Contextual Interaction for Geospatial Visual Analytics on Mobile Devices

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ABSTRACT

Limited display area creates unique challenges for information presentation and user exploration of data on mobile devices. Traditional scrolling, panning and zooming interfaces pose significant cognitive burdens on the user to assimilate the new context after each interaction. To overcome these limitations, we examine the uses of "focus + context" techniques, specifically for performing visual analytic tasks with geospatial data on mobile devices. In particular, we adapted the translucency-based "focus + context" technique called "blending lens" to mobile devices. The adaptation enhances the lens functionalities with dynamically changing features based on users' navigation intentions, for mobile interaction. We extend the concept of "spatial context" of this method to include relevant semantic content to aid spatial navigation and analytical tasks such as finding related data. With these adaptations, the lens can be used to view spatially clustered results of a search query, related data based on various proximity functions (such as distance, category and time) and other correlative information for immediate in-field analysis, all without losing the current geospatial context.

Keywords: Mobile Visualization, Mobile Visual Analytics, Geospatial Analytics, Focus + Context, Mobile Interfaces, Law Enforcement Visual Analytics

1. INTRODUCTION

Researchers in cartography have suggested the need to explore new metaphors and their effectiveness in map interaction based on blur, transparency and focus.[1] Cartwright et al.,[2] identified the need to adapt map representations to new devices and to determine the most appropriate interaction methods for different applications and users. Even though these needs were identified a few years ago, most map applications on mobile devices today still use simple pan and zoom interactions. A major issue with these current interaction metaphors is that a user cannot remember the interaction context as he navigates through the map. "Focus + Context" and "Overview + Detail" interaction techniques were introduced to address the issue of context maintenance. However, these techniques were found to have very task-specific benefits. While the "Overview + Detail" technique is preferred over "Focus + Context" in general,[3] the latter technique has specific benefits for tasks such as selecting small targets with a stylus.[4] However, their adoption on mobile devices has been slow due to limited computational resources.

With the recent advances in graphics capabilities on mobile devices and standardization of graphics APIs such as OpenGL | ES and OpenVG, it is possible to exploit hardware accelerated rendering features to render lenses based on new interaction metaphors. Recently, Pietriga et al.,[5] introduced new lenses in a lens space that combines speed and transparency in novel ways to create distortion-free lenses. Their studies also suggested that one of these lenses (speed-coupled blending lens) outperformed others for focus targeting tasks. In this work, we explore the usage of these lenses on a mobile device for performing simple in-field geospatial analysis. In the first part, we present the necessary adaptations and modifications to speed-coupled blending lens and its implementation on mobile devices exploiting hardware accelerated vector graphics features.

Context plays an important role in interaction by helping a user cognitively orient himself while navigating the information space. On mobile devices, contextual cues are highly beneficial because the screen space limits

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the navigable space and a user's attention can shift to activities other than device operation. However, geospatial data representation on mobile devices has been traditionally limited to location-aware services[6–8] and limited analytics,[9, 10] without focusing on the issues of interaction context. In the second part of our work, we aim to address this issue, by providing geospatial analysis tools that can be operated in a focus + context setting allowing users to reorient themselves while navigating and analyzing the data.

In-field personnel (such as law enforcement officers and emergency responders) often need to view geospatial data for enhanced situational awareness. Specifically, in the field of law enforcement, various personnel such as foot, vehicle and supervisor patrols and criminal analysts work with geospatial data. Foot and vehicle patrols are usually in the field and collect data/evidence and share this information with other colleagues. Supervisor patrols, on the other hand, are responsible for the placements and whereabouts of other patrols, for reviewing reports (which is performed off the field) and are usually deployed in the field. Criminal analysts (located off the field) analyze reports from these patrols to find trends in incidents and come up with suggestions for changes in patrol focus. While all of these personnel can benefit from mobile geospatial data display, simple analytic tools can especially help the supervisors who are already in the field and help the criminal analysts who can come out of the office and operate in the field during emergencies. In accordance with their requirements, we present intuitive tools for simple geospatial analysis on the field and describe initial analysis results of a criminal incident reports dataset using these tools.

2. RELATED WORK

The role of context in mobile interaction has been studied in the context of displaying calendar data, web pages and maps on mobile devices. However, no one has applied contextual interaction techniques to perform geospatial visual analytics on these devices. In this section, we review previous work in these and related areas focusing specifically on mobile devices.

2.1 "Context" in Information Presentation on mobile devices

Various interaction and presentation techniques represent context either explicitly or implicitly. Here we discuss some of these techniques starting from the earliest to the latest.

Scrolling and Panning: These basic interaction techniques provide a sliding window into a larger information space and have been directly adopted from the desktop to mobile interfaces. These techniques spatially separate the focus region (i.e., currently displayed region) from the larger information space.[3] However, they are not suited for the small display screens on mobile devices. Firstly, selecting and dragging a scroll bar on a mobile device is difficult due to its small footprint. Moreover, small screen size necessitates larger number of interactions compared to a desktop sized screen. Secondly, constant scrolling and panning require the user to keep track of the context of previous interactions thus slowing down performance.[11]

Zooming: Zooming techniques are used to view the information space in increasing levels of detail. These are commonly used for viewing maps, images and documents. Zooming techniques temporally separate focus regions from the larger information space.[3] However, these techniques require significant cognitive effort from the user to assimilate new context after each interaction. At higher zoom levels, this leads to a condition termed as "Desert Fog" by Jul et al.,[12] wherein there are no cues on which to base further navigational actions.

