1 Introduction

Crime maps can be useful for both law enforcement agencies (LEAs) and citi- zens. The first crime maps depicting the rate of crimes relative to social factors in regions of 1830s France have been attributed to the subsequent creation of the fields of criminology and sociology3 . In this digital age moved well beyond mapping with physical illustrations, crime mapping is used in varying levels of complexity and for various purposes for LEAS. One important use of crime mapping is public transparency. However, the adoption of digital crime mapping for public use has not been a consistent service of LEAS. In the United States (U.S.), the Federal Bureau of Investigation (FBI) has used the Uniform Crime Reporting (UCR) program to promote transparency and generate reliable crime statistics for the U.S. since 1930 . The current UCR standard for law enforce- ment agencies (LEAs) is to report individual incidents via the National Incident Based Reporting System (NIBRS). As more LEAs conform to NIBRS, there is an increasing body of standardized incident reports available to LEAs and the public. Incident based crime reports are raw in format, not aggregated like the former UCR program reports. This format provides flexibility for exploring crime data.

The resources available to U.S. LEAs for crime data analysis are wide ranging. There are approximately 18,000 U.S. law enforcement agencies across federal, state, county, and local jurisdictions [Banks, Hickman, 2016]. These agencies

3   http://criminal-justice.iresearchnet.com/criminology/research-methods/crime-mapping/2/

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range in department size from 1-30,000 officers with the majority of agencies having 10 or fewer officers [Banks, Hickman, 2016]. Furthermore, the fragmented nature of U.S. law enforcement as a collection of independent agencies makes the adoption of data handling practices disparate. Given the importance of putting crime data on maps, poor map making is a concern. LEA's and generally the resource putting the crime map together for public consumption is a novice map mapper. This paper provides an introductory framework for geovisualization that can be affordably adopted by LEAs and engaged citizens interested in exploring geographical trends in police incidents.

Our solution was to build a geovisual framework for displaying criminal in- cidents using open-source software. We then built a tool called opencrimemap- ping.org to display our framework in a workable website. The tool is built with open-source tools. Opencrimemapping.org displays various types of thematic maps using the framework we lay out in the paper. We also show maps that don't fit the framework presented to show how color, basemap, variable and time selection can impact the look of the map. Infrastructure for the design and use of maps for crime display could lead to increased communication between police and citizens and thus improve quality of service and reputation. Novice map creators have the ability to display crime incidents on maps with a few lines of code and little to no money.

First, this paper explores the history of open data and the importance of open data to promoting the use of data analytics in new domains such as public safety. For the novice LEA or citizen data analyst this paper explains the critical process of

exploratory data analysis (EDA). Then, the value of geographic visualizations is discussed in the context of the birth of computing and modern crime analytics.

This paper moves on to describe the open source, NIBRS compliant, incident data of the Dallas Police Department used to build a framework for geovisual- ization. The methods section breaks down the major steps that should be taken to generate a reliable police incident map. Beyond the essential components of the framework, this paper lends examples of specific open source software and code that can be reused by novice crime analysts.

2 Geographic Visualization

Geovisualization is deeply rooted in traditional cartography which has been around for thousands of years in human history. Geovisualization is the visu- alization of geospatial information to create human understanding that leads to data exploration and decision making [1]. Traditional maps known as static maps are simply fixed images. These maps can be produced on traditional mediums such as hardcopy, like books, atlases and magazines. They can also appear online as images on websites in file formats such as Portable Network Graphic (PNG), Joint Photographic Experts Group (JPEG), Portable Document Format (PDF), etc. Interactive maps allow the user to zoom in and out, hover-over popups, etc. to engage data and find underlying patterns in greater depth. Interactive maps are produced and viewed on computers.

Some early work in geovisualization can be traced back to the term geo- graphic visualization by the National Science Foundation in 1987. If we go back a decade earlier, we find that Jacque Bertin presented design principals for pre- senting cartographic and information design to explore data [2]. The Interna- tional Cartographic Association (ICA) created a Commission on Visualization in 1995 to stimulate geovisualization research and encourage interdisciplinary research to create highly interactive, exploratory methods to initiate knowledge construction. The ICA now has the Commission on Visual Analytics to support geovisualization which was formed in 2015. This commission focuses on interac- tive visualizations that can support knowledge construction and insights from spatial data in forms that are both big and small4.

Modern information availability has helped lead to an explosion of geovisu- alization tools. These tools can be found not only in our opencrimemapping.org tool for mapping crime, but in search for real estate in applications such as Zillow and Realtor.com. There are numerous private companies using geovisu- alization as revenue driver. Perhaps the best known is Google's Maps Platform. Google's Map Platform has over one billion monthly active users and gets 25 million updates a day5. Google sells their platform to companies to display infor- mation spatially. Government agencies use geovisualization for military, forestry, fishery, demographic and economic data display for both internal and external communication.

