysis outcomes in lessening the amount of time spent on its completion. The Spatial Data Management box offers a wide range of resources that are made available for generating, managing, and managing, and fixing problems, as well as for growth, design, management, and advancement, by using function datasets.

Jefferson [26] made use of a mixed-methods methodology, taking into account work with the Predictive Analytics, as well as analytical documentation pertaining to city-planning documents from the police, to examine the role of predictive technology in co-prediction on complex problem-solving with the socialized policing. Indeed, there is a rising number of geospatial intelligence specialists and law enforcement agencies as well as well as criminal justice departments that see GIS and predictive analytics playing a role in improving police targeting to "to placing a focus on the arrest of criminals at particular places rather than on "groups of persons or geographies. The author signified with the added consideration of temporal factors, these Chicago researchers are investigating the dynamics of department partnerships, including geographical intelligence scientists and police experts who are presently collecting time-based data and spatial information in GIS maps to determine where potential criminal activity will arise. The author focused on important police-distant policing as well as well as on societal spatial dynamics to learn more about the extent to which predictive crime mapping has on shared data strategies.

Jayakrishnan and Shook [27] demonstrated how spatial simulation methods can be used to extend spatiotemporal analysis methods to the general case on massive datasets. A separate parallel calculator was created to help our team keep track of their work for ensuring its continuous improvement, which was then compared to an existing one to track of the same purpose, real crime data analysis was used as well as established tools to help in understanding how scalable it is, and an assessment of performance gains occurred in this latter function. Both the author highlighted Crimes, by their nature, are spatial phenomena, and in terms of its locations, are temporal phenomena repetitive, descriptive, describing, and objectively measuring the locations and time intervals of criminal activity are used to classify, characterize, and document spatial-temporal trends of criminal activity. Similar speech about criminal behavior improves comprehension of commutability as well as spatial and temporal relationships.

This article explored this as something that is well suited to temporal studies because it provides spatially referenced crime data, or spatial correlations, enabling crime data to be mapped out in time and determining the actual relationship between them.

2.3. Crime Hotspot Prediction

Yang et al. [28] delve into a large percentage of people, such as the general public, are affected by crime in a negative way. Previously, hotspot prediction has been proposed as a means to expand law enforcement jurisdiction. There are different ways of predicting which metropolitan regions are crime magnets, some of which depend on data analysis of historical incidents and events, and others which don't. It is only available through the current methods, though, that have shown to have the ability to classify hotspots based on the past history of crime. None, however, have shown the predictive potential of the more recent analyses of social and urban evidence. The author and group presented this study in which we outline Crime Telescope, a visual platform combining various kinds of data which employs both prediction and visualization to examine crime hotspots If the initial set of data is obtained, it searches for core properties in the data through mathematical and linguistic study. Lastly, it gathers data from various places and allows users to zoom in on them on a digital map to find specific locations with highlighted risk areas. The paper prospected that urban councils ought to do not only to enhance the protection of city neighborhoods but also to help the environment of the towns and cities where they live in. They turned inside out that a picture used to find locations with a significant rise in crime incidents, and then a dot or line indicates an area's relationship to other dots in the chart and their general location on the image, as criminologists use it in this context (i.e., crime hotspots). If police and city governments want to find out where the violence occurs in cities, they need to use a high-predictive "hot spots" chart that more closely matches actual areas where crime already occurs with risk factors.

Chainey [29] signified that a hotspot mapping strategy is also employed for assisting police with enforcement activities including directing patrols to certain areas where they are needed and lowering crime. Histogram approximation is still has long been used, but in modern times there are several alternative methods that have emerged, which seem to be more common is KDE. Known because of the unique graphical representation of crime visualization and is the most closely followed by government crime analysts, which uses the density of land mapping is that KDE also incorporates is considered with other hotspot mapping techniques. Entering values for two key parameters in the command produces two kinds of output: cell size and bandwidth must be done to achieve KDE results. The few studies that have been done have looked at these to date on their influences have so far have only looked into their general hotspot-mapping purposes. No study has yet looked at the function of these criteria on a hotspot chart, although it can be assumed that these may be used to see where crime occurs in the future. This studies helped to fill this void by utilizing information on various cell sizes and statistics on crimes committed by people with separate from the population on residential robbery and abuse. This study established that a null influence relationship between cell size and crime hotspots on spatial trends of crime, but wireless capacity does impact crime. In the end, we will be addressing how the findings of this research can enable the police and researchers to improve the way we use KDE for criminal investigation. The author explored that Not only has the introduction of heat mapping, but even the use of hot-spot policing is credited with the birth of this new approach.

Araujo et al. [30] highlighted the use of an algorithmically an infrastructure architecture, which can then be implemented to service current and future public protection networks and channels. The system is based on the ROTA strategy, with public safety initiatives as its background, which was devised for the greater purpose of improving urban services in Brazil's new African metropolis, Natal. The results of an experiment gave valuable information regarding the various estimators. Furthermore, the outcomes of the algorithm selection test on the hotspot detection challenge shown by executing a simulation. The author suggested a statistical method for detecting hotspots that addresses geographical, temporal, and categorical configurations of crime utilizing machine learning algorithms that are more specifically calibrated for average danger levels. This architecture is applied as a service using the algorithm as an API. The structure is able to accommodate many data streams, has several different ways of seeing, offers a wide range of specifications, which allows for machine learning to be included, and includes the use of an algorithmic decision making. The system produces an efficient artifact for the process of developing and maintaining patrols, called a program card. Author and the group explored that a significant amount of research has shown that the possibility of predictive analyses leading to higher accuracy in identifying patterns and predictions of crime patterns has been explored through using quantitative experiments. The use of a novel portfolio of machine learning algorithms offers a mechanism that more specifically identifies locations and periods when law enforcement officers might be at greater risk of being targeted, allowing them to adjust their schedules to certain instances with more exactitude.