Overview + Detail: These techniques were introduced to alleviate the navigational issues in the earlier techniques. Overview + Detail techniques also spatially separate focus or detail regions from overview regions either by overlaying the overview on the detail region or by displaying them separately. The former is used commonly in desktop mapping applications while the latter can be seen as the thumbnails in applications such as Microsoft PowerPoint and Adobe Reader. In both these cases, the overview usually contains a navigation cue indicating the relative position of the detail region. However, these are not suited for mobile devices since the overview region obscures parts of the already small sized screen.[13] Moreover, these also require the user to mentally integrate the spatially separated detail and overview regions into a single information space, which might be reasonable only on a desktop platform.

Focus + Context: Focus + Context techniques embed focus region within the larger information space using a smooth transition function, thus overcoming problems of contextual disorientation. Most of the transition functions distort the display in the transition region to accommodate the magnified focus region.[14,15] Such distortions are collectively termed as "fisheye." Smooth distortion functions create better looking visuals[15] although they are computationally expensive. Discrete transition functions, on the other hand, are easier to compute and therefore preferable on a mobile device. Discrete transition functions have been used in rectangular fisheye displays for navigating maps[14] and displaying calendar data.[16] However, evaluations of focus + context techniques suggest that they are not always beneficial.[3,11] Fisheye distortions have been found to interfere with a user's spatial comprehension.[11] Moreover, object targeting becomes difficult due to "hunting effects" of the fisheye.[17] To overcome the hunting effect, Gutwin et al.[17] proposed to dynamically increase the fisheye distortion proportional to the speed of a user's interaction. Pietriga et al.[5] introduced the blending lens (defined in a more generic sigma lens space) which uses alpha blending to overcome distortion problems. However, this was developed for a desktop environment. In this work, we adapt this concept of a blending lens to a mobile device and consider mobile device specific rendering issues. Moreover, we explore the idea of using this lens to perform geospatial visual analytics.

2.2 Geospatial Visual Analytics on Mobile Devices

Supporting exploratory spatial visual analysis tasks on mobile devices is quite difficult due to their form factor limitations. Earlier efforts have resulted in stripped down versions of mainstream GIS products such as ArcPad[18] by ESRI. More recently, people have started researching on various usages of mobile devices for decision analysis.[19] However, most of it use simple representations and do not allow for interactive manipulation. More visually assisted analysis and interaction tools have been relatively unexplored. Initial steps in this direction have been taken by Lodha, et al.[10] and Burigat et al.[9] The former work provides tools to visually access and query GIS datasets. Their system provides answers to queries such as "where," "closest," etc. and users can query by directly drawing geometric primitives such as lines and polygons on the screen. However, their emphasis is on consistent representation of data from various GIS databases rather than the analytics part. In the latter work, the authors develop visualization and interaction for evaluating dynamic visual queries. They developed the MAGDA system, which allows users to issue dynamic visual queries and view results that both partially and completely match the given search criteria. Although, this work focuses on visual representation for data analysis, they do not consider the issue of context maintenance while navigating the geographic space. Thiede et al.[20] propose "Smart Lenses" for adapting specific aspects of visualization in a specified region of interest. Although the ultimate goal of this work is similar to our work, their emphasis is on the automatic selection or user specification of lens parameters and was developed for the desktop platform. Our work, on the other hand, considers issues of adapting focus + context lenses to mobile devices and interaction specific aspects on small screens.

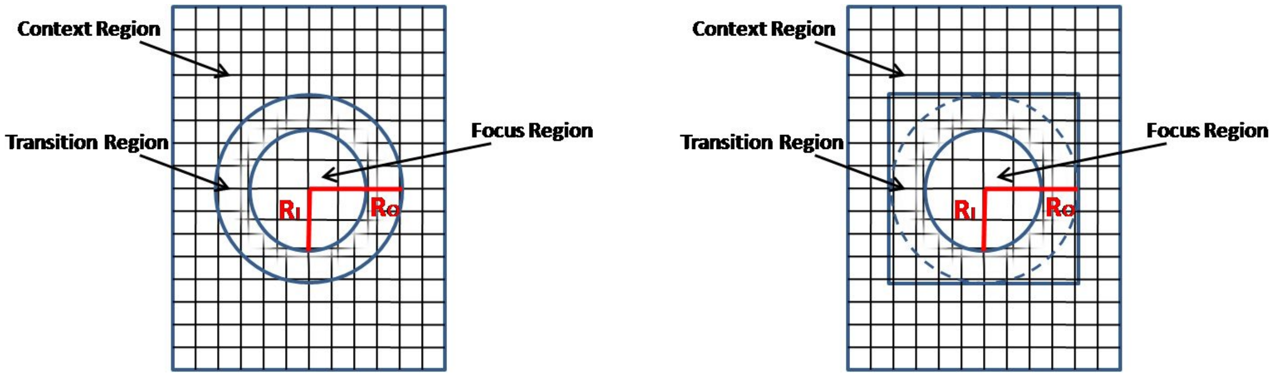
2.3 In-field Visual Analytics for Law Enforcement

Use of mobile devices for in-field law enforcement has been highlighted only by very few researchers such as Baddeley, et al.[21] Their work focuses on gathering requirements and designing a full-fledged system using various in-built sensors in the mobile devices to collect evidence, collaborate and share information with other officers. In contrast, our system focuses on just the interaction aspect especially with geospatial data for analysis.

