A user-centered approach for designing and developing spatiotemporal crime analysis tools

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1. Introduction to Crime Analysis and *GeoVISTA CrimeViz*

Crime analysis describes the systematic collection, preparation, interpretation, and dissemination of information about criminal activity to support the mission of law enforcement (Boba 2005). Leading theories on the sociology of crime emphasize the importance of geography (Shaw and McKay 1942; Cohen and Felson 1979; Sampson and Groves 1989), as the demographic and socioeconomic characteristics of a community illuminate the etiology of crime (Cahill and Mulligan 2007) and past spatial patterns of crime are useful in predicting future incidents (Chainey, Tompson, and Uhlig 2008). Researchers in crime analysis recently have called for increased application of GIScience techniques to the domain of law enforcement (Getis et al. 2000; O'Shea and Nicholls 2003; Wilson 2007), particularly emphasizing the importance of developing statistical and visual techniques that support analysis of criminal activity in both space and time (Ratcliffe 2009).

Despite the potential for GIScience techniques to identify and explicate clusters and trends in crime, many police departments lack adequate analytical tools and training to explore and make sense of their crime incident datasets. This concern is particularly poignant in medium to small municipalities that are unlikely to have dedicated crime analysts on staff (Harries 1999). Here, we introduce *GeoVISTA CrimeViz*, a web-based map application that supports spatiotemporal exploration and sensemaking of criminal activity. The *GeoVISTA CrimeViz* concept provides understaffed departments with an extensible, easy-to-use tool for conducting spatiotemporal crime analysis and mapping. We are currently in the process of completing a user-centered approach to ensure that the tool 'works' for its intended audience; a description of this approach and work in progress is provided in the following subsections.

2. Background: User-Centered Design

The evaluation and refinement of GIS and geovisualization software applications has become an important research topic in recent years (Slocum et al. 2001; Fuhrmann et al. 2005; Hakley and Zafiri 2008; Roth and Harrower 2008), with the explicit goals of improving the usability (i.e., ease-of-use) and utility (i.e., usefulness) of the software (Koua and Kraak 2004; Roth, MacEachren, and McCabe 2009). These scholars have drawn upon research on interface evaluation in such disciplines as human-computer interaction, human factors, information visualization, and usability engineering to tailor an approach for GIScience. A consistent recommendation in this body of work is placement of an early and active focus on the needs and expectations of the targeted end users during design and development, a philosophy described as *user-centered design* (Norman 1988).

Multiple scholars within GIScience have proceduralized the user-centered design philosophy into a formal set of iterative stages (Howard and MacEachren 1996; Gabbard, Hix, and Swan 1999; Slocum et al. 2003; Fuhrmann and Pike 2005; Robinson et al. 2005). Figure 1 illustrates the user-centered design process recommended by Robinson and colleagues (2005) that includes six stages: (1) a work domain analysis (discussion with the users about the type of tasks that the application should support), (2) conceptual development (identifying the essential features for inclusion in the application), (3) prototyping (developing mockups of the interface), (4) interaction and usability studies (evaluation of the partially-featured prototypes), (5) implementation (development of the fully-featured interface), and (6) a final round of debugging prior to technology transition and deployment. Stages #2-5 are completed multiple times during design and development, with each round acting as a loop of software evaluation and revision.

