A Mobile Visual Analytics Approach for Law Enforcement Situation Awareness

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Abstract— The advent of modern smartphones and handheld devices has given analysts, decision-makers, and even the general public the ability to rapidly ingest data and translate it into actionable information on-the-go. In this paper, we explore the design and use of a mobile visual analytics toolkit for public safety data that equips law enforcement agencies and citizens with effective situation awareness and risk assessment tools. Our system provides users with a suite of interactive tools that allow them to perform analysis and detect trends, patterns and anomalies among criminal, traffic and civil (CTC) incidents. The system also provides interactive risk assessment tools that allow users to identify regions of potential high risk and determine the risk at any user-specified location and time. Our system has been designed for the iPhone/iPad environment and is currently being used and evaluated by a consortium of law enforcement agencies. We report their use of the system and some initial feedback.

Index Terms—Mobile visual analytics, situation awareness, public safety

1 INTRODUCTION

In 2010, the number of handheld devices reached a staggering volume of 4 billion devices globally [7]. With a large and diverse user base, it is the only truly universal computational platform today. With this global explosion in the usage of modern smartphones and handheld devices, users now have more connectivity to the digital world and the ability to ubiquitously ingest data and transform it into knowledge that enables them to comprehend a situation better and make more effective decisions. However, challenges associated with the data processing, exploration and analysis on a mobile platform are becoming prominent due to the increasing scale and complexity of modern datasets and limited screen space of mobile devices. These challenges are being addressed by the emerging field of visual analytics [37]. Visual analytics in the mobile domain utilizes state-of-the-art mobile devices and provides users with the ability to effectively and interactively analyze large and complex datasets on-the-go, thereby providing analysts, decision makers and other users insights into any emerging or emergent situation in real-time (Figure 1).

In this paper, we present a mobile visual analytics approach for solving one such problem in the public safety domain. Our work leverages the ubiquity of the mobile platform and focuses on the geotemporal exploration of criminal, civil and traffic (CTC) incidents. Our mobile system (Figure 1b) provides on-the-go situational awareness tools to law enforcement officers and citizens. Our system has been designed in collaboration with a consortium of law enforcement agencies and first responder groups and has been developed using a user-centered approach. In addition, we have also leveraged our experience gained from deploying a desktop-based law enforcement toolkit [25] to a group of law enforcement agencies in designing our mobile system. Designing a mobile visual analytics system in this domain provides a unique set of challenges that range from identifying the mobile needs of a diverse group of end-users to understanding the applica-

Fig. 1: Mobile crime analytics system gives ubiquitous and context-aware analysis of law enforcement data to users.
bility of a mobile solution to improve the day-to-day operations of law enforcement officers. This paper discusses these challenges and presents our mobile solution.

We list the main contributions of this work as the following:

- **Identifying the needs of first responders and law enforcement agencies in the mobile domain.** Our collaboration with the law enforcement agencies enables us to explore and discuss the use of our system in their day-to-day tasks at different organizational levels in the agencies. We also discuss the use case scenarios of our system for citizens.
- **Discussion of the design of a public safety mobile visual analytics solution for the first responder community.** We adapt several visual analytics methods and techniques that are normally designed for the desktop system to the mobile system and modify them to work effectively in a mobile environment that has different interaction methods, usage scenarios, and objectives.

## 2 Related Work

The use of mobile devices in visual analytics has proliferated greatly over the past few years. Mobile devices should not be thought of merely as auxiliary devices for use while on the road but they are the new personal computers [7]. With the explosion of the number of users of smartphone, tablets and other mobile devices, the interest to develop visual analytic systems on the mobile platform has greatly increased. For example, work by Kim et al. [21] presents a mobile visual analytics system for emergency response cases and highlights the use of such systems in time-critical applications. However, these systems face a unique set of challenges compared to the commonly used desktop systems. Some of the main constraints of mobile systems include limited performance, small displays, and different usage environments [28, 35]. Novel methods that deal with these unique constraints are thus a must. Pattath et al. [29], for example, focus their work mainly on addressing the display and interaction area size constraint by utilizing the focus+context technique. Additionally, the development of mobile visual analytics systems provides novel use cases that traditional desktop systems cannot provide.

For a dataset of geospatiotemporal nature (data with information to geographical location and time) such as public safety data, geographic information systems (GIS) play an important role in the exploration and analysis processes in decision support environments [1]. There exist many GIS systems that provide tools to support the Exploratory Data Analysis (EDA) [38] process. Many of these systems provide a geospatial interface along with statistical tools for analysis and are usually designed to enable users to explore trends, patterns and relations among such datasets [4, 14]. For example, André et al. developed the Descartes system [3] that automates the presentation of data on interactive maps. The GeoDa system [6] also provides an interactive environment for performing statistical analysis with graphics. Many systems are also tailored to focus on specific applications in a given domain. Examples of these include GeoTime [19] and Flow Map Layout [30] that focus on tracking movements of objects in time. Other domain specific applications include traffic evacuation management [17] and urban risk assessment [22].