3. BLENDING LENS

The blending lens, introduced by Pietriga et al.,[5] is an example of focus + context lens that uses alpha blending for smooth transition from focus to context regions. The blending lens is a specific example of a larger space of lenses called the sigma lens which use time and translucence based functions for the transition. Here, we briefly revisit core concepts of the blending lens.

The "Lens region" is defined by two concentric circles as shown in Fig.1(a). The inner circle forms the "Focus region" or the "Flat-top region" with a radius R_I and the outer circle with a radius R_O forms the lens boundary. Entire display region outside the lens' boundary forms the "Context region." The area between the focus region and lens boundary forms the "Transition region" where the focus gradually blends into the context.



(a) (b)

Figure 1. Various regions formed by the blending lens in a viewing window. The combined region including the "Focus region" and "Transition region" forms the "Lens region." (a) The original blending lens. (b) Our adaptation of blending lens - the outer boundary is defined as a square for easy spatial querying and R_O is defined as the perpendicular distance from the lens center to any side of the square.

The final rendering is obtained by compositing (blending) the lens region with the contents of the context region behind the lens. The composition function uses Porter and Duff's "Source **over** Destination" alpha-blending rule[22] with a value of α. Assuming p_x is a (r, g, b) point in region x and p_{comp} is a point in the lens region obtained after composition, the compositing rule is defined as:

$$p_{comp} = p_{source} \otimes_\alpha p_{destination} = p_{lens} \otimes_\alpha p_{context} = \begin{pmatrix} \alpha \cdot r_{lens} + (1-\alpha) \cdot r_{context} \\ \alpha \cdot g_{lens} + (1-\alpha) \cdot g_{context} \\ \alpha \cdot b_{lens} + (1-\alpha) \cdot b_{context} \end{pmatrix} \tag{1}$$

The α value is defined using a drop-off function based on the distance d of the current point (x, y) from the lens center (x_c, y_c) as:

$$\mathcal{D}_\alpha : (x, y, d) \mapsto \alpha \tag{2}$$

$\mathcal{D}_\alpha$ is usually a monotonically decreasing function of distance and the range of α is defined from $[0, \alpha_{min}]$, where, α_{min} (usually set to 1) is the least transparent region in the lens (the lens center) and 0 is the most transparent region (the lens boundary).

In addition to the composition function, the region inside the lens is magnified using a constant magnification factor given by MM to increase the level of detail of the focus region. Accordingly, the final rendered pixel $r(x, y)$ anywhere in the viewing region is given by:

$$r(x,y) = \begin{cases} (x_c + \frac{x-x_c}{MM}, y_c + \frac{y-y_c}{MM}) \otimes_{\alpha_{min}} (x,y), & \{\forall(x,y) \mid d(x,y) \le R_I\} \\ \\ (x_c + \frac{x-x_c}{MM}, y_c + \frac{y-y_c}{MM}) \otimes_{\mathcal{D}_\alpha(x,y,d)} (x,y), & \{\forall(x,y) \mid R_I < d(x,y) < R_O\} \\ \\ (x,y), & \{\forall(x,y) \mid d(x,y) \ge R_O\}, \end{cases} \tag{3}$$

where the three cases represent points rendered in the "Focus," "Transition," and "Context" regions respectively.

4. ADAPTING THE BLENDING LENS TO MOBILE DEVICES

We need to consider several issues when adapting the blending lens to a mobile device. These issues arise mainly due to the limited processing power, API limitations and non-conventional interaction methodologies on a mobile device. Accordingly, we describe the adaptations we made in lens rendering and lens interaction to address these issues.

4.1 Rendering

We chose the blending lens for focus + context interaction on mobile devices because of two reasons: First, it does not have distortion related issues associated with fisheye lenses. Second, many rendering APIs such as OpenGL|ES and OpenVG for mobile devices support "Source **over** Destination" alpha blending in hardware. Moreover, OpenVG also has pre-defined functions to compute variable per-pixel alpha values[23] which can be used for the smooth drop-off function $\mathcal{D}_\alpha$ mentioned in Sec. 3. However, there is no such support to compute drop-off functions for distortion based lenses in hardware. We found that computing these functions per frame in software on a mobile device was very slow.

Due to the support for pre-defined blending functions and the need for vector graphics (for resolution independent display) on devices, we chose OpenVG for rendering the lens effects. Moreover, we decided to render the lens as a square to allow for fast spatial querying as shown in Fig.1(b). However, for blending purposes, we define R_O as the perpendicular distance from the lens center (x_c, y_c) to any side of the square.

Two important aspects of Eq. (3) are the magnification and the blending composition functions. The rest of this section discusses the computation of these functions (and in turn $r(x, y)$) in hardware by taking advantage of the OpenVG rendering pipeline.