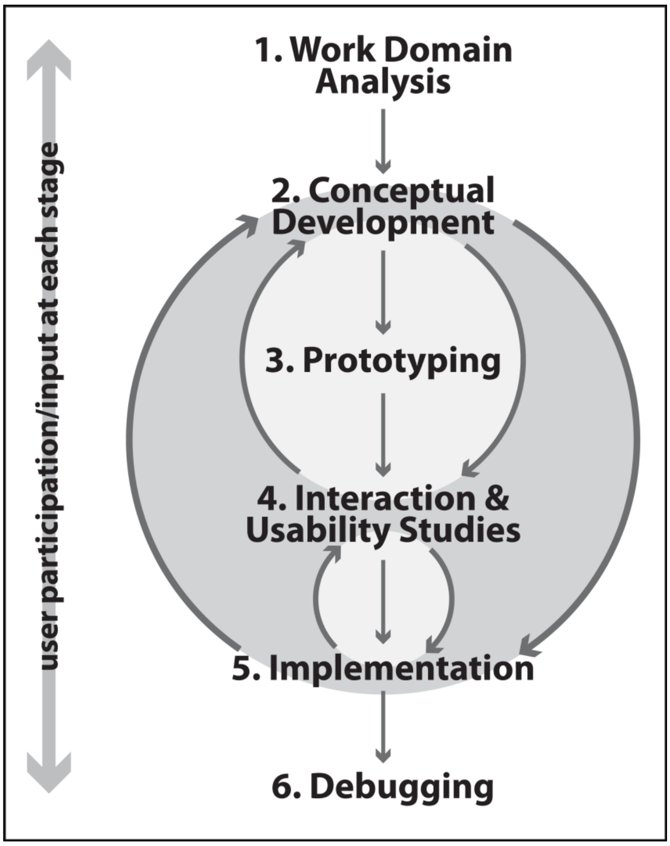

Figure 1: Robinson et al.'s (2005) six-stage user-centered design process.

3. DC CrimeViz Prototype & Modified User-Centered Approach

Strict adherence to the Robinson et al. (2005) workflow is not always practical. The research reported here addresses the concern that arises when a prototype is developed prior to completion of a work domain analysis (Figure 1, stage #1). Failure to complete a work domain analysis prior to development may lead the project team to design for an imagined (and thus non-existent) user group and ultimately may limit the utility of the application. Completion of a work domain analysis prior to design may not be practical for several reasons:

- Many projects must first generate a prototype with a small amount of seed money before being given a larger budget adequate to include user input.
- It is common for a designer or consulting firm to join a poorly managed project midway or to begin design on a new version of an existing application.
- The project team may not have access to the target users at the time of development, or the end user community may not yet be established (which is common with Web 2.0 software, which tend to create their own user groups).
- The initial prototype may have been purposed for a very constrained set of users (perhaps only the designers/developers themselves), but must now be improved and extended to meet the needs of a much broader user community.

GeoVISTA CrimeViz leverages a previous prototype referred to as DC (Washington, District of Columbia, USA) CrimeViz. The original DC CrimeViz prototype (Figure 2) was developed as a 'one-off' to demonstrate the potential of web mapping mashups for spatiotemporal crime analysis. The prototype uses the Google Maps API for Flash to visualize a dataset of violent crimes published to the web in near real time by the District of Columbia (http://data.octo.dc.gov/). The prototype implementation includes a central interactive map, linear and composite animations functions, an interactive temporal legend that doubles as a frequency histogram, and a set of togglable reference map layers. The purpose and functionality of the initial DC CrimeViz prototype are described in more detail in Ross et al. (2009) and Roth and Ross (2009).