Similarly, GIS systems provide important support in the public safety domain [9]. In analyzing and modeling the spatiotemporal behavior of criminal incidents, Chen et al. [10] developed a crime analysis system with spatiotemporal and criminal relationship visualization tools. However, in contrast to our focus on risk assessment and situational awareness in the mobile domain, their system focuses on finding relations between datasets and is developed for a desktop environment. Moreover, there exist many web-based crime GIS tools (e.g., [11, 12, 26, 27, 31, 34, 36]). However, most of these tools offer only basic crime mapping and filtering functionalities and provide basic analytical tools to allow users to perform EDA. Also, many of these systems target casual users only. Similarly in the GIS domain, some systems also target non-GIS specialists (e.g., [2, 6]). Our system, on the other hand, is designed to enable both ordinary citizens and domain experts to explore and analyze spatiotemporal CTC incidents. Our work uses the notion of casual visualization [32], but further provides statistical tools that help users identify trends, patterns and relations within the data in the EDA process.

The ability to have situational awareness in law enforcement is essential in maintaining public safety. Situational awareness by definition [16] enables one to perceive, comprehend, and project into the future to make more effective decisions. Law enforcement officers make decisions in resource allocation and patrol planning to reduce crime while citizens make decisions to be at a place at any particular time. Critical to gaining awareness of a situation are the fundamental questions of where, what, and when an event/incident occurs [5]. Our mobile system, similar to many GIS tools, presents the law enforcement information in a place-time-object organization to allow for information exploration and sensemaking using the different views that we have implemented.

## 3 Requirements and Challenges

This section discusses the requirements and challenges in the design of our system from our user-centered approach and the special form factors of mobile devices.

### 3.1 Domain Analysis of Requirements

Our collaboration with our partners from the local law agencies started with our previous work [25]. To further extend the application of visual analytics in their operation, our partners approached us with the idea to develop such a system on the mobile platform. As such, we had several meetings and informal discussions about the use of such a mobile system in their day-to-day tasks to get the system requirements.

In this subsection, we identify the requirements of the law enforcement agencies and explore the use of such a mobile system based on our formative engagements with officers ranging from shift supervisors, patrol officers, detectives, and crime analysts.

**R1: Near real-time data** The shift supervisor is primarily responsible for resource planning and allocation. He needs to have access to the most recent data and look at all the CTC incidents from the prior and current day to prepare for the shift change briefing and roll call. Thus we design the mobile system on a server-client architecture that centralizes the entire data on the server, which is always kept up to date. A mobile client accessing the data will have to make a request to the server that will respond with the most up-to-date data. Our current data acquisition process is on a daily basis in to our database server but we are in the process of increasing the data import frequency to four times daily and have the data up to date before a patrol shift change and during patrol.

**R2: Trend analysis and visualization** During shift briefings, shift supervisors discuss the current crime trends with patrol officers and review, for example, what has been happening over last week, day, this day last week, and so far today. They use this information for tasks including planning their patrols and deciding on what they should be on the lookout for. This is also important for detectives and crime analysts to be able to see the patterns of specific crimes over space and time. Visualizing CTC trends over time is thus an important task required for the mobile system. To address this need, we enable several visualizations for the temporal data to allow users to see spatial and temporal trends at different levels.

Visualization is a powerful tool to have for patrol officers in the field because their current mobile computer terminals (MCT) system which they use in their patrol vehicles supports some degree of data checking and foraging to be made. For example, officers may request from the dispatch that a check of previous calls or cases against an address be made prior to responding to an incident but this information is passed to the officers in a textual format and does not include nearby locations. The role of visualization here is powerful in capturing all this information, potentially in a single view.
Fig. 2: A screenshot of our mobile visual analytics law enforcement system. (left) Visualizing all CTC incidents for the city of Seattle, WA, USA on February 20, 2011. The map view (a) plots the incidents as color-coded points on a map. The interactive time series view (b) plots the incident count over time with the estimated weighted moving average (EWMA) control chart overlaid. The bottom-left image (c) shows an overview-detail calendar view of the CTC incidents. (right) Visualizing all CTC incidents for Tippecanoe County, IN, for the month of February 2011. The county’s census tracts have been overlaid on the map. The bottom right image (d) shows the interactive clock view to provide an hourly view of CTC incidents for the month selected. The interactive time slider (e) allows users to scroll through time and offers various temporal aggregation levels.

R3: Mobile information The shift supervisors typically use paper print outs of the incidents that happened the previous day on a map during shift briefings to point out certain incidents of interest and show their geospatial trends. We identify that the need to offload information from a workstation to something a person can carry around (e.g., paper) is essential and that the person must be able to explore the information (they may carry multiple print outs of the map showing different information). Our mobile system is interactive and provides an easy access to CTC information, allowing users to explore the incidents through time and different levels of details.

R4: Easy operation Mobile systems are often used ubiquitously, sometimes in less than ideal conditions (e.g., while walking, screen glare). Additionally, using a mobile system in such conditions often requires users to divide attention between the system, the task they are performing, and their surroundings. This is especially relevant to in-field officers, who, in patrol have to pay attention to their surroundings when not tactical (e.g., overseeing an area in their patrol beat in a parked patrol vehicle) and cannot operate the system while driving on the road. Thus the visualizations need to be easily comprehensible in a short glance and interaction should be simple and easy. We continue this discussion in Section 3.2.