4.1.1 Magnification

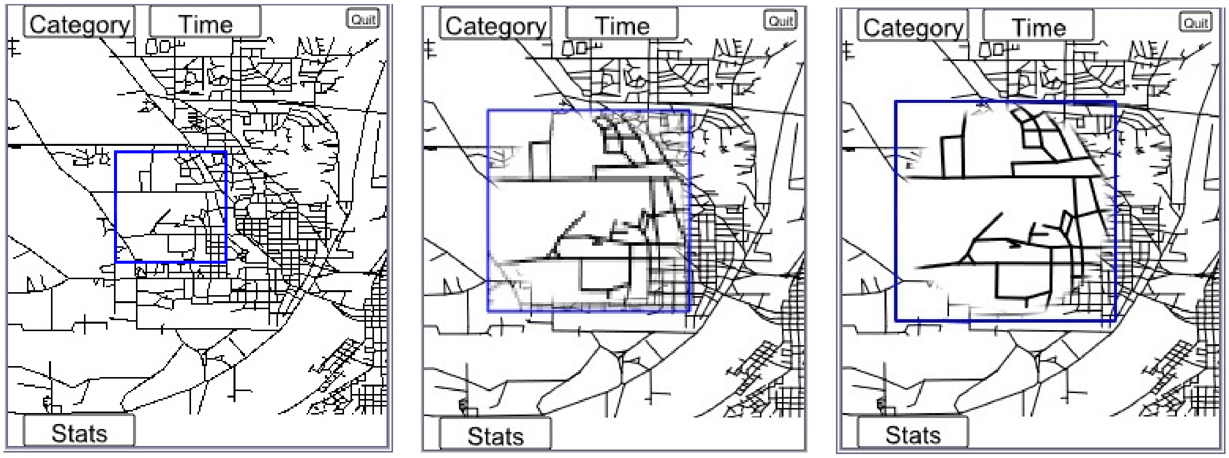
Trade-off between rendering quality and speed is an important consideration for graphics rendering in general and mobile rendering in specific. Depending on the type of user interaction (discussed in Sec. 4.2), a user might prefer one to the other. Accordingly, we have two levels of rendering: low-quality and high-quality as can be seen in Figs.2(a) and 2(c). These two levels differ in the magnification step. However, the blending step (described in Sec. 4.1.2) remains the same. The important steps in the magnification process for these two rendering levels are as follows:

Low-quality rendering:

1. Render contents of the screen with display quality set to VG_RENDERING_QUALITY_NONANTIALIASED.
2. Read pixels from the current lens location into a VGImage.
3. Magnify the image with the current magnification factor MM. MM varies according to user interaction status (Sec. 4.2) such that,
$$Mag_{min} = 1 \leq MM \leq 2 = Mag_{max} \tag{4}$$
4. Blend the magnified image with the contents of the screen at the lens' current location (See Sec. 4.1.2).

High-quality rendering:

1. Render contents of the screen with display quality set to VG_RENDERING_QUALITY_BETTER.
2. Create a pbuffer surface from a VGImage using *eglCreatePbufferFromClientBuffer* function and set it as the current drawing surface.
3. Define scissor rectangle based on the lens dimensions.
4. Re-render the contents of the screen using current magnification factor MM onto the pbuffer surface. Here MM is set to Mag_{max}
5. Restore drawing surface.
6. Blend the pbuffer surface image with the contents of the screen at the lens' current location (See Sec. 4.1.2).



(a) (b) (c)

Figure 2. Views of blending lens with different parameter settings changed according to the stylus drag speed. (a) Low quality rendering with no magnification and effectively transparent lens when the stylus is being dragged. (b) Intermediate stage when the stylus has just reached idle mode. (c) High quality rendering with maximum magnification and full blending effect when stylus has been idle for a specified time.

4.1.2 Blending

The blending process takes the image obtained from the magnification process and blends it with the contents of the screen regardless of the rendering quality. Important steps in this process are enumerated below:

1. Set paint type to VG_PAINT_TYPE_RADIAL_GRADIENT. This generates a radially distributed gradient paint.
2. Set color ramp stops for the gradient paint at the following points: (x_c, y_c), R_I and R_O. These values define the lens center and boundaries for focus and transition regions respectively. R_I and R_O vary according to user interaction status (Sec. 4.2) as follows:

$$R_O \propto MM, \tag{5}$$

$$R_I = 0.9 * R_O. \tag{6}$$

3. Set (r, g, b) values to $(1.0, 1.0, 1.0)$ for all the three ramp stops.
4. Set α values to α_{min}, α_{min} and α_{R_O} at the three ramp stops respectively, where α_{R_O} varies according to user interaction status (Sec. 4.2) such that,

$$0 \leq \alpha_{R_O} \leq \alpha_{min}, \quad and \tag{7}$$

$$\alpha_{min} = 1. \tag{8}$$

   This setting ensures that D_α is a smooth drop-off function in the "Transition region" since α will be linearly interpolated along each radial direction in the lens between each ramp stop.[23]
5. The final rendering is obtained by pre-multiplying the lens image with the gradient paint and setting the blend function to "Source **over** Destination" rule.[23]

4.2 Interaction

Focus + context techniques are known to cause "hunting effects" that interfere with a user's ability to select or navigate to targets.[17] Speed coupled lenses were introduced to alleviate this problem where some of the lens parameters are adjusted based on the mouse speed to provide minimal distortion or change when the mouse is moving and maximal distortion or change in the mouse's idle state. Pietriga et al.[5] use this idea to adjust the α value based on mouse speed while mentioning that it can be applied to other parameters of the lens such as lens radii R_I and R_O. We extend this idea to adjust magnification, R_O and α_{R_O} parameters based on the stylus' dragging speed.