Opencrimemapping.org uses geovisualization as a tool of interactivity so users can gain knowledge of criminal activity in their areas to construct insights. The maps have the ability for users to hover-over, zoom and out, base map layer selection, time selection, variable selection and color selection for knowledge construction.

3 Crime Analytics

It is unsurprising that news media coverage of crime data analytics has a ten- dency to focus on the most ground breaking and intriguing innovations of the moment. A 2016 Science Magazine article detailed the use of advanced predic- tive software by

agencies looking both to predict where crimes will happen and the actual individuals who may commit or become victims of crimes [3]. For example, PredPol is proprietary software that uses algorithms to predict where crimes are likely to happen during a shift [3]. While forecasting crimes is a highly pertinent application of incident data, it is not a cure-all for understanding and effectively using crime data. Furthermore, it does not engage the public.

In 2015 President Obama initiated the Task Force on 21st Century Policing to investigate and speak to the rifts between police and the public1. The final report outlined six pillars detailing recommendations and action items. The first

4 Robinson, Anthony, "New Directions in Geovisual Analytics: Visualization, Computation, and Evaluation", International Cartographic Association Commission on Visual Analytics, 2/2/2018, https://viz.icaci.org/

5 Google Maps Platform, https://cloud.google.com/maps-platform/maps/

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pillar was the importance of building trust and legitimacy between police and those they serve. Part of the recommendation on building trust and legitimacy was to nurture accountability and transparency. Subsequently the Police Data Initiative (PDI) was launched per recommendation of the Task Force on 21st Century Policing2. The PDI is a collective network of law enforcement agencies, researchers, and technologists already developing and delivering best practices for collecting and publishing public datasets as well as utilizing data and tech- nology for the improvement of policing and community relations. As of March, 2018, there are 130 contributing agencies and over 330 available data sets through the PDI website. The PDI demonstrates and embraces the diversity of law en- forcement agencies needs and resources with both large and small department participants.

4 Data

Data was sourced from the Dallas Open Data website hosted by Socrata in order to provide an illustration of the process of using open source NIBRS compliant incident data6 . This website is designed to provide transparency to citizens and developers with a variety of data sets that pertain to city governance, services, and culture. The NIBRS based data set of interest on Dallas Open Data is titled Police Incidents. The Police Incidents data set is provided by the Dallas Police Department and is updated daily with incident reports dating back to June 1, 2014.

As of May, 2018, there are approximately 357,000 incident entries and there are 103 incident attributes. The complete list of incident attributes is found in the appendix. Some important features of an individual incident report include the unique identifier, Incident Number w/Year, the location details of the incident, the descriptive details of the complainant, the reporting officer details, and the details of the type of incident that occurred.

4.1 Open Data

The open data movement came on the heels of Internet globalization and is still developing rapidly [4]. In 2007 prominent academics and open data champions met to outline the guiding principles of open public data . In 2013, the U.S. gov- ernment formally recognized open public data as a valuable national resource in a memorandum to the heads of executive departments and agencies titled M-13-13 Open Data Policy-Managing Information as an Asset [5]. The motivation behind the memo was to make information resources accessible, discoverable and usable by the

public [5]. As one of the key pillars defined in the memo, accessibility sug- gests that open data must be made available in convenient, modifiable and open formats. These formats must be machine-readable and should be made available to the widest range of users for the widest range of purposes [5]. The larger goal

6 Dallas OpenData, City of Dallas, https://www.dallasopendata.com/

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of open data is to promote transparency in democratic governments, citizen par- ticipation, and drive innovation that can ultimately generate economic value . This project focuses on open data generated by the NIBRS set forth by the FBI UCR Program in partnership with the Bureau of Justice Statistics (BJS) in 1989. The NIBRS succeeded the Summary Reporting System (SRS) which provided aggregate statistics from law enforcement agencies with only one crime recorded per-incident regardless of the number of crimes that occurred . NIBRS provides uncombined incident information that is more easily usable by interested parties. However, NIBRS has been slowly adopted by law enforcement agencies on a vol- untary basis until now. Recently, the FBI set forth a NIBRS compliancy deadline of 2021 for all law enforcement agencies in the U.S. Former FBI director, James Comey, emphasized the importance of conforming to NIBRS in a 2015 speech to the International Association of Chiefs of Police (IACP): NIBRS is a way in which we can collect data that will identify patterns, trends, and help us prevent crime and have thoughtful, informed conversations at the national level .