3.2 Mobile Challenges

Today, tasks that were once only done commonly using desktop computers can now be done using devices that can fit into a pocket [7]. But developing such a system brings about unique foci, tasks, goals, and constraints. In the following paragraphs, we discuss how some of these constraints affected the final design of our mobile system.

C1: Different task and user intent Due to the form factor of mobile devices, certain tasks are better done on mobile devices, and certain tasks are better done on desktop workstations. For example, long-term risk assessment and resource allocation are usually done using desktop workstations, not only because desktop machines usually have better hardware to perform advanced analytics, but also because they are usually used in a more comfortable office environment. This allows users to focus more on their task and spend hours exploring and analyzing the data and perform long-term analysis of the data. On the other hand, mobile devices are often used when officers are away from their workstations, or when they want to get a quick access to the data and focuses on rapid situation assessments.

C2: Different usage environments As briefly discussed above, the usage conditions of these systems also differs in that desktop systems are often used in a controlled office environment, whereas mobile systems are more geared for use on-the-go. For law enforcement officers working in the field, our system is highly beneficial in providing them with tools to increase their situational awareness within their areas of responsibility [15]. Additionally, using such a mobile system out in the field introduces new challenges in that it requires the officers to have divided attention between their surroundings and the system, thereby stressing the need of having views that are intuitive and easy-to-read. This need is further motivated by another user group of the mobile system, ordinary citizens, who might have limited knowledge to understand complex visualizations and to use advanced analytical tools. Our system makes use of casual visualization [32] concepts in addressing this issue.
C3: Limited computing resources  The limited physical size imposed on mobile devices, which restricts their hardware capability such as computing power, memory, display area, and input capabilities due to miniaturization also limits the device performance. Speed is a key feature that users look for when performing EDA, especially because mobile systems are often used in time-critical situations. For example, officers may use this system as they respond to dispatch or emergency calls; and citizens may want to get a quick check of the safety around their area as they walk to their office. This gets ramified by the fragmentation of mobile devices and the maturity of this line of devices in the market. Newer mobile devices, for instance, could support hardware that are more than twice as fast as the previous generation, and for devices early in its maturity unlike desktop systems, this translates to a huge performance difference. Designing a system with good performance across multiple end devices was thus a key concern in the development of this system. With our mobile system, we choose to determine a default data size limit (the number of incidents to load) depending on the device used and the network to guarantee an interactive performance. In this case, the most recent incidents are chosen and shown using the system.

C4: Limited/varying display and interaction area  Device fragmentation in terms of display area was another key factor in the system design process. The screen of a smartphone can only display a fraction of what is displayable on a tablet’s screen (e.g., compare the iPhone’s 3.5-inch screen to the iPad Mini’s 7.9-inch and iPad’s 9.7-inch screens). Additionally, interaction also becomes an issue where users would get a richer experience using the iPad’s bigger interaction area on its touchscreen as opposed to the small touchscreen on the iPhone [18]. We thus designed the system to be context-aware and behave differently based on the device used – multiple views can be shown at once on the iPad whereas only one view can be shown at a time on the iPhone. In our implementation, each view is implemented as a separate module of the system that adapts its presentation style to an iPad or an iPhone. With a small display area, views on mobile devices tend to be small and occlusion is likely to happen for systems with multiple views. We designed our system to enable users to hide and move views around the screen to overcome this.

C5: Security  One of the main benefits of having a risk assessment system on the mobile platform is its ubiquity. The system can be used by law enforcement agencies in situ while responding to dispatch or emergency calls. This increases the risk of having the device misplaced or stolen and thus the risk of having sensitive data falling into the wrong hands. Being used in the public, the system is also more susceptible to being a target of data sniffing. To ensure data confidentiality, we use a secure protocol to transmit encrypted data to the end-devices.

4 Mobile Visual Analytics Environment for Law Enforcement

Our mobile visual analytics system provides users with an overview of public safety data in the form of criminal, traffic and civil (CTC) incidents. It comprises a suite of tools that enables a thorough analysis and detection of trends and patterns within these incident reports. Our system has been developed for visualizing multivariate spatiotemporal datasets, displaying geo-referenced data on a map, and providing tools that allow users to explore these datasets over space and time (R2). We further provide filtering tools that allow users to dynamically filter their datasets. Our system also incorporates linked spatiotemporal views that enhance user interaction with their datasets.

Figure 2 shows two snapshots of our system. Figure 2 (left) shows all CTC incidents for the city of Seattle, WA, USA occurring on February 20, 2011, and Figure 2 (right) shows the CTC incidents for Tippecanoe County, IN, USA occurring in the month of February 2011. The main view of the system is the map view (Figure 2(a)) that provides users with the ability to plot the CTC incidents as color-coded points on the map (Section 4.3).