Even though both Ref. 17 and Ref. 5 use a continuously varying function of the mouse speed, we found that it was too computationally intensive for a mobile device. Therefore, we have only two modes of interaction based on the status of the stylus' movement: "Moving mode" and "Idle mode." Moreover, for our visual analytics application, these modes can be interpreted as the user performing "Exploration" and "Inspection" actions respectively.

For exploratory action (when the stylus is in "Moving mode"), we set the rendering quality parameter to lower quality for faster rendering. Moreover, during exploratory actions, a user may not be interested in finer details. In this mode, we also set magnification to one (Mag_{min}) and α_{R_O} to one so that there is no magnification and the lens is "effectively completely transparent" as shown in Fig.2(a). This helps the user to orient and navigate accurately to intended targets. The lens boundary, R_O, is also changed proportional to the magnification factor. This helps a user to accurately determine the portion of the screen that is being magnified once the stylus goes to "Idle mode."

For inspectional action (when the stylus is in "Idle mode"), we set the rendering quality to highest quality since the user is not navigating anymore. Moreover, during inspectional actions, a user might be interested in finer details. Once the user enters this mode, we gradually increase the magnification from one to (Mag_{max}). We set (Mag_{max}) to two, since larger values obscured large portions of the original screen. We also gradually reduce α_{R_O}, so that based on our gradient paint, the blending lens effect is obtained. For both these parameters, the gradual change is computed using linear interpolation with respect to elapsed time. Fig.2(b) shows an intermediate stage during the gradual change and Fig.2(c) shows the final view with highest quality rendering. This gradual change shown as an animation helps users to orient quickly to the new spatial context created by the magnified and blended focus region.[24]

5. GEOSPATIAL VISUAL ANALYTICS

In-field analysts often have to work with geospatial data. Most often these analysts are engaged in other activities and depend on mobile systems for taking actionable decisions. Providing preliminary analysis capabilities in the field with easy interaction methods can rapidly reduce the time needed to gather information, analyze and form a decision. For example, in-field law enforcement personnel such as supervisor patrols are usually posted at different locations and often have to take in-situ decisions to determine the placements and whereabouts of other patrols. In emergency situations with various incidents occurring in a local area, the supervisors typically cannot take quick decisions since they need to wait for information from their offices regarding the latest situation. A mobile system with a simple geospatial analysis tool enhances their situational awareness and allows them to perform simple in-situ analysis to determine pockets of incidence of events and change patrol focus faster than with the existing modes of communication.

With the current map interaction methods (pan and zoom), these personnel will have to invest significant cognitive resources during interaction to keep track of their navigational context. Therefore, we propose to use focus + context interaction method based on the blending lens introduced earlier, to provide tools for visual analysis. We have introduced various visual filters to intuitively query the dataset based on its attributes. Further, we also display simple statistical information on the fly for the filtered results.