Kang & Kang [31] signified to increase the accuracy of criminal activity modeling; they investigated the design of protective factors, for example, the principle of broken windows and the use of environmental protection measures. To present this article, they have come up with a data fusion approach that takes the text and contextual information into account, which utilizes a deep neural network (DNN). They did a comparative analysis of the interactions to see whether crime occurrences were correlated with the results of the study. This process allowed for an excellent and successful forecast of crime patterns to be made, as deviants harm the prediction. It is a multi-modal prediction model and suggested here that they shall use to make more reliable estimates of criminal activities. The dataset of this article was compiled from numerous Chicago, Illinois web datasets, such as violence, demographic, and meteorological and photographic/archaeological information, as well as photos and photographs of the city. First, Authors did some statistical analysis on crime-making patterns before training the model with crime-related evidence. With spatial, temporal, environmental, and function dependencies, our DNN additionally consists of four layers: spatial, temporal, environmental, meaning, and joint feature representation. Coupled with the pertinent data from different contexts, our analytics is an efficient decision-making process that employs data redundancy analysis, our DNN integration is an effective way to glean critical insights.

Macbeth & Ariel [32] explored that the first phase of a proactive hot spots policing approach was the effective detection of crimes that have been occurring for a long time and can be expected to continue. The second stage is managing any crime that is changing or appearing for the first time; such issues cannot be defined as hot spots, since they are still volatile and inconsistent. Based on research this document indicated where violence is likely to occur, "recidive hot zones" is observed to focus more specifically. when using this location feature, statistical forecasts will serve as a kind of professional judgment as a "experts" about whether an idea has promise, through how well it would do in various places. Although well-positioned predictive "hot spots" and "hurricane damage" forecast possible events of coastal flooding, just 50% of the paths are marked correctly" Business and political judgment will erroneously locates future crimes, and is more suitable for handling incidents of a criminal nature. Recidivism is a significant, however only one is relevant since it is characterized as a "a hot spot on the map": it is the precise region in microdot locations.

Lin et al. [33] enlightened that grid-based crime modeling and spatio-temporal details provided by the Google's Places API was used to show a variety of temporal and spatial characteristics in Taoyuan City, Taiwan. In the first place, the authors have examined two traditional approaches: a spatial-temporal and an empirical model. The use of spatial and temporal models is widely accepted as being effective for crime reduction, including Kernel Density

(KD) and Time Series. They expanded on sentence: These two approaches only deal with time or space only, but crime is significantly influenced by a lot of other variables. Due to the centralized data processing and grid-based reasoning, machine learning is particularly useful for grid-based crime prediction. The most accurate model was learned to be a new Deep Neural Networks classifier, which was found to outperform Support Vector Machines, Random Decision Forests, and K-Nearest Neighbor algorithms. By comparing our F1 scores to a base scores, the design' 100-baseline 100-month moving average, they found that our performance increased by around 7% (meaning its top score improved). This article proved that their design outperforms the standard by being more effective at locating crime displacement in the designs. In this case, they described "generally" as the process of creating new algorithms, or "typically" of improving feature design model efficiency to raise model accuracy,whereas kernel density estimation (high pattern-level estimation) models which often look for blocks and distributions (predictions resulting from) diminishing data.

The extensive literature survey performed on diverse techniques of spatial interpolation and autocorrelation techniques present that no convergence has been observed till now. This paper provides a proposed framework which presents a novelty in the domain of GIS which shall have immense applicability in diverse domains. It can be observed that Kriging interpolation and kernel density interpolation are widely used interpolation techniques in GIS. Further, Getis-Ord G_i^* also is a popularly used tool in the domain of crime analysis since it provides hotspots and coldspots in a very efficient manner.

3. Materials and Methods

3.1. Proposed Framework

The proposed framework is a four-tiered architecture represented in Figure 1 which epitomizes the implementation of spatial interpolation techniques converged with spatial autocorrelation features. The primary tier i.e., the geospatial data pre-processing tier serves the most inevitable part of the implementation framework. Since, the data available have multiple lacunae such as missing values, noise and many such. To deal with such data we need to pre-process the dataset. Since, we are dealing with spatial interpolation as well as autocorrelation, we require the creation of vector files i.e., in ".shp" format (also called as shape files). Further, missing values can be handled by either properly filling the values or by instantiating the values with a common name like N/A, Null, etc. Further, in cases where we are required to use non-geospatial data i.e., data with no coordinate specifications, we need to perform geo-coding operation where automatically the dataset is filled with latitude and longitude values which makes the dataset geospatially compatible. The second tier comprises of the vector analysis tier where initially we need to join a common attribute of the vector file and the considered dataset in order to make the vector file suitable for further analysis. Then, we need to generate choropleth map in order to classify diverse zones based on the specific classifiable attribute. A graduated color map is generated where we are required to fix the range of the classifiable attribute based on which color allocation will take place. After the choropleth with proper rane fixation is done, the next layer needs to be implemented.