With temporal data, the system allows for visualization using several views, namely the time series graph view (Figure 2(b)), the calendar view (Figure 2(c)), and the clock view (Figure 2(d)). The time series graph view allows users to visualize the temporal aspect of the incident data using line graphs and model the data for abnormal event detection. The calendar view [40] lays the temporal data in the format of a calendar, allowing users to visualize the weekly and seasonal trends among the CTC incidents. The clock view, on the other hand, allows users to visualize the hourly distribution of the CTC incidents. A time series slider (Figure 2(e)) is provided to allow users to scroll in time, updating all linked views dynamically. Furthermore, our system also provides users with risk profile tools that allow them to dynamically assess the risks associated with their neighborhoods and surroundings.

4.1 Public Safety Data

Our system was developed using CTC data collected by a consortium of law enforcement agencies in our local county and from publicly available data. Each report entered into the database consists of, among other fields, the date and time of when the incident was reported, the time range between which the incident was thought to have occurred (e.g., in case of burglaries) and an associated geolocation. We also provide multiple aggregation levels to group the different crime incidents. Our system provides support for the Uniform Crime Code (UCR) categorization of CTC offenses utilized by the Federal Bureau of Investigation [39] that helps increase familiarity with the system (R4). Our data acquisition method is done via a daily data dump from the county Sheriff’s Office and we are working to increase the frequency of this to every six hours or about once before and during any patrol shift (R1). In addition to the this local law enforcement dataset, we have also tested our system using Chicago, San Francisco, and Seattle police department incident report datasets to demonstrate the flexibility of our mobile platform architecture to accommodate different datasets.

4.2 System Design

Our system consists of two main components, a server back-end for processing and computation, and a client front-end composed of our interactive mobile visual analytics system.

![Fig. 3: A conceptual diagram of our server-client architecture. Note that the user is an integral part of our visual analytics system.](image)

The server-side system includes data preprocessing and cleaning, data transformation and cleaning, and data transfer to the client. The client-side system consists of temporal modeling, user interface, and geo-spatial modeling. The system also includes risk assessment and optimization for decision-making.

Figure 3 provides a conceptual diagram of our server-client architecture. The server back-end consists of a database that enables querying and provides data to the client. The data going into the server...
undergoes a pre-processing and data cleaning stage so it becomes ingestible to our client system. The front-end consists of the mobile device that provides a user interface for the visualization, exploration, and analysis of the spatiotemporal public safety dataset. Our system provides them with the tools necessary to explore the risks around different neighborhoods and trend identification tools that allow for trend prediction in the future, the results of which are further optimized by users. The user further uses his/her domain knowledge and expertise to further refine the analysis process by repeated interaction with the system. Note that the user is an integral part in this exploration and analysis process.

This exploration and analysis modeling is done per user on his/her device and it could be advantageous to have the ability to share this visualization or data exploration state with another user. However, since this is not in our initial list of requirements (Section 3.1), we leave this for future work.

4.3 Geospatial Displays

Our visual analytics system provides multiple views to visualize the spatial component of the datasets. We allow users to plot the incidents as points on the map that are color coded [8] to represent the different parameters of the datasets (e.g., agencies responding to the incident, offense type). The map has been dimmed so as to distinguish these color-coded incident points from the map colors. In addition, we utilize a kernel density estimation technique [23] to allow a quick exploration of the incidents on the map and to identify hotspots. The system also allows users to overlay different layers on the map (e.g., law beats, census tracts, bus routes) [41] and allows them to place custom placemarks. The users can also overlay driving and walking routes on the map, enabling them to visualize the CTC spatial distributions along their intended routes. An example of this has been shown in Figure 2(a).

In addition to plotting individual incidents, we also allow users to spatially aggregate the incidents by geographic regions (e.g., census tracts, city law ordinance beats), allowing them to visualize the incidents in the form of choropleth maps [13]. These choropleth maps are colored on a sequential color scale to reflect the number of incidents falling within each region. Furthermore, we allow users to select a region to subset the data by tapping on a region loaded from a shapefile or by drawing arbitrary rectangles and circles shapes on the map. Users may then obtain a tabular summary of these incidents. We also allow users to save these reports for future analysis.

Furthermore, as is the case with most multivariate datasets, the CTC dataset is often incomplete. For example, many of the incidents do not contain valid geolocation data, causing uncertainty in the analysis process. In order to account for the uncertainty caused by this incompleteness in the dataset, we provide the ratio of correct incidents as a percentage value to show the accuracy of the visualization. This becomes important for users to accurately extract information from their dataset [20].

4.4 Temporal Displays and Analysis

Our system provides users with three temporal displays that allow them to visualize the temporal distribution of their datasets. We provide a time series display that presents the distribution of the incidents over time as a line graph, a calendar view visualization that lays the temporal data in the format of a calendar and a clock view that visualizes the hourly distribution of incidents.