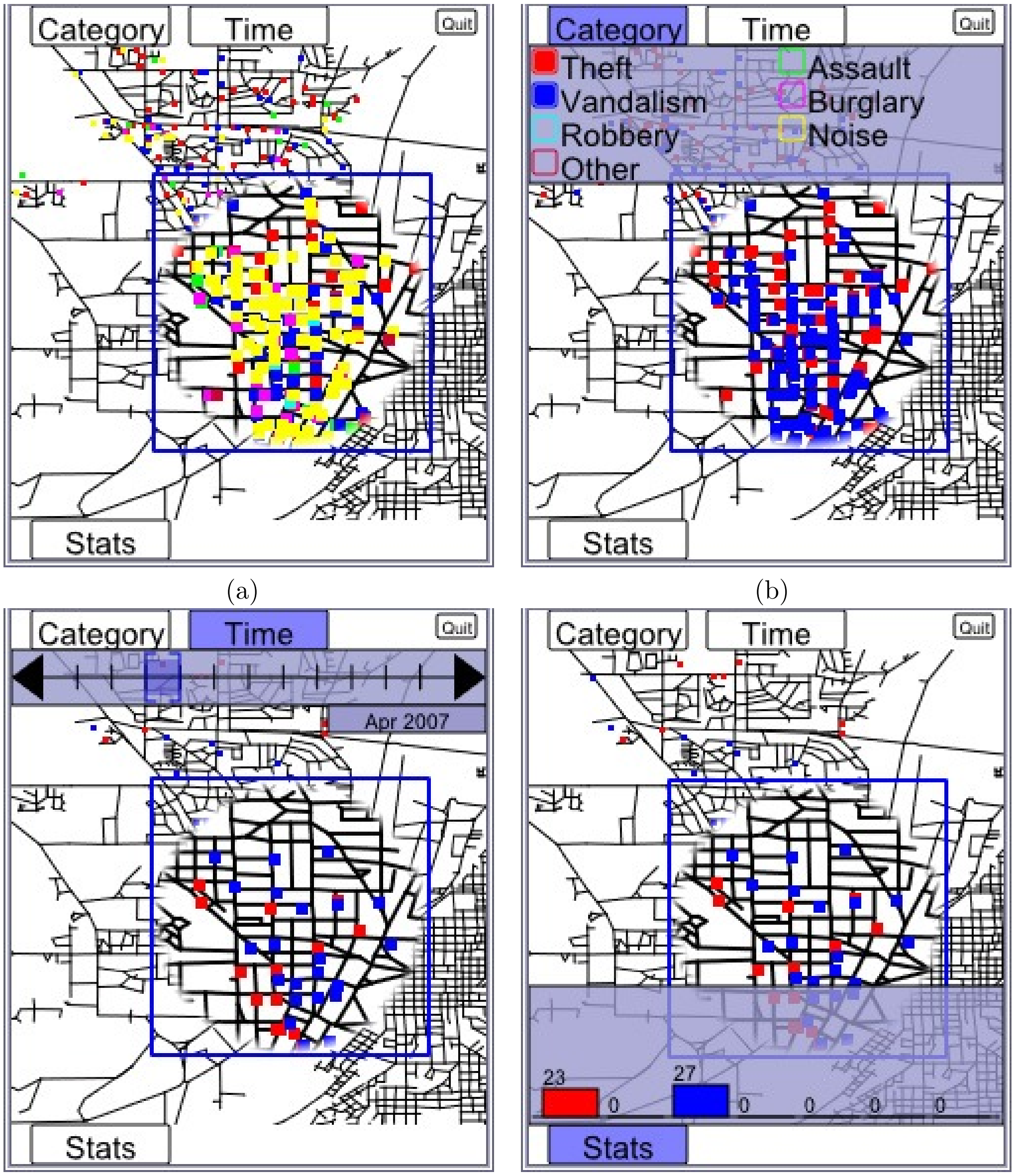
5.1 Dataset

We used a timestamped, geo-tagged crime report dataset for West Lafayette, IN area for the years 2007 and 2008. The data is categorized into various incident types. Each incident type is uniquely color-coded and overlaid on the map at their geographic locations. The maps are rendered from shape files for West Lafayette area's road network obtained from TIGER census data provided on ESRI's website.[25] The shapefiles are simplified initially using the MapShaper[26] tool for fast rendering.

5.2 Data Filtering

We created three data filters based on the attributes of the dataset: Spatial ($\mathcal{F}_{\mathcal{S}}$), Categorical ($\mathcal{F}_{\mathcal{C}}$) and Temporal ($\mathcal{F}_{\mathcal{T}}$). These filters can be combined in any order to form composite filters which are equivalent to conjunctive queries. The composite filter can be specified as:

$$\mathcal{F}_{comp} = \mathcal{F}_{comp} \otimes \mathcal{F}, \tag{9}$$



(a) (b) (c) (d)

Figure 3. Visual analysis tools in our system. (a) Spatial filter (large blue square indicating the lens) applied to the crime dataset. (b) Categorical filter applied to display only "Theft" and "Vandalism" incidents from 2007 in the region selected by the lens (c) Temporal filter applied to display incidents from selected categories in the month of April, 2007 in the selected region. (d) Statistics of selected incident categories in the month of April, 2007 in the area selected by the lens.

where $\mathcal{F}_{comp}$ is initialized as $\mathcal{F}$ and $\mathcal{F}$ can be one of $\mathcal{F}_{\mathcal{S}}$, $\mathcal{F}_{\mathcal{C}}$ or $\mathcal{F}_{\mathcal{T}}$.

5.2.1 Spatial Filter

The spatial filter ($\mathcal{F}_{\mathcal{S}}$) is implicitly formed by the lens boundary. Therefore, this filter is always on and activation of any other filter will result in a composite filter. Computation of the spatial filter is fairly expensive and has to be performed very frequently. In order to simplify this computation, we represent the spatial filter (i.e., the blending lens) as a square so that the spatial query is reduced to a comparison with the bounding box. Figure 3(a) shows an example of a spatial filter showing all the reported incidents in the selected region in the year 2007.

5.2.2 Categorical Filter

The categorical filter ($\mathcal{F}_{\mathcal{C}}$), shown in Fig.3(b), is just an option panel with checkboxes to select one or more incident types to be displayed. For our dataset, we have categories related to Thefts, Assaults, Vandalism, Burglary, Robbery, City noise ordinance violations, and other minor incidents. Figure 3(b) displays all reported incidents of Thefts and Vandalism in the selected region in the year 2007.

5.2.3 Temporal Filter

The temporal filter ($\mathcal{F}_{\mathcal{T}}$), shown in Fig.3(c), is displayed as an interactive timeline. For fast querying, the data is categorized and stored internally into pre-determined time bins. When a user selects a time range using the timeline, all the time bins that intersect with the selected range are queried. Each tick represents the end of a month of the year 2007. Currently, the selectable time range is fixed at a month's granularity and the user can only shift the time range across the timeline. Figure 3(c) displays all reported incidents of Thefts and Vandalism in the selected region in the month of April, 2007.