5 Framework Tool: www.opencrimapping.org

Opencrimemapping.org was created to showcase some simple examples of what can be accomplished by using this framework. The data used to build the appli- cation was sourced from the Dallas Open Data website. This website is designed to provide transparency to citizens and developers with a variety of data sets that pertain to city governance, services, and culture. The data set of interest is titled Police Incidents. The Police Incidents data set is provided by the Dallas Police Department and is updated daily with incident reports dating back to June 1, 2014. As of May, 2018, there are approximately 357,000 incident en- tries and there are about 103 incident attributes. The complete list of incident attributes is found in the appendix. Some important features of an individual incident report include the unique identifier, 'Incident Number w/Year', the lo- cation details of the incident, the descriptive details of the complainant, the reporting officer details, and the details of the type of incident that occurred.

The maps on opencrimemapping.org were developed using R, Leaflet and R Shiny. R is an open-source language that is used for statistical computing and it compiles and runs on both Windows, MacOS, and multiple UNIX plafforms[2]. R was used to gather and clean up the data so that it could be used on our maps. For the examples provided we are only using the records that provide location information. Any incidents that did not provide location information were discarded.

Leaflet is an open-source JavaScript library that provides all of the necessary functions to create interactive and mobile-friendly maps[3]. Leaflet was used in conjunction with R to map all of the points that were provided by the Dallas Open Data dataset. Using leaflet allows it's user to have interactivity with the maps, they provide a number of different map types and the map creators can use different color

markers as well as an array of different base maps. All of which are very important parts of this framework.

Shiny is an R package that helps in building web applications[4]. Shinny was used to publish the maps created on this framework on the web.

6 Framework

The goal of this project is to create a framework to be used by LEAs that outlines a standard process for generating crime maps utilizing NIBRS data as input variables, open-source software, and design strategies that best promote transparency with the public. Law enforcement agencies at the state and local levels are held to criminal and civil law compliance by the U.S. Department of Justice. For example, these include laws that ensure all law enforcement of- ficers do not deny any individual in the U.S. of rights set forth by the U.S. constitution7 . Standards for the delivery of service by LEAs remain mostly self-regulated. In 1979 the Commission on Accreditation for Law Enforcement Agencies (CALEA) was created as an independent credentialing authority that works to create standardized practices to improve the delivery of public safety services8. In 2017 there were just over 1,000 LEA enrolled in the CALEA accred- itation program. With at least 30,000 LEAs servicing the U.S. this leaves many agencies without a standard practice for the delivery of crime incident data to the public. This framework includes practical guidelines and an example website with the goal of being easily replicable and enhancing legitimacy and trust with the public.

6.1 Time

Time or temporal analysis in maps has been in use with thematic maps for many years. Like space, time is heterogeneous [6]. We see day differences in terms of weekdays and weekends. The analysis of spatiotemporal data can be complex with many numbers of distinct planes. This can cause in the example of a dot map to display too much information and leaving the user with no knowledge to be gained from the map. To help with this interactive maps should be time bound. Users of opencrimemapping.org are able to switch between time periods to obtain knowledge.

Time in most visualization methods is considered linear. Most visualizations that incorporate time do so based on a timeline [7]. Actions in time can occur in cycles. With burglaries in Dallas weekdays display higher densities of instances than on weekends.

In crime mapping victims, offenders, and property managers adjust densities over time around specific places. Using the drop down to select different years on our tool the user can see differences in density as displayed in figure [x]. The user can recognize that less burglaries happened in 2017 verse prior year in 2016.

7 Addressing Police Misconduct laws enforced by the Department of Justice, U.S. Department of Justice, https://www.justice.gov/crt/addressing-police-misconduct-laws-enforced-department-justice

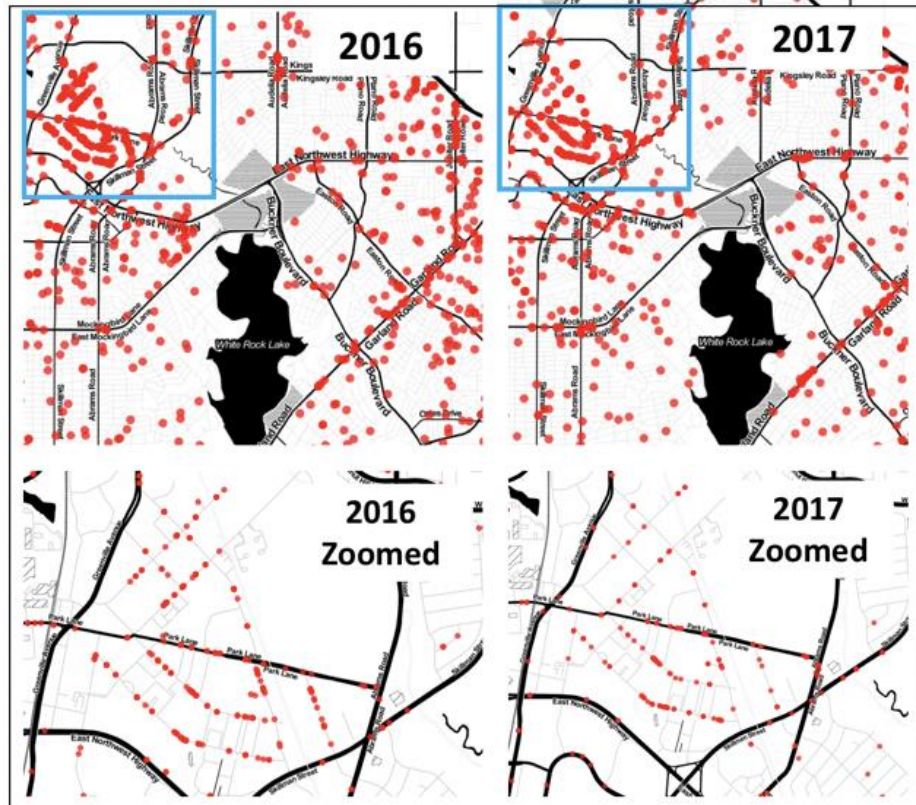8 The Commission, CALEA, http://www.calea.org/content/commission