The interpolation tier deals with diverse interpolation methods. We need to specify radius at which interpolation shall be carried out. Further, shape of interpolation also needs to be specified based on the application domain. For, TIN interpolation there exists two interpolation attributes i.e, linear and Clough-Toucher (cubic). Further, for IDW interpolation we require distance attribute only. Also, for kernel density interpolation we need to specify the kernel shape i.e., either quartic (bi-weight), triangular, tri-weight, uniform or Epanechnikov. After the interpolation is successfully implemented over the vector file, we need to perform autocorrelation which is epitomized in the subsequent tier.

The fourth tier deals with spatial autocorrelation implementation. We need to specify the LISA indicator which stands for local indicators of spatial association. There are two types of LISA indicators existing in GIS i.e., Moran's I and Getis-Ord G_i^*. Moran's I is used in case of identifying correlation among two data points whereas Getis-Ord G_i^* is used to find hotspots i.e., highly dense regions as well as coldspots i.e, lowest dense regions. In order to perform the task of autocorrelation we need to specify the spatial weight matrix which are of types : queen, rook, bishop, distance and nearest neighbors. After, the autocorrelation is performed we observe a graduated map providing $p-$values as well as $z-$scores.

The output is a weighted-overlay map, heatmap, choropleth map classified according to the considered attribute, an interpolated map, spatial autocorrelation map providing proper zonal analysis and corresponding $p-$values and $z-$scores.

3.2. Dataset Specification

The data collected from [34] comprised of 15 columns and 2,829 rows i.e., a total of 42,435 instances which comprised crime statistics from 1975 till 2015. We have reduced the number of instances as per our implementation convenience. The modified dataset comprised of 16 columns and 414 rows i.e., a total of 6,624 instances that comprised of crime statistics from 2010 till 2015. Also, the base data didn't have latitude and longitude values and thus, the modified data has been geocoded to automatically allocate latitude and longitude values to each row. Also, since it becomes difficult to join the dataset with the vector shape file if joining attribute is not properly designed, this led towards adding one more column to the modified dataset that entailed provinces to which the regions belong to. Thus, the final dataset was made geospatially compatible in order to perform geospatial crime analytics over it. The prime attributes i.e., selected during the implementation phase includes number of violent crimes, latitude, longitude, crime per capita, and region. The term "crime per capita" means the ratio of number of violent crimes to the total population in a region-wise fashion.

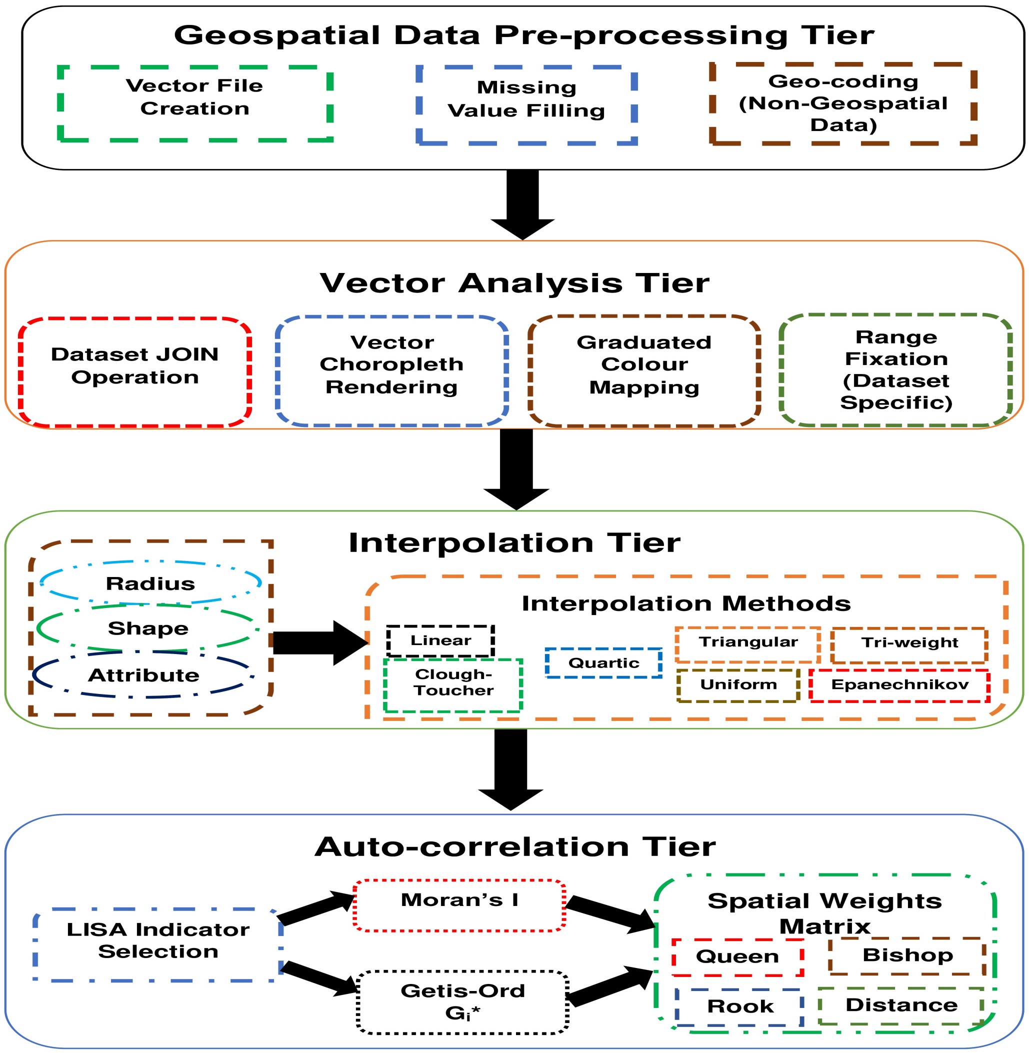

Figure 1: 4-tiered proposed framework for geospatial analytical implementation in context of spatial interpolation and autocorrelation.