5.3 Statistics

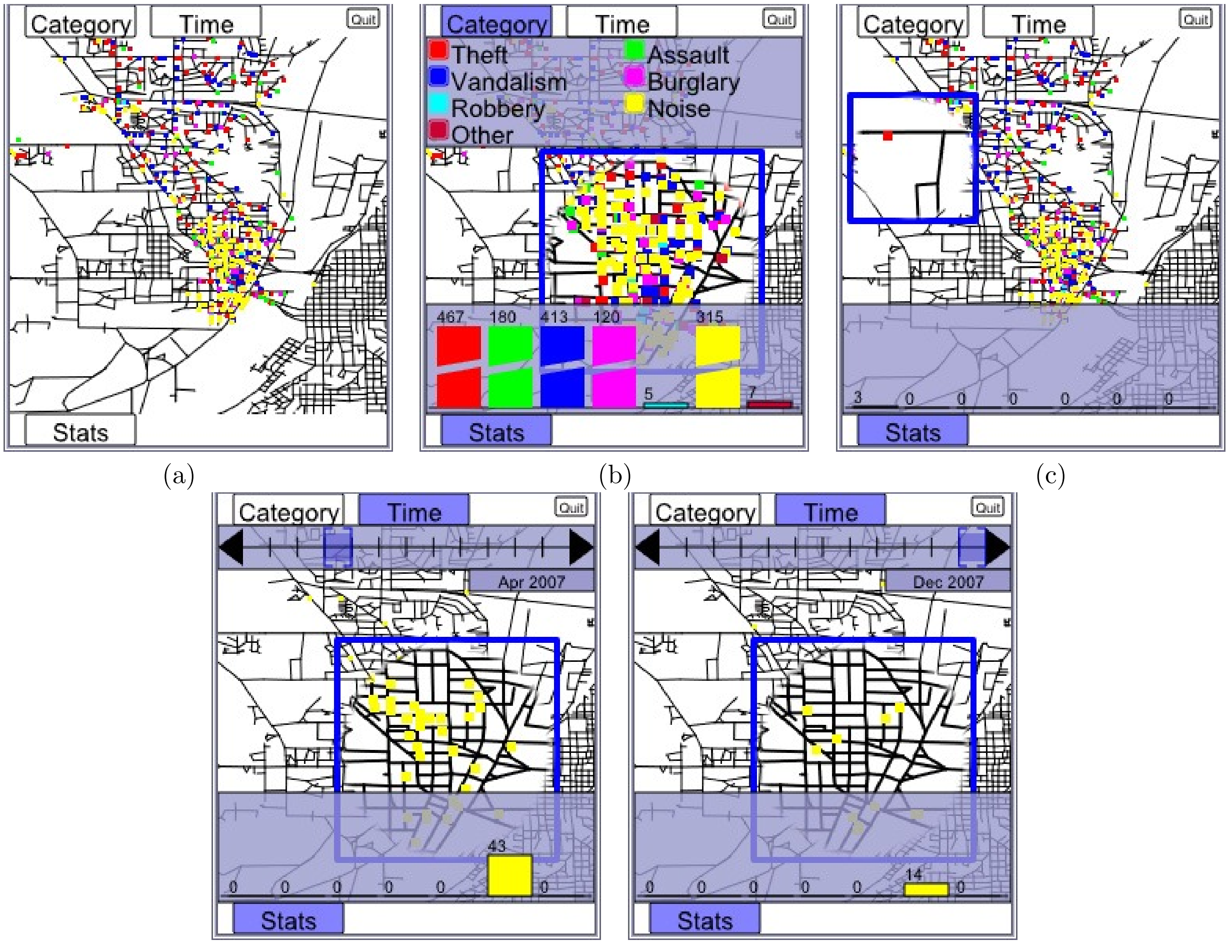
For analytics purposes, we compute and display simple statistics in the form of bar graphs indicating the number of incidents of each crime type in the selected geographic area and time range. If the number of incidents cross a threshold, we display a broken bar graph, along with the actual number of incidents. The statistics are computed on the fly for easy comparison among various filter combinations. Figure 3(d) displays the bar graphs for the number of reported incidents returned by the composite filter ($\mathcal{F}_{comp}$) obtained by combining the filters in Figs. 3(a), (b) and (c).

6. IMPLEMENTATION AND RESULTS

We implemented and tested our tool on a Dell Axim X51v PDA running Windows CE with an Intel 2700G graphics processor and 64MB of RAM and on an AT&T 8525 PocketPC phone running Windows Mobile 5.0 with a 400 MHz Samsung 2442A processor and 64MB of RAM. However, our tool is designed to run on any Windows based PDA or Smartphone with sufficient processing capabilities. We use the OpenVG library provided by Hybrid Graphics, which is a reference implementation and provides functions of OpenVG 1.0 and EGL 1.3 specifications. All images in this paper were captured with the Win32 simulation version of our system. Figure 5 shows our system running on a Dell Axim X51v PDA and an AT&T 8525 PocketPC phone.

To render maps, we need access to editable map data. However, most of the map webservices do not offer such flexibility. Therefore, we decided to use shapefiles because they are represented as vector data and can be easily manipulated. A downside of using shapefiles is that we do not have access to map annotations such as street names. Moreover, these shapefiles are not available in smaller resolutions suitable to render on a mobile device. Hence, most of the graphics resources on a device are currently consumed for drawing the vector maps inspite of the simplification mentioned in Sec. 5.1. These are currently two limitations of our system.

We analyzed the crime incident report dataset for our university town (West Lafayette) using our system. Plotting the incidents on the map immediately shows that most of the incidents are concentrated in the middle of the map (Fig.4(a)) where our campus is located. Using our spatial filter and looking at the bar graphs, we can see that most number of reported incidents were regarding thefts, vandalism and noise ordinance violations (Fig.4(b)). The broken bar graphs indicate that values are above the display threshold. Figure 4(c) shows another advantage of using our spatial filter in combination with bar graphs. The bar graphs display all incidents that occurred in the same spot, even though the corresponding dots overlap on the map. In this case, if not for the bar graph, we could not have inferred that there were three incidents of thefts at the same location. Finally, from the observation of noise violation incidents throughout 2007, we found that the number of reports were high during the end of each semester. However, we observed that it was much higher during April (Fig.4(d)) than during December (Fig.4(e)).