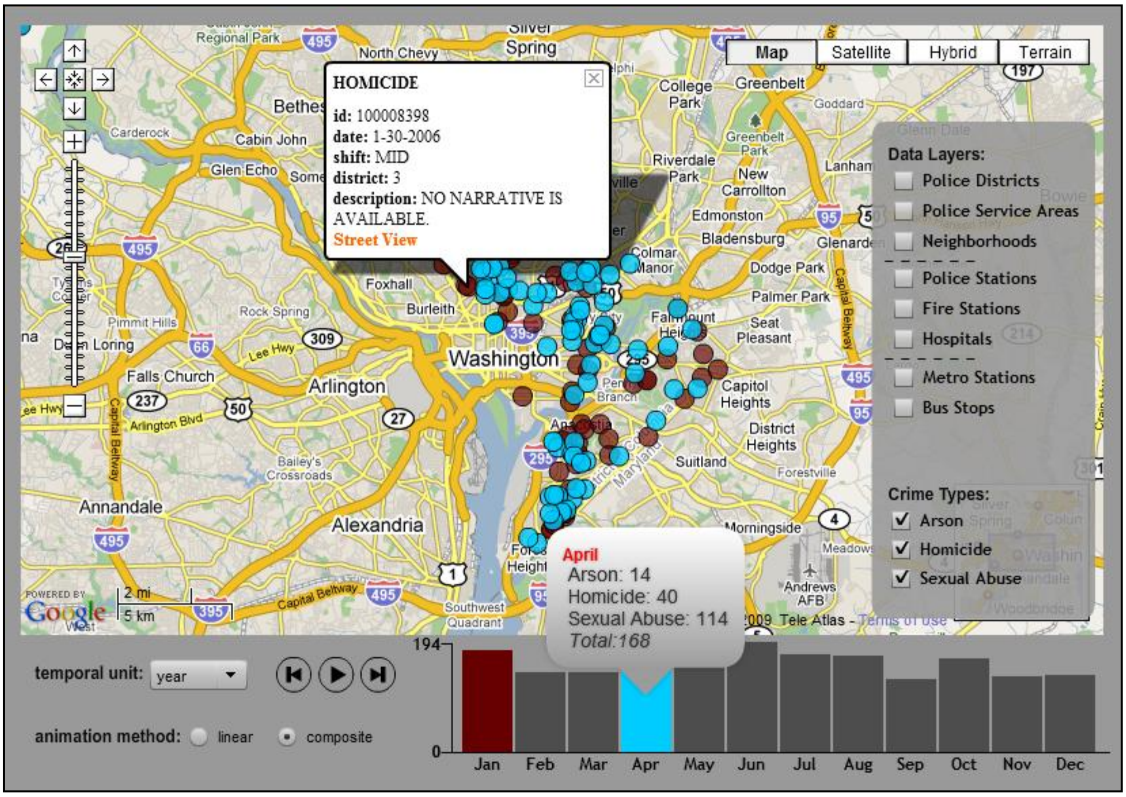

Figure 2: The initial DC CrimeViz prototype.

A robust work domain analysis was not completed prior to prototyping for the reasons described above. While we do not recommend deviation from a user-centered design approach, we also do not believe that it is necessary to abandon an application if a work domain analysis was not performed prior to prototyping. Prototypes and previous software versions can be used to elicit additional suggestions and opinions from end users, which in turn better guide the application redesign.

We modified the six-step approach outlined by Robinson et al. (2005) in order to leverage the DC CrimeViz prototype for conceptual development of *GeoVISTA CrimeViz* (Figure 3). The first step in the modified approach is prototyping; this predates a formal conceptual development stage, as features are added to the prototype as the designers/developers think of them. Formative interaction and usability studies are then performed on the prototype, not to debug the prototype completely, but to stabilize it enough from a usability perspective to be demonstrated. The prototype is then introduced as the final step of a work domain analysis to prompt useful ideas and reactions that users might not otherwise think to offer. This feedback is integrated with the novel ideas generated during the rapid prototyping stage and the findings of the more traditional work domain analysis to formalize the conceptual development of the fully-featured application. As with the Robinson et al. (2005) process, formalization of the conceptual design triggers multiple iterations of interface implementation, interaction and usability studies, modification to the conceptual design of the interface, implementation of the redesign, and so on, ending with a final debugging stage.

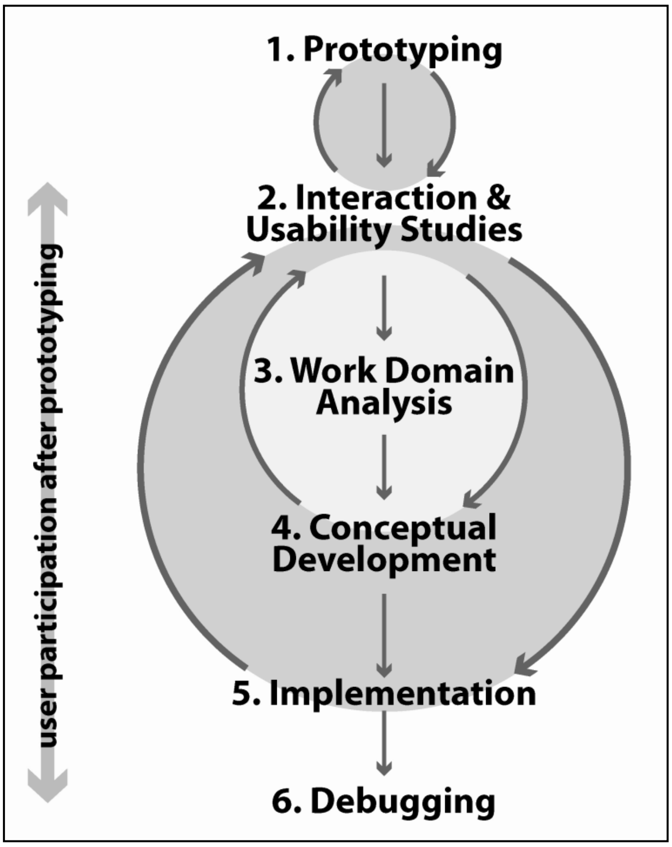

Figure 3: A modified user-centered design approach.