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Fig. 1. This dot map has been zoomed in a location in Dallas with a high density of burglaries. Using the drop-down button the user is able to see the difference in density from one year to the other.

6.2 Interactivity

Growth in computer processing speed and Internet technologies have help lead the to the growth of interactive map availability, design and consumption. Carto- graphic interaction is the use of a digital map by a user facilitated by a computer. This creates a dialog between user and map.

Maps manifest themselves as knowledge from the mapmaker about the map's variable of interest. The goal of a map whether successful or not is the transfer of geographic insight from the mapmaker to the map user [8]. In User-Centered Design for Interactive Maps: A Case Study in Crime Analysis by Roth et. al. an interactive framework for maps is presented in which focuses on the needs of the user when conceptualizing and implementing an interface [9]. This framework focuses heavily on ease-of-use. The User-Centered Design (UCD) framework is designed around three U's.

Usability describes the ease of using an interface to complete the user's objec- tive. Opencrimemapping.org's interface is set up from Shiny. Through Shiny we provide tools for the user to select through parts of framework. We use a drop- down button, so the user can move through periods of time easily. The user is also has the ability to pan, zoom in and zoom out with the map displayed in fig- ure [x]. We also provide

the user with the ability to hover-over specific instances. When the user hovers-over they are presented with more detailed information about the incident.

The usefulness of an interface for completing the user's desired task is called utility. Utility taxonomy essentially breaks down to identifying one data element. Opencrimemapping.org uses color themes are well thought out to ensure a user can find data elements on a map. The second taxonomy of utility is being able to search for information through space and time to help answer "when" and "where" questions. Our tool covers utility with our framework using time-bound maps and base maps that are easy to read.

Finally, to complete the UCD loop is the user. The targeted user is often not an expert in the field that the tool focuses on. Target user's needs will change over time and cause an iterative process in designing a user interface. This tool did not use a formal research method to identify user needs. Instead our tool was developed through a qualitative process of trial and error with users that were not part of the tool's development.

6.3 Color

Thematic maps through history have used color to communicate activity within a geography. With early maps the information was imprecise. The imprecise nature of maps led map makers to choose between pictorial or abstract representation of more accurate data[10]. Color in early maps was more colorful than in early production maps when printed color had limited selection of color mixes. By the 19th century printing improved enough to allow to expand the role of color again [10].
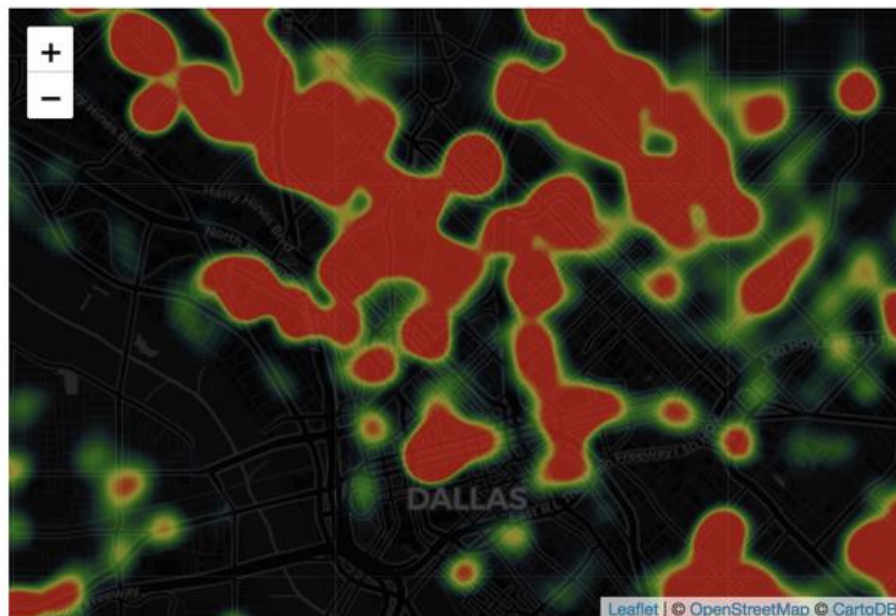
Fig. 2. This heat map uses Shiny to create interactive interfaces so users can select different periods of time by selecting the drop down button on the upper right.