3.3. Experimental Setup

The machine on which the experimentation has been performed includes hardware specifications as 1 TB hard disk drive (HDD), 4 GB random access memory (RAM), Intel Core i3 processor, and 2GB graphics card. The software tools used for the desired implementation is QGIS 3.12 Bucuresti. For dataset modification, the tool used is Microsoft Excel. Also, in order to perform the geocoding operation on the dataset, Google Sheets were used with GeoCode package so as to allocate geographical coordinates to each region automatically by retrieving it from Google.

4. Results and Discussion

This chapter entails all the results obtained by practically realizing the proposed framework. Figure 2 presents the initial task of geospatial crime analytics i.e., weighted-overlay analysis with labels signifying regions in diffenent provinces of U.S.A. where crime has been reported as per the considered dataset. Further, to visualize crime per capita in a region-wise fashion, a weighted-overlay map has been labelled with the crime statistics in Figure 3. Further, to identify crime hotspots based on crime per capita parameter, a symbological graduated heatmap has been designed where based on color intensity the density of crime can be visualized in diverse regions of U.S.A. The heatmap is presented in Figure 4. Further, a vector analysis, i.e., a choropleth map is designed after joining the vector layer with the dataset and properly labelling it in equal intervals is presented in Figure 5. Finally, the prime motto of geospatial crime analytics is fulfilled by performing interpolation implementation with the assistance of kernel density estimation. The radius is set to 5 units and kernel function set to "quartic", an interpolated map is obtained which is represented in Figure 6. Further, Getis-Ord G_i^* which is a local indicator of spatial association, used to signify spatial autocorrelation is implemented. Based on the $z-$scores obtained, the map is autocorrelated spatially. The regions can be identified as hotspot or coldspot based on the color code allocated as per specific $z-$scores. The spatial autocorrelation analysis is presented in Figure 7.

The results presented shows a detailed analysis of crime statistics in diverse regions of U.S.A. based on which police patrolling, and other preventive measures can be taken in the regions which are identified as crime hotspots. Further, the results also can be visualized as a zonal analysis of crime parameters in the regions of U.S.A. based on which risk analysis can also be done.

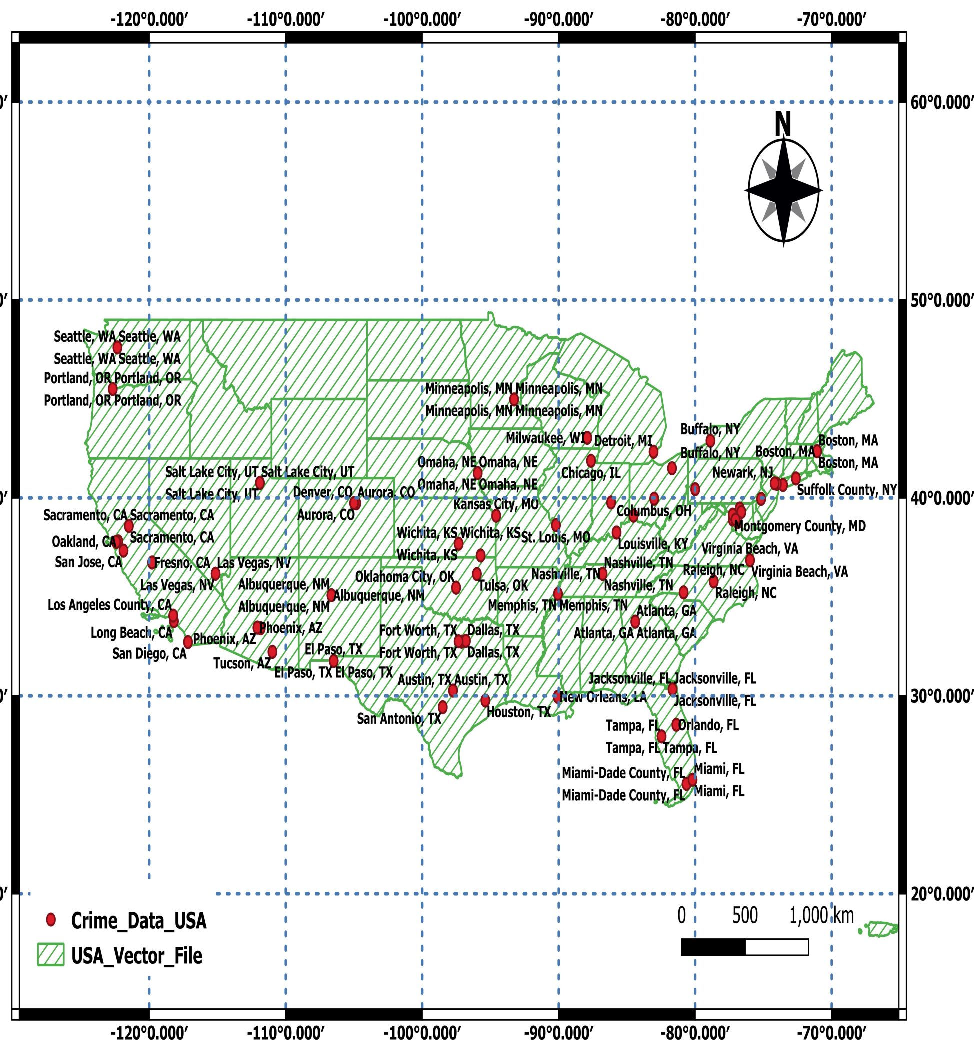

Figure 2: Weighted-Overlay analysis labelled with regions of crime in USA.