4.4.1 Time Series View

The system allows users to simultaneously select multiple offenses and displays them as time series line graphs highlighting the trends between multiple datasets. Furthermore, we provide users with several temporal aggregation options to aggregate their datasets. For example, users may choose to aggregate the incidents by day, week, month or year, and visualize the results dynamically. We further note that the time series display is interactive, allowing users to touch the screen to get the incident count at any particular time. A time series tape measure tool [24] in the graph view allows users to determine the temporal distance between any two points on the graph. We also provide users with tools that allow them to accurately model the data using an Exponentially Weighted Moving Average (EWMA) control chart for event prediction [24].

4.4.2 Calendar View

We adopt the calendar view visualization developed by van Wijk and Selow [40] to provide a temporal overview of the data in the format of a calendar, allowing users to visualize the data over time. Each date entry is colored on a sequential color scale that is based on the overall yearly trend to show the relative count of incidents for each day with respect to the maximum daily count over that calendar year.

To account for the smaller screen space of mobile devices (C4), we provide an overview-detail view. This is shown in Figure 2(c), where the left portion of the calendar view shows the weekly overview of the entire calendar. The overview display draws the individual rows based on the selected aggregation level (e.g., week, month) and are colored on a sequential color scale to reflect the weekly count of incidents. Users may tap on any portion of the calendar overview, updating the calendar view visualization dynamically to the position touched by the user. The overview-detail calendar view allows users to quickly identify weeks of high activity, and provides an easy way to scroll to them.

Additionally, we vary the height of each row of the calendar based on the weekly total compared to the global weekly maximum. Weeks with lower significance (low CTC activity) thus take up less vertical space on the screen as shown in Figure 4a.

4.4.3 Clock View

In order to visualize the hourly distribution of the CTC incidents, we implement a clock view (Figure 4b) that organizes the data in the format of a clock. The clock view is a radial layout divided into 24 slices that are colored on a sequential color scale [8] to reflect the number of incidents that occur during each hour of a day.

As is the case with geospatial data (Section 4.3), many of the incidents do not contain a valid time field, causing uncertainty in the analysis process. Thus, we use the same method of displaying uncertainty for geospatial data in this domain, by showing the accuracy of the clock view visualization.

4.5 Risk Profile

The risk profile visualization shows the spatial and temporal distribution of incidents with respect to the current location and time of the user.

![Calendar View](image)

(a) Calendar view

![Clock View](image)

(b) Clock view

Fig. 4: Calendar and clock views showing the temporal trends of all crimes against person in the Tippecanoe County for the month of June 2012. The calendar view shows day of the week and seasonal trends while clock view shows time of day trends.
4.5.1 Context-aware Analysis

Our system utilizes the GPS feature of the mobile device and factors in the geospatial location of the user, the current time, and the historic CTC incidents occurring within their neighborhoods to provide estimates of CTC activity in their surroundings. These provide users with an overview of all the incidents and allows them to increase their level of situational awareness of the safety risks involved in their surroundings.

Now, in order to show the spatial distribution of historic incidents, we utilize the map view and plot the incidents as points on the map. When users enable the risk profile feature, the system shows the current location of the user as a small blue circle on the map, and draws a circle (of a user-controlled radius) around their current location. The system then performs a query to the server and acquires all incidents that occur within this circle within a ±3 hour offset (adjustable by the user) with respect to the current time, for a date range specified by the user. The resulting incidents are then displayed as points on the map. Also, the temporal distribution of all incidents falling within the circle is shown in an interactive bar graph (Figure 5a (top)). We highlight the hours on this graph to reflect the hours on which the incidents are being displayed.

In order to show which incidents happen nearer in time (with respect to the current time of day), we modify the kernel density estimated heatmap (as described in Section 4.3) to encode the temporal distance from the current time. So in this case, the heatmap gives more weight to those incidents that fall closer to the current time within the ±3 hour window, than to those that are farther away from the current time. The hotspots that so emerge provide an estimate of those incidents that happen closest in time with respect to the current time. An example of this approach is shown in Figure 5, where the user is visualizing all offenses against person and property for the month of February 2013. We can see hotspots emerging in different locations that show the distribution of incidents that happened closest to the current selected time.

4.5.2 User-defined Analysis

We allow users to visualize the risks over any specified historic temporal periods. For example, users may choose to visualize any desired offenses over a period of the last three years to get an overview of the activity levels in their surroundings within the selected time frame. Note that in addition to visualizing the risk profile for the current location and time, users may also choose to generate risk profiles for any desired spatial locations (by dragging the pin provided on the map) and for any hour of the day (by selecting a time by tapping on the risk profile time series graph (Figure 5a (top))). The users can then get a geotemporal overview of risk at any location and time. We finally note that the risk profile visualization refreshes dynamically by time and as users moves from one spatial location to another to provide them with a real-time overview of the scene.
4.6 Hotspot Alert

Our system also provides a feature to help users identify unusual localized high-frequency patterns of crimes and identify crime hotspot locations. Each data entry in the database is checked for other crimes with similar properties (defined by the user). This is done within a 200 meter block radius of the incident location, and for a 14 day period that extends from the day the incident occurred backwards in time. The system then highlights the incidents with the most number of similar incidents within the space-time window (Figure 6) which is updated dynamically as new data is entered into the database by the user. This alerts law enforcement officials of areas with higher probabilities of nearby localized suspicious criminal activity and allows for more effective resource allocation and patrol planning.