The start of modern color in thematic maps can be traced to Jacques Bertins 1983 Book Semiology of Graphics. Bertin presents the goal of giving the reader of a map a clear visual indication of what is happening on the surface of the earth [11]. One way this is accomplished is through using color to show the dif- ference between entities. ColorBrewer developed by Mark Horrower and Cynthia Brewer in 2003 helps in choosing appropriate color schemes for mapping needs. The authors point out that choosing color schemes can be very difficult when designing thematic maps. Most GIS software does have color schemes, but they dont provide direction on the use of color.

When a thematic is displayed on a laptop LCD it may not print the same way. The ColorBrewer system suggest color schemes if an agency needs to have the maps available through multiple media types. There is a total of 35 color schemes or sets. They are divided into three groups: qualitative, sequential and diverging. Sequential work well for when order is needed in data from low to high. Diverging colors are good for separation variables. Qualitative color schemes use differences in hue to create a set that does not imply order [12]. In opencrimemapping.org we use a diverging scheme two show the difference between residential burglaries and business burglaries on a dot map shown in figure [x]

Colors in thematic maps also need to take into consideration. Pastel like colors were found to be more confusing to color-vision impaired users than darker colors. This is an important consideration to take into account when in a group
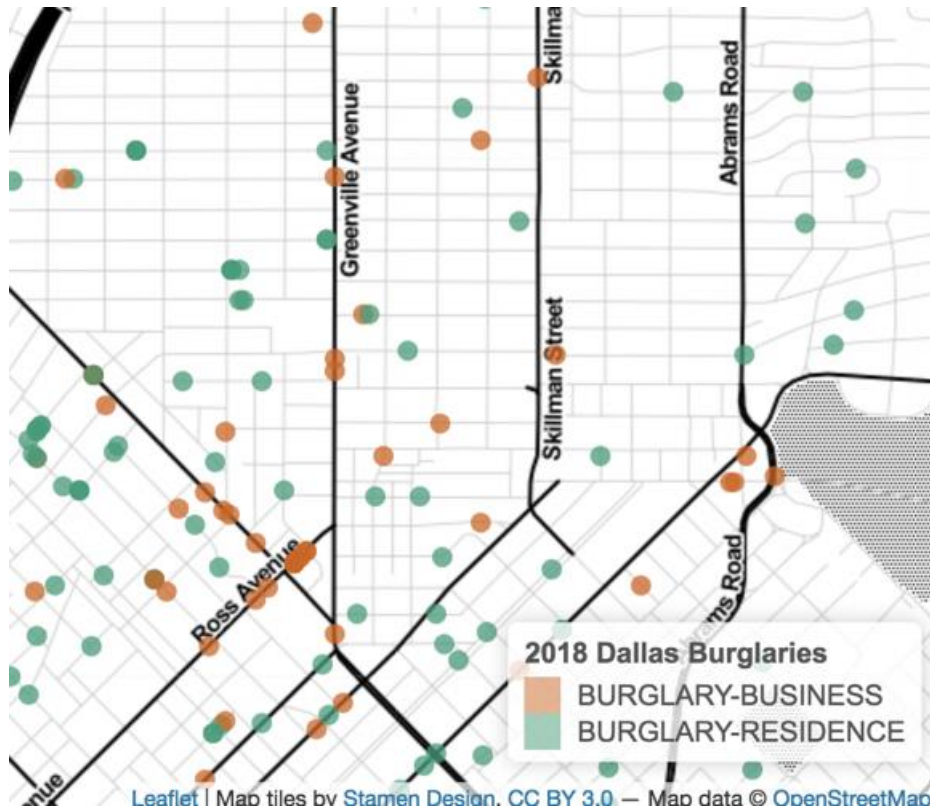
Fig. 3. This dot map uses diverging colors selected from ColorBrewer.org to display different burglary types. The color selection in this map also takes advantage of ColorBrewer's option for managing color blindness.

of 25 at least one person is likely to be color-vision impaired [13]. Finally, color selection needs to take into account considerations such unintended bias. When mapping crime data using a color scheme that may match skin tones could create a perception that areas may be more heavily populated by a specific ethnicity.

Its important that the map maker make a careful and well-thought-out choice in the data colors that are displayed on a map. Failure to do so could lead to the user not gaining new information from the map.