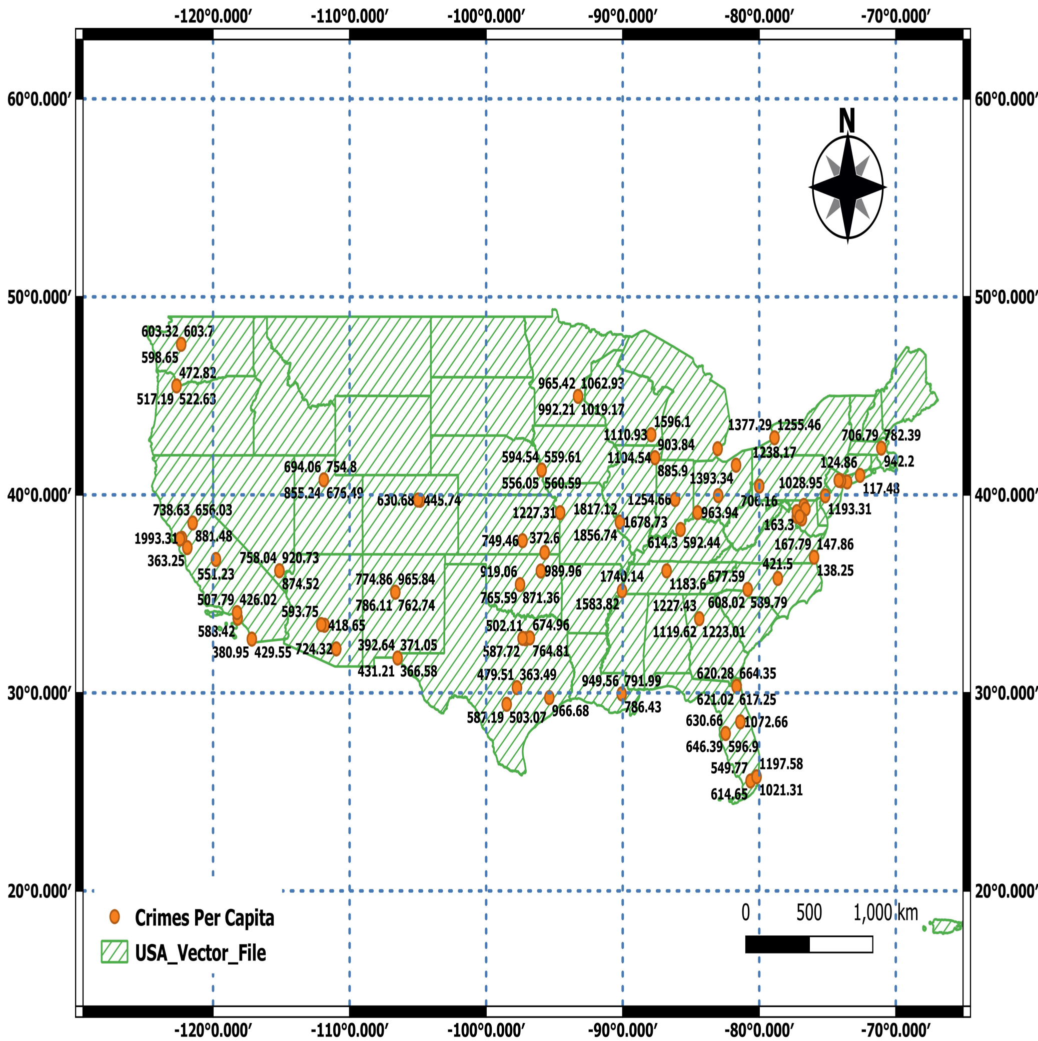

Figure 3: Weighted-Overlay analysis representing crime per capita in a region-wise fashion over USA vector file.

5. Challenges

There are few challenges which has been encountered during the phase of implementation which includes:

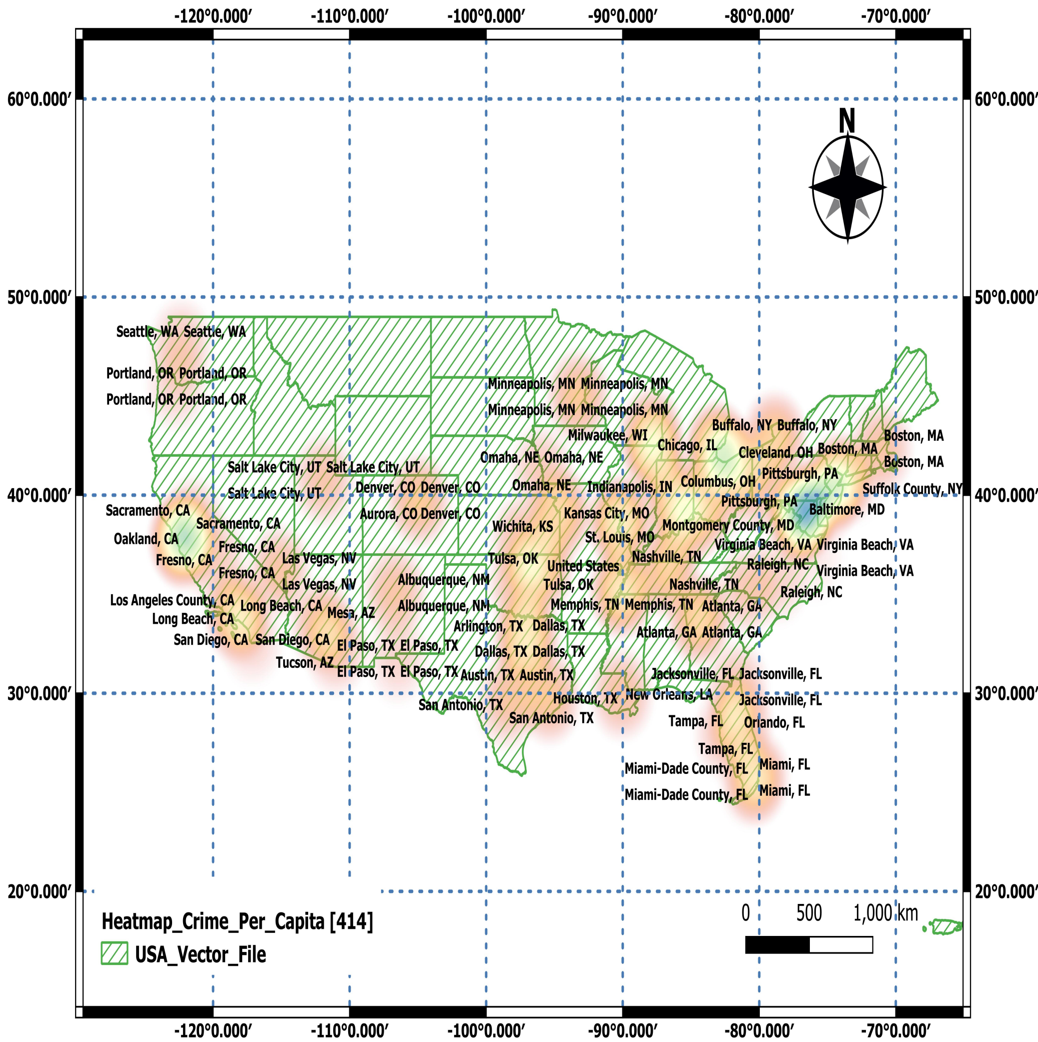

Figure 4: Symobological graduated heatmap analysis to identify crime hotspots in USA based on historical data.

- Dealing with geospatial big data is still a major challenge with local engines which makes the geospatial big data analytics task a hectic one.
- Switching to cloud GIS for real-time implementation requires much resource to be allocated and its equivalent cost constraints. This challenge