While reviewing the map view showing all incidents and their associated locations, Sergeant Mills identifies incident location hotspots. He pans the map around and zooms into the areas of interest using the standard touch, pan, and pinch conventions. Sergeant Mills then uses the region select tool to subset the CTC incidents to only include those incidents that occurred in the identified areas of interest.

Using this data, Sergeant Mills identifies specific types of incidents occurring in these specific areas. This allows him to instruct the officers tasked with patrolling these areas in the recommended patrol methods that will improve the officer’s efficiency with regards to the current trend of incidents. Sergeant Mills may also use this data to re-allocate patrols into troublesome areas and notice when another local agency is experiencing high levels of incidents in bordering neighborhoods.

During the roll call briefing, Sergeant Mills communicates these trends by showing the officers the hotspot locations on his tablet using a projector. He focuses their attention to the specific areas of interest and the specific incident types by panning the map view to show those areas and filtering the incidents by changing the selection parameters from the list of incident categories.

5.1.2 Patrol Officer

Patrol officer Joe brings a tablet along with him during his patrol so he can get access to the CTC incident data while working in the field. While he is parked and monitoring a location on patrol duty, Officer Joe turns on the risk profile feature that shows the most concerning incidents by filtering those CTC incidents to those near his current location and time. Using this feature, he is able to visualize certain crimes of interest that occurred recently and from the same date range the past 2 years and within a 3 hour time window from the current time. Activating this feature also restricts the geospatial region to a quarter mile radius from his current location (Figure 5). This gives him more insight into the locations of higher probabilities of activity within the current time window based on historical data to complement his expertise and knowledge of the area.

During his patrol, Officer Joe receives a dispatch call to a reported burglary incident. While processing the crime scene, he pulls up the system and checks the recent crime patterns in the area. He notices that a similar crime was reported last night just across the street, suggesting that he should be more aware in processing the evidence as it may be a case of a serial burglary. He can also review that case file using the system and look for possible connections with this case.

The mobile computer terminals system being used by officers in their patrol cars currently have sophisticated but limited capabilities. While it has the functionality to point the location they are being dispatched to on a map, the system only allows one incident to be viewed at a time. The officers may also request the dispatch to find past incidents at a certain location but the result is sent in text format over the computer terminal. Our mobile system allows officers to visually explore multiple incidents that occurred around a location and identify crime recurrences or identify past incidents that are related to a new incident in question. We are also in the process of obtaining the data for emergency calls and tips so patrol officers would know when several calls have been made when responding to an incident and get more information from tips.

We envision a future expansion of this system to also include the exploration of court records. This would enable the officers that respond to dispatches to better understand the situation in order to take more effective measures when dealing with the problem at hand. For example, a police officer gets dispatched to respond to a complaint of domestic violence at a particular residence. By exploring court records, the officer may find relevant records of divorce or child custody battle cases that give the officer on duty more insight into the problem and a better understanding of the situation to effectively resolve the situation.

5.7 Implementation Notes

Our mobile system front-end has been developed for the iPad/iPhone environment on the iOS platform. The system requires iOS version 5.0 onwards and is developed in the Objective-C environment using XCode 4. The PROJ.4 Cartographic Projections Library [33] is used to switch between map projection systems and the Google Maps library is used for routing.

On the back-end of our server-client architecture, the database is managed by MySQL that enables data querying and the web service that handles data requests by the client uses PHP. Data is transmitted securely (CS) using HTTP over SSL/TLS in XML or plain text format to keep the data format simple and generic for other uses.

5 USE CASE SCENARIOS

In this section, we illustrate some use case scenarios where law enforcement personnel with different requirements and citizens can use our system to build and maintain situation awareness about the CTC incidents in their immediate surroundings.

5.1 Law Enforcement Officer User

We describe a scenario from the perspectives of officers of different levels of operation.

5.1.1 Shift Supervisor

In this scenario, we focus on the point of view of the shift supervisor, say, Sergeant Mills. Prior to the morning shift change and roll call, Sergeant Mills accesses the most recent data on a tablet mobile device, looking at all the CTC incidents from the prior and current day.

While reviewing the map view showing all incidents and their associated locations, Sergeant Mills identifies incident location hotspots. He pans the map around and zooms into the areas of interest using the standard touch, pan, and pinch conventions. Sergeant Mills then uses the region select tool to subset the CTC incidents to only include those incidents that occurred in the identified areas of interest.

Using this data, Sergeant Mills identifies specific types of incidents occurring in these specific areas. This allows him to instruct the officers tasked with patrolling these areas in the recommended patrol methods that will improve the officer’s efficiency with regards to the current trend of incidents. Sergeant Mills may also use this data to re-allocate patrols into troublesome areas and notice when another local agency is experiencing high levels of incidents in bordering neighborhoods.

During the roll call briefing, Sergeant Mills communicates these trends by showing the officers the hotspot locations on his tablet using a projector. He focuses their attention to the specific areas of interest and the specific incident types by panning the map view to show those areas and filtering the incidents by changing the selection parameters from the list of incident categories.