6.4 Base Map Selection

A basemap is GIS data that has been planimetrically corrected. A planimetric image has had the effects of tilt and perspective removed and only displays the horizontal surface features of the Earth's surface. The basemap is what we think of when we imagine the boundary lines defining countries and states, it provides the setting. A basemap can be as simple as a few boundary lines. However, with GIS technology base maps can include intricate details about natural and cultural surface features.

Leaflet maps use 'tiles' like most digital maps9 . Tiles are individual map images that are joined along invisible seams when called. This preserves compu- tational efficiency while enabling zoom. The process of building a map in Leaflet is described as stacking layers. For example, the first layer is the generally the

9 Using Basemaps, Leaflet for R, https://rstudio.github.io/leaflet/basemaps.html

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base map so markers showing the location of police stations would be layered on top. This layering capability provides flexibility to selecting a basemap because even basemaps can be layered together assuming a level of opacity is used to allow the bottom basemap to show through the top basemap.

With Leaflet one does not need to build their own basemap, but that is still an option. Leaflet provides pre-designed basemaps created by Leaflet as well as third parties that can be printed to a screen in 3 lines of code or less10. There are many impressive open source basemap tile designs available. Before choosing a basemap for crime display it is important to ask, "Who are these maps for and how will these maps be used?" and to remember that the quality of these maps also reflects on the LEA as a professional entity. The 1999 U.S. DOJ publication Mapping Crime: Principle and Practice, described the process of using maps as creating abstractions of reality. As the abstraction increases the further from reality we move. However, abstraction allows a complex story to be told simply [DOJ]. The process of selecting a basemap is a balance between abstraction and reality. The goal of police transparency revolves around telling what is true as best as possible. Transparency also depends on the ability of citizen users to understand. The figure below shows a basemap of Dallas, TX that has a watercolor design and a basemap that has a more realistic topographical details. While the watercolor map is appealing, it does not allow a user to easily determine locations of interest in Dallas. On the other end of the spectrum, a basemap could potentially show so many details that when using the zoom feature incident depictions get easily lost in the chaos. For example, a web- based test of basemap usability conducted by Konen et al. found that all tasks completed with a topographic basemap took longer to complete and suggest that topography can be cognitively challenging [15]. Ultimately, the selection of a basemap should minimize frustration for the user.

Fig. 4. These basemaps illustrate artistry verses clarity in the selections of basemap options within Leaflet.

10 Leaflet-providers preview, Leaflet, http://leaflet-extras.github.io/leaflet-providers/preview/index.html

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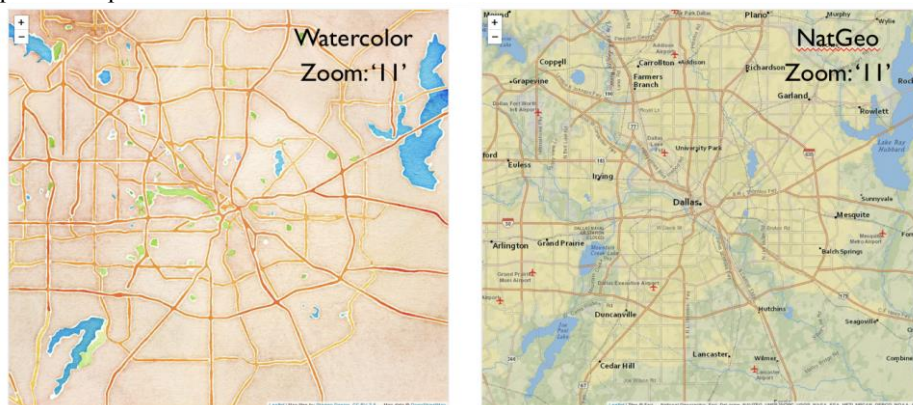
6.5 Map Types

There are a variety of major map types that can be used to display crime inci- dents. Digital maps can be extended well beyond push pins in a hanging map. In combination, map types can paint both images of individual incidents and overall trends. If not carefully constructed, digital crime maps can also be misleading.

Dot Maps Dot maps are a traditional mapping style where each dot represents a discrete object. Dot maps can be effective at showing where individual crime incidents occur and the distribution of many incidents across space.

Individual dots will be most accurately represented using a coordinate system such as latitude and longitude or state coordinates. When using data from dif- ferent sources it is essential to use a single coordinate system. State coordinates cannot be accurately placed on a map developed using latitude and longitude because state map coordinates represent physical distances on the ground.

Dot size is also important. Dot sizes too large can oversaturate a map and lead to lots of overlap. Dot sizes too small can be hard to perceive. On the other hand, larger dots may be preferred to obfuscate the exact location of incidents. If a dot overlaps a few residencies rather than pointing to a single residence it will offer some protection of privacy to victims and/or accused. If a formal algorithm for selecting dot size is not used, it is best to compare several dot sizes to determine the most accurate and useful representation of a single incident. With leaflet, dot sizes can increase upon zoom to retain their relative size to the geographical area they represent. This is an important feature to have so that upon closer inspection the location of a single dot still appears to be in the correct coordinate space.