(a) (b) (c)

(d) (e)

Figure 4. Results of analysis of crime incidents in West Lafayette using our system.

7. CONCLUSIONS AND FUTURE WORK

We have adapted a focus + context interaction lens based on new metaphors of time and transparency to a mobile device. We further explored the usage of this lens for performing geospatial visual analytics usable by in-field personnel. The focus + context technique not only provides distortion free contextual interaction to navigate a map but also acts as a semantic data filter allowing the user to visually query a geo-tagged dataset and view simple statistics.

In its current form, the system has a few limitations in map rendering. We intend to improve these limitations and add additional visual analysis features in our future work. Specifically, we will work on simplifying map representations for mobile devices and adding map annotations. We will also add further analysis tools such as a multi-level timeline and time history of incidents for a selected spatial region. Moreover, we will perform usability studies of the system with in-field personnel to improve the system based on their feedback.

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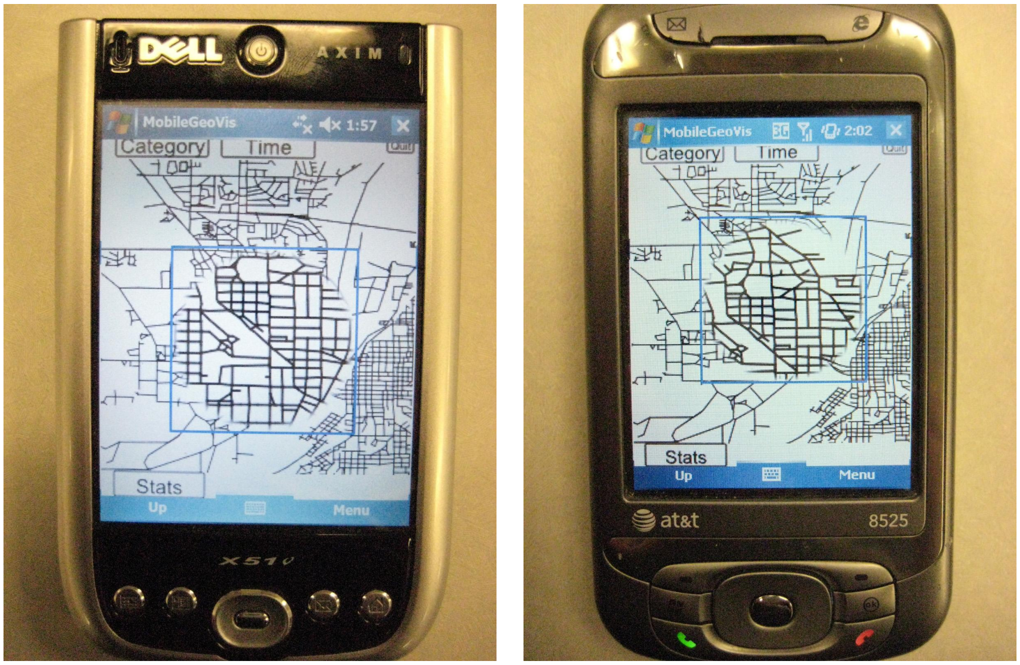

(a) (b)

Figure 5. Photos of our system running on (a) Dell Axim X51v PDA and (b) AT&T 8525 PocketPC phone

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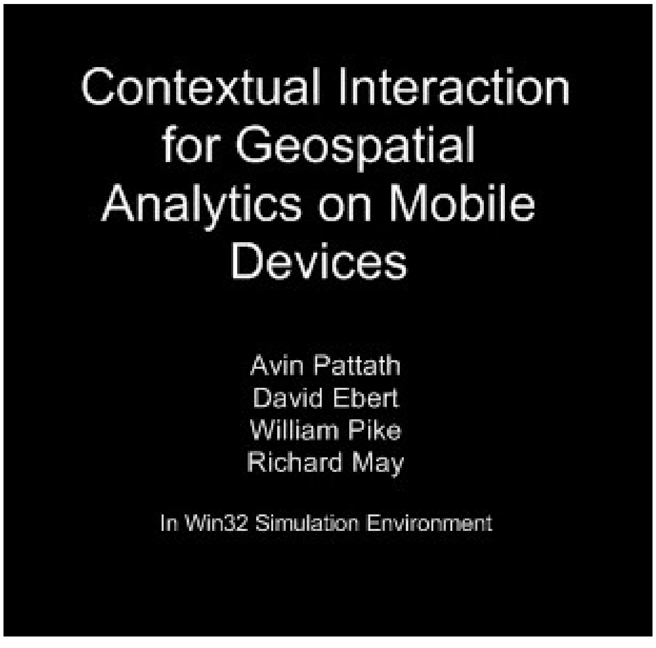

Contextual Interaction for Geospatial Analytics on Mobile Devices

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In Win32 Simulation Environment

Figure 6. Video 1: This video demonstrates the interactive functionalities of our system in a Win32 simulated environment. http://dx.doi.org/10.1117/12.805476.1