5.1.2 Patrol Officer

Patrol officer Joe brings a tablet along with him during his patrol so he can get access to the CTC incident data while working in the field. While he is parked and monitoring a location on patrol duty, Officer Joe turns on the risk profile feature that shows the most concerning incidents by filtering those CTC incidents to those near his current location and time. Using this feature, he is able to visualize certain crimes of interest that occurred recently and from the same date range the past 2 years and within a 3 hour time window from the current time. Activating this feature also restricts the geospatial region to a quarter mile radius from his current location (Figure 5). This gives him more insight into the locations of higher probabilities of activity within the current time window based on historical data to complement his expertise and knowledge of the area.

During his patrol, Officer Joe receives a dispatch call to a reported burglary incident. While processing the crime scene, he pulls up the system and checks the recent crime patterns in the area. He notices that a similar crime was reported last night just across the street, suggesting that he should be more aware in processing the evidence as it may be a case of a serial burglary. He can also review that case file using the system and look for possible connections with this case.

The mobile computer terminals system being used by officers in their patrol cars currently have sophisticated but limited capabilities. While it has the functionality to point the location they are being dispatched to on a map, the system only allows one incident to be viewed at a time. The officers may also request the dispatch to find past incidents at a certain location but the result is sent in text format over the computer terminal. Our mobile system allows officers to visually explore multiple incidents that occurred around a location and identify crime recurrences or identify past incidents that are related to a new incident in question. We are also in the process of obtaining the data for emergency calls and tips so patrol officers would know when several calls have been made when responding to an incident and get more information from tips.

We envision a future expansion of this system to also include the exploration of court records. This would enable the officers that respond to dispatches to better understand the situation in order to take more effective measures when dealing with the problem at hand. For example, a police officer gets dispatched to respond to a complaint of domestic violence at a particular residence. By exploring court records, the officer may find relevant records of divorce or child custody battle cases that give the officer on duty more insight into the problem and a better understanding of the situation to effectively resolve the situation.

5.1.3 Detective / Crime Analyst

A detective or crime analyst will have significantly different usage patterns than a shift supervisor or patrol officer. Although a patrol officer may do a deeper dive into the historical data concerning a specific
event or subset of events, the analysis capabilities will be used more extensively by detectives or analysts.

In a scenario focused towards analytical processing, Detective Peters is investigating a specific burglary that occurred in a residential neighborhood. As part of her investigation, Detective Peters focuses on the device on that neighborhood and changes the record selection parameters to include only burglary or unlawful entry crimes. She then extends the time period selection to include all of these crimes over the past couple months. From this display, Detective Peters can determine if there has been an increase of these incidents in this neighborhood by selecting the calendar view to show how many of these incidents have occurred. To enhance her investigation, Detective Peters can then change the selection parameters to include trespass and vandalism crimes. The combination of these selections may provide additional insight into the nature of the burglary.

Taking the same scenario even farther, Crime Analyst Mike gets a request from Detective Peters to analyze the possible correlation between trespass incidents and subsequent burglary incidents in this particular neighborhood. Mike begins with the same data set as Detective Peters then takes it even further. Mike changes the time period selection to include the incidents from the previous year. Using the different temporal views, Mike can notice any discernible crime patterns from the occurrence of trespass and robbery incidents. Mike can see these potential correlations either by season (using the time series view), day of the week (calendar view), or time of the day (clock view).

As an added level of analysis, Mike then plots the locations of all establishments that sell liquor in the surrounding areas by adding a placemark for each. This allows Mike to visually explore any potential correlation between these crimes and the locations of these establishments. In conjunction with the plotting of the liquor establishments, Mike can also display the known public transportation routes by selecting that specific shape file and exploring the possibility of the incidents being related to proximity of public transportation.

Additional analysis can be accomplished by using the ‘select region’ capability. Mike can display the general area of concern then display the crimes in a list or report format by selecting a relevant shape file that defines the area (e.g., neighborhood, law beat, census tract). Regions can also be defined on an ad hoc basis by simply drawing a rectangle or circle around the desired areas. Once regions are defined and selected, Mike can then view all the incidents in a report format to aid in further investigation.

5.2 Citizen User

Citizens are simply concerned with what is going on in their neighborhood or the neighborhoods surrounding their children’s schools and extra-curricular activities. This is accomplished easily by using the current location positioning capability while using the device from their home as well as the location of their children’s activities.

If a citizen is concerned about the route his children may be taking to and from school, he can build a display of the route the children are taking by using the route tool. This allows the user to designate a starting and ending address as well as any specific points along the way. Once the route is defined, the citizen can visually see what types of incidents are occurring along the route and what times of the day are the safest (using the clock view).

6 USER EVALUATION

In this section, we provide user feedback of our mobile visual analytics law enforcement system from two different user groups. The first group consists of domain experts from our local law enforcement agencies who make up our focus group for the system’s testing and evaluation. The second group is made up of citizens, who would give feedback from the general public user’s perspective.