Dot maps can be used to look for trends. If dots are displayed with opac- ity, it is possible to see density more clearly for highly populated maps or maps with strong clustering. The patterns in a crime map are both an im- portant investigative tool as well as possible source of misleading information. A cluster of incidents may appear to be a hot spot, but they may also rep- resent a more highly populated area [Mapping Crime: Principle and Practice https://www.ncjrs.gov/pdffiles1/nij/178919.pdf].

Dot maps can be used to look for trends and patterns. If dots are displayed with opacity, it is possible to see density more clearly for highly populated maps or maps with strong clustering. The patterns in a crime map are both an im- portant investigative tool as well as possible source of misleading information. A cluster of incidents may appear to be a hot spot, but they may also rep- resent a more highly populated area [Mapping Crime: Principle and Practice https://www.ncjrs.gov/pdffiles1/nij/178919.pdf]. Dot maps are advantaged be- cause they can display segments of incidents or totally distinct incidents. Crime maps often include an assortment of icons to map many distinct types of inci- dents. The limitation of mapping many incident types at once is over saturation. The time frame for a map may need to be significantly reduced to fit many types of incidents onto a map. Furthermore, many incident types can be so busy it is difficult to interpret the map or use it as an investigative tool.
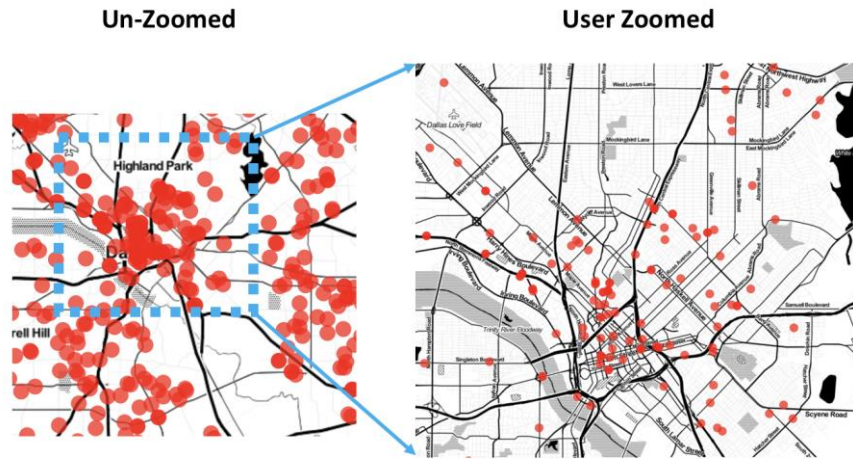
Fig. 5. This dot map shows the challenge of balancing appropriate dot map size in both a zoomed-out and zoomed-in view.

Cluster Maps Cluster maps are an extension of dot maps. Cluster maps rep- resent the collection of incidents for defined surrounding areas. Cluster maps are more computationally efficient than dot maps. With Leaflet, a cluster is labeled with the number of incidents represented within each single cluster. A mouse over effect allows the user to highlight the area captured by a single cluster. When a cluster is clicked on the map zooms in toward the area captured by the cluster and pulls smaller clusters and individual markers out of the first cluster. Figure 6 shows the mouse over effect and the 'spiderfy' effect of clusters as the zoom increases.

Fig. 6. The left cluster map shows the mouse over feature in leaflet that highlights the area captured by a cluster. The right cluster map shows a zoom view with smaller clusters and some individual markers representing single incidents

Heat Maps Heat maps in simple terms are fluid density projections placed on top of a basemap to indicate where incidents are most clustered. Heat maps use colors to represent a scale of numbers. Usually, as colors become darker they represent

increasing numbers. A heat map is useful for a big picture view of the distribution of a single type of incident. If incidents are combined for a density analysis they should be related or grouped together and defined as a larger category.

Heat maps are considered distinct from hot spot maps. Heat maps do not use statistical significance to distinguish between density. Hot spot maps are pro- jected into polygons that represent statistically different densities. When using a heat map it is important to consider this difference because there is a greater potential for misrepresenting data. If a density projection is too dark it may overemphasize crime incidents and if a projection is too faint it may be difficult to find any patterns.

6.6 Variable Selection

The selection of variables to be represented in crime maps for the public is a business problem. Police departments serve as public safety agents and crime maps are an extension of this service and a peek into the role of the police department. To continue along the theme of trust and legitimacy, departments should consider asking citizens what types of crimes they are interested in. They should also balance sensitivity. Some crimes, such as those related to sexual of- fenses or offenses involving children need more privacy and careful consideration before being shared with the public. Also, the display of multiple incidents at once may imply to the user that they are related in ways that they may not be. The correlation between incidents of specific types may be legitimate, but if causation or further research into correlations is not well understood the public interpretation could be incorrect.