4. Work in Progress and Outlook

We currently are progressing through the user-centered approach illustrated in Figure 3, having completed all or parts of three interface evaluation-revision loops. We first conducted a discount think aloud usability study (Ericsson and Simon 1993) with the original DC CrimeViz prototype to improve its usability (Figure 3, stage #2). Given this input, we completed a major revision to the DC CrimeViz prototype, including implementation of a back-end spatially-enabled database to support flexible spatial aggregation of incidents and complex GIS operations. The revised prototype, shown in Figure 4, can be viewed at: http://www.geovista.psu.edu/DCcrimeViz/app/.

We then completed a set of work domain analysis interviews (Bhowmick et al. 2008) with a combination of crime analysts and police chiefs at seven medium-to-large size police departments in order to identify their key needs, particularly emphasizing the needs that are unmet by their current GIS software (Figure 3, stage #3). Following the work domain analysis, we asked these participants to complete an online Likert survey (Harrower, Keller, and Hocking 1997) evaluating the revised DC CrimeViz prototype (first loop through Figure 3, stages #2-5).

We are currently revising and extending the DC CrimeViz prototype to the fully-featured *GeoVISTA CrimeViz* tool given our feedback from the work domain analysis and online Likert survey. We then expect to complete a multi-dimensional, in-depth, long-term case study (Shneiderman and Plaisant 2006) with a municipal police department to further improve the usability and utility of the application and prepare it for final technology transition and deployment.

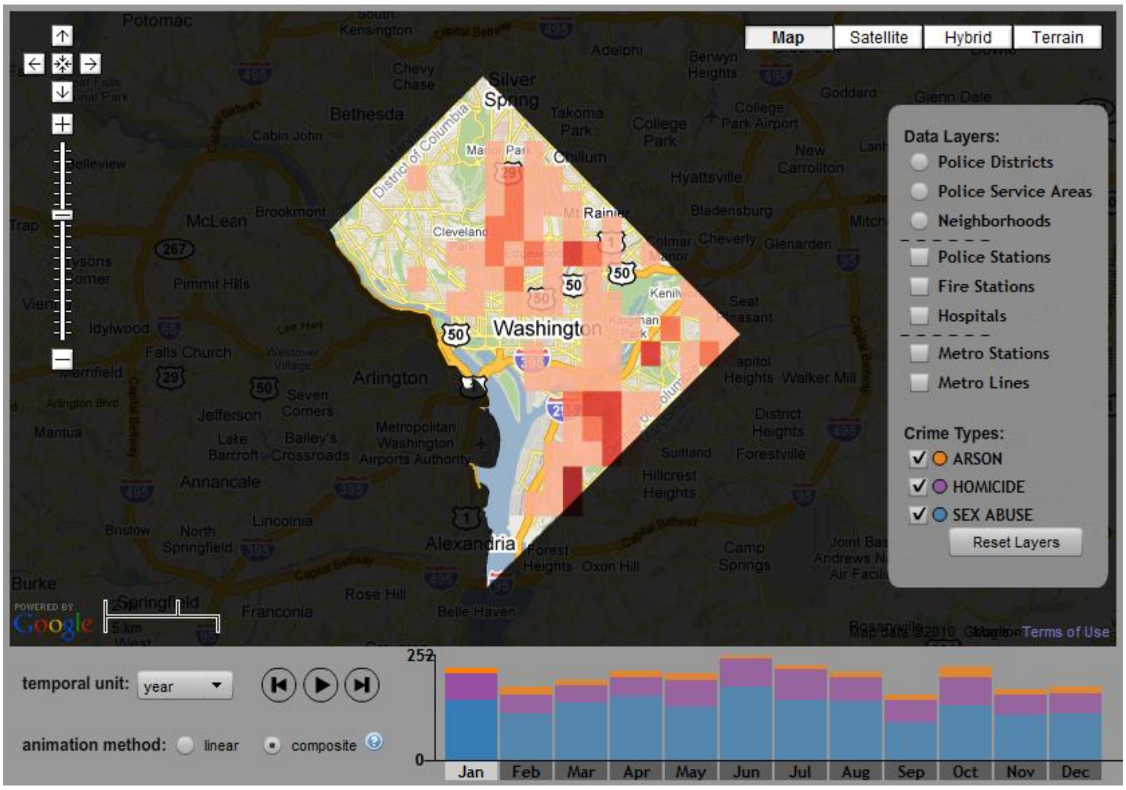

Figure 4: The revised DC CrimeViz prototype, available at http://www.geovista.psu.edu/DCcrimeViz/app/.

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