6.1 Domain Expert Feedback

For the purpose of evaluating our system, we formed a focus group of 15 domain experts consisting of several police departments in our local county as well as the county legal offices. We deployed our mobile system to this group in December 2012 and have made continuous modifications to the system based on their responses and feedback obtained from our meetings which include several demonstrations, independent reviews, and informal discussions. Here, we report some of the group’s initial responses.

In general, the feedback we have received from them has been positive. On a higher level, officers, especially the chief of police in our local community, saw the value and potential of the system for certain daily tasks. He cited one use of this system to increase public awareness of their safety from the criminal activities that occur in their surroundings during safety campaigns. He also mentioned its use to visualize the impacts of active crime prevention actions (e.g., resource allocation for patrol, public safety campaigns).

At another level, the shift supervisor role viewed the application as an improvement to their existing tools used for briefings and roll call. The features within our system that allow the display of the heat map of incidents displayed provided an added level of focus for incident location. The feedback provided by the supervisor indicated that they utilized the temporal reporting features in conjunction with geospatial features to assist in resource allocation planning. They also found the capability of having a mobile version useful for their roll call briefings that allows them to look at the past incidents and have discussions outside of the office space for instance while having coffee in the lounge.

Patrol officers saw the value of using the system while on the field to get CTC incidents data in a visual format to have an increased situation awareness. Furthermore, the officers particularly liked the risk profile feature that provides the regions with historically higher incident levels based on the patrol officers current position and time. They indicated that this feature was especially useful in conjunction to their domain knowledge to get a better picture of their surroundings when they were patrolling their area of responsibility.

During discussions with law enforcement personnel, additional information would be useful to officers responding to incidents (e.g., warrants, protective orders, non-contact orders). However, this information does not currently reside within their systems and, as such, the officers do not get access to such data while responding to incidents. We plan on incorporating these datasets in our system to assist the law enforcement personnel with operational decisions when responding to service calls.

At the role level of detectives and crime analysts, the usage patterns begin to shift more towards the predictive end of the spectrum as well as an increased usage of the temporal reporting features. Existing analysis tools tend toward a list generating, selection/filtering tool. Geospatial mapping does not appear to be prominently used at the present time as an analysis tool. The overall graphical user interface of our system looks promising for this role because of the ease of use and the widely known mobile application selection, zoom, and positioning conventions. One feature that appears to be the most promising is the ability to dynamically create regions or utilize shape files for geographic boundary definition. These features allow the crime analyst and/or detective to zero in on specific geographic areas of interest, like neighborhoods or law beats, without having to manually sort through data. These features also assist in generating historical reports for use in detailed crime analysis or investigation. The detective/crime analyst also found the selection capability within the calendar tool useful for seasonal crime analysis.

From our engagements, an intelligence analyst did not see much value of the system in his tasks but was enthused by its potential in other aspects of law enforcement duty. He was particularly interested in the crime monitoring process with the system and the potential to quickly identify incidents that are viewable by security cameras and pull up live and historical feeds by those cameras.

6.2 Citizen Feedback

We also had general citizens use our system and provide informal free-form feedback of their thoughts on the system. An ex-officer liked the system and remarked that such a system would be especially beneficial
for community crime watch groups. Basic-level citizens are primarily concerned with viewing the historical crime information that occurred in their immediate neighborhood. They accomplish this by using the main graphical map display and crime selection tool. Intermediate-level citizens may use the calendar or clock tools to find a specific incident. Regardless of the level, it does not appear citizens would utilize the advanced analytics capabilities of the application. For example, a user saw the use of this system to identify areas with low CTC activity to find safe residential neighborhoods (and relates to its potential in the real estate business). Another user liked the system but suggested that different crime categories should have different contributions to the heatmap to highlight more on serious crime incidents such as homicide or robbery.

7 Conclusions and Future Work

In this paper, we have presented our mobile visual analytics system that has been designed to equip law enforcement personnel and citizens with effective situation awareness and risk assessment tools. Our current work demonstrates the benefits of visual analytics in the mobile domain, and shows the effectiveness of providing users with on-the-go tools that allow them to make effective decisions. We have learned that the use of a mobile risk assessment system differs slightly in providing real-time situation awareness from a full, thorough analysis of CTC incidents with a full-fledged system on a desktop. From our interaction with our end users, we know that they do not have the time to tinker with a technology: it has to just work. Also with law enforcement agencies, they are trained to handle risky situations and would not rely on the system to gauge risk and determine if backup is needed. The use of the system is also limited in tactical situations where attention in certain actions takes precedence (e.g., focusing on the road while driving). In this case, a technology like speech recognition would significantly help but this remains a research direction we have not yet explored. Finally, as has been shown in this paper, we argue that there is great potential for the use of mobile visual analytics solutions to serve multiple role levels in the law enforcement and other related domains.

Future work includes adding advanced analytical and predictive capabilities into the system. We also plan on enhancing our routing methodology to factor in the risk and other parameters in order to allow users to plan safer routes. In addition, we think that incorporating multiple datasets (e.g., census data, street light locations, court records, weather) in the system would be an interesting research direction to explore the correlations between CTC incidents and other datasets.

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