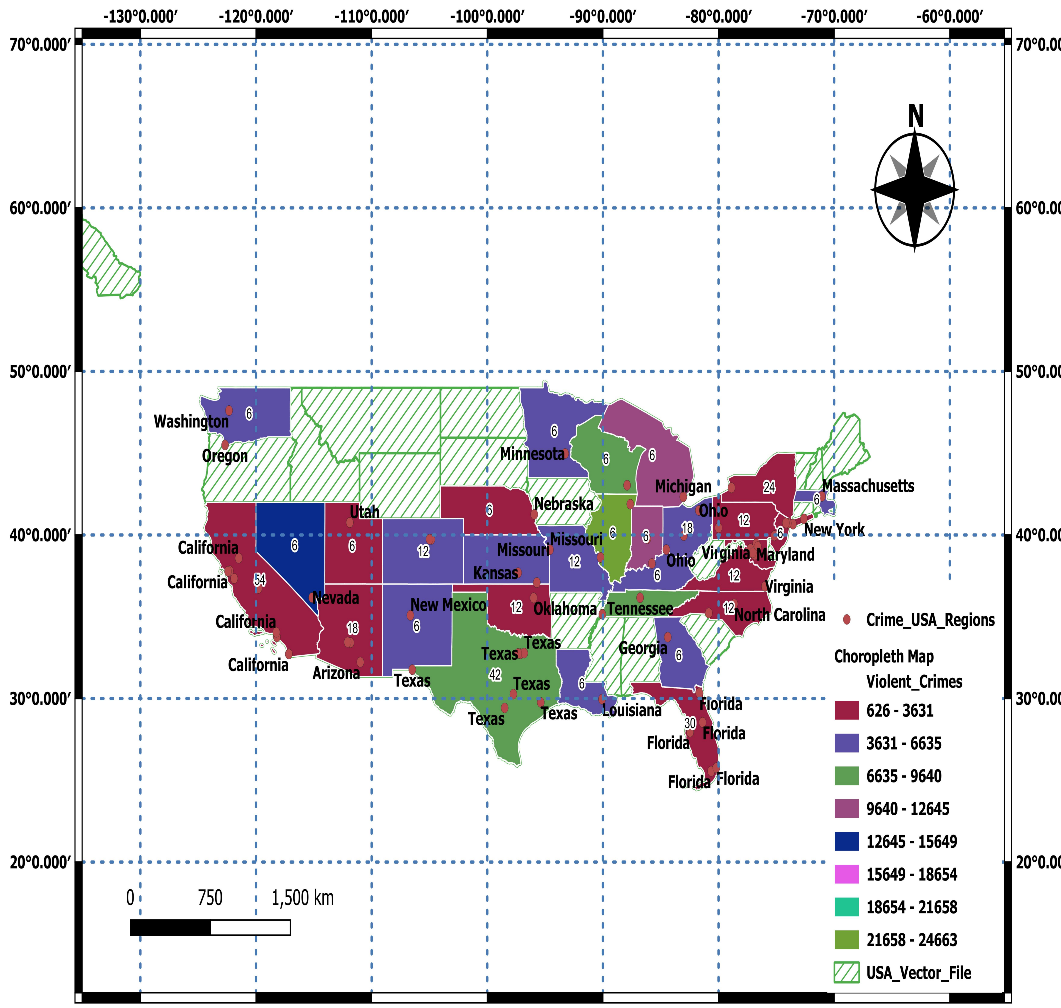

Figure 5: Choropleth analysis performed by graduating regions based on crime statistics.

can be overcame with serverless computing paradigm.

- Many machine learning tasks are used which are traditional like K-Means clustering, DBSCAN clustering, and many such which reduces the predictive competency of the geospatial model. It can be tackled with the

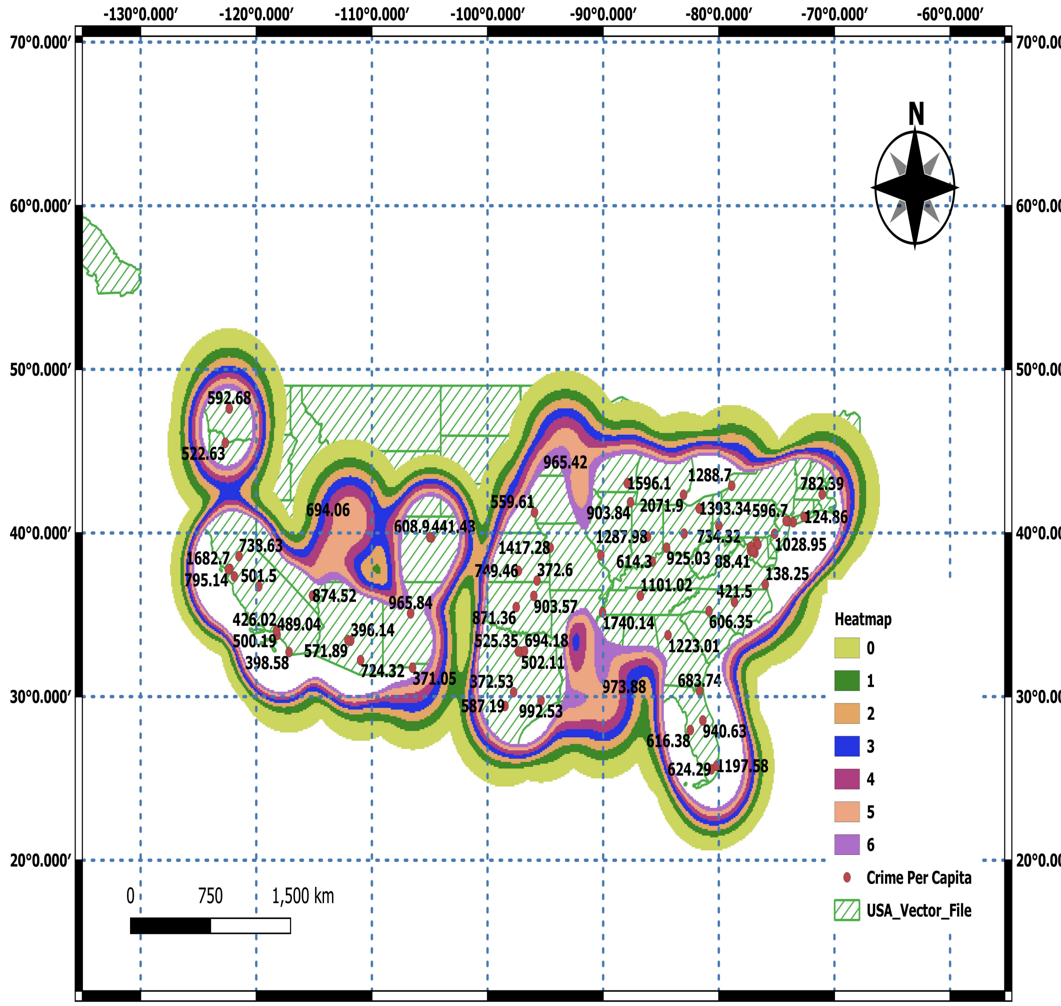

Figure 6: Kernel density estimation performed with radius 5 units and quartic functionality to visualize spatial interpolation.

advent of deep learning models.

- Crime hotspots could be predicted through this dissertation but to predict where next crime is going to happen requires much more powerful model since crime is an unprecedented event.