7 Ethical considerations

Open data in public safety presents some ethical considerations. One such ethical issue is the publishing of the complainant information. Specially in the Dallas Open Data Public Safety Police Incident data set the user is able to find the complainant name, race, gender, age, and address. The complainant could be the person who reported the crime that took place, or the victim of the incident. The offender or parities interested in protecting the offender could use that information for malicious intent.

Including the complainant's name appears to be a common practice among open data sources. This was highlighted in a Federal Trade Commission memo by their Chief Technologist Lorrie Cranor in 2016 stating that there was a possibility that people who access open police data may able to identify crime victims or

reveal their locations11Cranor identified several instances where the agencies had fully identified victim information. Another city had names removed but continued to post location information. Even with cities that attempted at victim de-identification other databases might have been used that may contain pieces of the identification once pieced together.

8 Conclusion

Opencrimemapping.org is an online tool that is designed to help novice map- makers make thematic maps that will lead to increased communication between police and citizens and thus improve quality of service and reputation. Open- crimemapping.org features different types of thematic maps showing the same data set so novice map makers can make choices based on the geovisual frame- work presented in this paper. Other valuable features include: (1) multiple base- map selection tools to see the effects of different basemaps; (2) The ability to change time frames; (3) Check different coloring methods outside of our frame- work and compare them with our

framework; (4) See different intensity levels on a heat map to show heatmap ambiguity. Maps that present crime incidents that are communicated to the public are important, and the combination of open- crimemapping.org and the framework presented in this paper help novice map creators improve the quality and reputation of their respected LEA.

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Reviewer's Comments:

Please consider these comments in a positive note. The review is not intended to undermine your paper. I am sure that your team have done a great job to achieve the project objective. The comments here are made to the best of my understanding. Please ignore if any of the comments are not applicable.

Overall, this is not a very well written paper. A technical paper should be a story-teller, but the flow is missing here. I have observed numerous formatting issues (not sure whether few of them were result of file conversion or not). The format of our template has been violated. Footnotes are displayed in middle of the pages (no clue why??) and references are not properly aligned. This would cause a serious penalty in your final submission and hence more attention to the paper format is suggested. Grammatical errors, punctuation mistakes and poor sentence constructions are annoying for readers.

Citation is required for "The first pillar was the importance of building trust and legitimacy between police and those they serve." in section 3 otherwise it will become an issue of plagiarism.
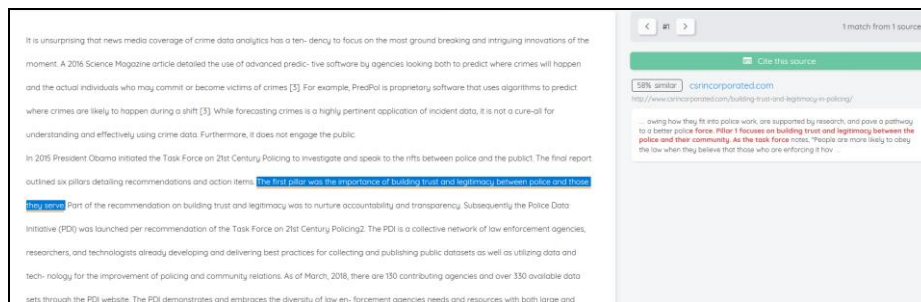
Below are detailed observations and suggestions on each of the sections.

1. **Introduction:** This section is more or less fine. Definition and explanation of the technical terminologies would add value to this section. A little deeper background information with a source of motivation would be great.
2. **Geographic Visualization:** Except formatting issues this is a good section. A more elaborate portray of the evolution of crime data visualization through various stages would be wonderful. How visualization has changed from static maps to today's digital and interactive visualization, would improve the flow of this paper.

3. **Crime Analytics:** This section has a good start but has not ended well. The paper should explain why predictive analytics is not the sole purpose of crime analytics, and how an interactive data visualization would be helpful. Need to elaborate how public availability of this visual info will have a positive impact on our society.
4. **Data:** This section is good. A sample tabular picture of the dataset would help readers to understand your work better. If multiple sources and tables are used, then a layout of the schema would be appropriate.
5. **Framework Tool:** This section ideally should not talk about the objective and data. A detailed description of the tools and software used would be more appropriate.
6. **Framework:** This section begins with the objective and other background information which have already been mentioned before. On the contrary, a summary on all the aspects (time, interactivity, color…) of your framework would be more relevant. Explain your purpose behind selecting this set of parameters. Moreover, it is not clear from the writeup that how much was done before and what additional areas your project has addressed. A graphical comparison of previous work and your result would add value. It would also justify success of your project.
7. **Ethical Consideration:** This section is fine except the minor issues mentioned in the marked-up comments.
8. **Conclusion:** This section should elaborate on how well the project has achieved the goals and talk about future possible improvements.