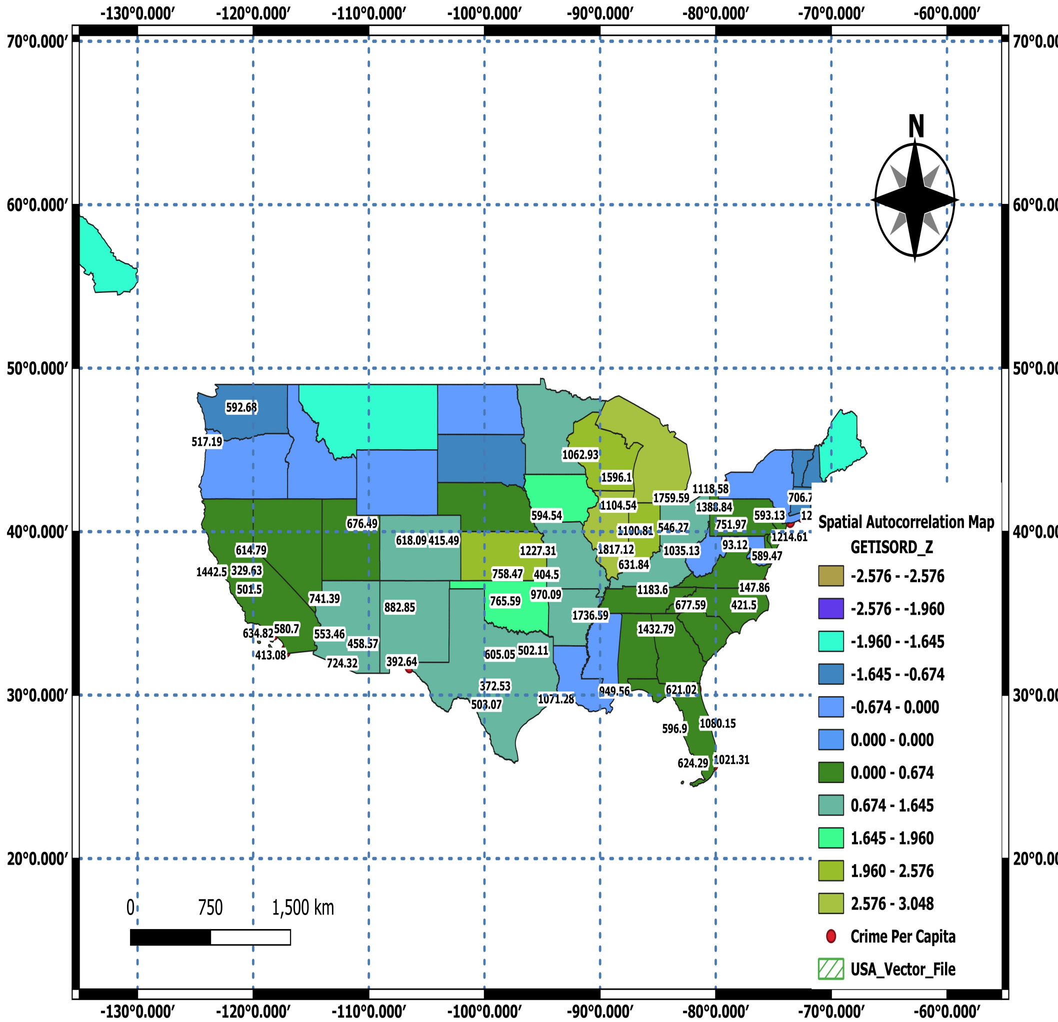

Figure 7: Getis-Ord G_i^* technique of spatial autocorrelation implemented to identify crime hotspots and coldspots.

6. Conclusion and Future Scope

The report consisted a thorough literature survey on spatial interpolation techniques as well as spatial autocorrelation methods used in the field of geospatial crime analytics. The report also entailed a proposed framework which epitomized the implementation of the merger of spatial interpolation and autocorrelation for a better geospatial crime analysis paradigm. The interpolation techniques entailed in this report includes Kringing interpolation, TIN interpolation, IDW interpolation and kernel desity interpolation. Further, the two spatial autocorrelation techniques i.e., also known as LISA indicators were enclosed within this report that comprised of Moran's I and Getis-Ord G_i^* techniques. In order to practically realize the efficacy of the proposed framework to perform geospatial crime analytics, a dataset comprising of diverse crime types enclosed within the attribute "violent crimes" for the regions in U.S.A. has been considered. Further, the dataset has been geocoded to automatically allocate latitude and longitude values to each region. The dataset after preparation has been overlaid on the vector shape file of U.S.A. so as to perform the weighted-overlay analysis. The weighted-overlay analysis maps have been labelled with different key attributes. Then, heatmap analysis has been performed and crime hotspots has been identified based on crime statistics. Further, the choropleth analysis has been performed in order to epitomize the join operation between the vector shape file and the corresponding dataset. Also, the interpolation technique chosen from the proposed framework was kernel density interpolation. Kernel density interpolation by specifying kernel function to be "quartic" has been implemented to visualize the interpolated map. Finally, spatial autocorrelation was implemented using the immensely used technique in the domain of crime analytics i.e., Getis-Ord G_i^*. The considered interpolation technique is well-known since it can classify both hotspots as well as coldspots (crime hotspots and coldspots in our case). Thus, a detailed geospatial crime analytics has been performed in this dissertation to entail all the available GIS-based features which can be used to efficiently perform geospatial crime analytics. The emerging rage of GIS technology has led towards immense applicability areas where GIS can play a key role. Sectors like crime mapping, disaster management, healthcare and many such have immense applicability of proficient techniques. Hotspot identification is a prime task in GIS and it can be done with the assistance of spatial interpolation by generating heatmaps based on density as well as spatial autocorrelation techniques. The ever-growing demand of GIS technology can have future spaces where the task of interpolation and autocorrelation might be merged with techniques of artificial intelligence, machine learning, cloud computing paradigm, serverless computing framework and many such.

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