

Visualization in Law Enforcement

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ABSTRACT

Visualization techniques have proven to be critical in helping crime analysis. By interviewing and observing Criminal Intelligence Officers (CIO) and civilian crime analysts at the Tucson Police Department (TPD), we found that two types of tasks are important for crime analysis: crime pattern recognition and criminal association discovery. We developed two separate systems that provide automatic visual assistance on these tasks. To help identify crime patterns, a Spatial Temporal Visualization (STV) system was designed to integrate a synchronized view of three types of visualization techniques: a GIS view, a timeline view and a periodic pattern view. The Criminal Activities Network (CAN) system extracts, visualizes and analyzes criminal relationships using spring-embedded and blockmodeling algorithms. This paper discusses the design and functionality of these two systems and the lessons learned from the development process and interaction with law enforcement officers.

Author Keywords

Spatial and temporal visualization, crime network, association network, social network analysis, law enforcement, crime analysis.

ACM Classification Keywords

H5.2 User Interfaces: GUI

INTRODUCTION

Two purposes for which the field of law enforcement can use visualization techniques are: crime pattern analysis and criminal association discovery. Very few applications currently exist to perform these functions. In crime pattern analysis, the temporal and spatial attributes of criminal events are studied and used as the basis for formulating plans to interrupt the crime patterns. Criminal association discovery is an important function of crime analysis. Analysts use various data sources, including police reports, national criminal databases and vehicle records to discover associations in order to find investigative leads and build conspiracy cases.

This paper discusses two crime analysis-supporting systems

developed in the AI Lab: Spatio-Temporal Visualization (STV) and Criminal Activities Network (CAN), designed with these two purposes in mind. The STV enables crime analysts to examine the same data from three different views simultaneously and to identify crime patterns. The STV is currently deployed at the Tucson Police Department (TPD) to be used for crime analysis. The CAN is able to extract criminal association networks from the COPLINK system automatically and visualizes the network with a spring-embedded algorithm to help crime analysts understand and analyze these relationships efficiently. COPLINK [1,2] is an integrated information and knowledge management environment. A prototype for COPLINK was initially developed at the University of Arizona's AI Lab in collaboration with the TPD. It was then commercialized by Knowledge Computing Corporation (KCC) and deployed in approximately one hundred law enforcement agencies nationwide

STV: PATTERN IDENTIFICATION VISUALIZATION

In law enforcement agencies, a dedicated group of police officers known as criminal intelligence officers (CIO) and civilian crime analysts are responsible for criminal intelligence analysis and for providing investigative reports for detectives and patrol officers. The reports are based on CIOs' domain knowledge and thousands of police reports generated weekly. However, due to the massive amount of reports, the CIOs have to make judgments on what subset of the reports to include. This manual analysis routine takes over a week to accomplish. When a high profile crime or a serial crime happens, the CIOs perform deep analysis by collecting all the related police reports based on the type of crime, the time and location of the crime and manually plotting these incidents onto a map of the city. The time and description of the incident are labeled next to the incident. This map is then updated daily and serves as a visualization tool to help identify the crime patterns. Figure 1 shows a serial sexual crime investigation map created by a TPD CIO. The current visualization routine used in law enforcement agencies such as TPD only provides visual assistance on identifying spatial patterns and ignores temporal attributes of the incident.

Design and Functions of STV

To enable CIOs to identify more crime patterns in addition to spatial attributes, the STV is designed to integrate three

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types of visualization techniques: a GIS view, a timeline view and a periodic pattern view. Each technique has its own strength. For example, the GIS view displays incidents on a map for spatial analysis; the timeline view displays incidents and incident density along time; the periodic pattern view displays patterns with respect to time. These three views are synchronized and controlled by the central time-slider that illustrates global time bounds and current time window being viewed. The combination of these three different and complementary views allows users to examine the same data from various angles and to identify possible patterns quickly. This visualization tool is used to visualize electronic police reports extracted from the COPLINK system where these reports are carefully dated and geo-coded.



Figure 1. A map created for a serial sexual crime investigation by a Tucson Police Department CIO.

GIS View

The GIS view uses ESRI software (<http://www.esri.com>) to display a map of the city of Tucson on which incidents can be represented as points of a specific color based on crime type. Like most GIS systems, the users can zoom in and out of the map to see different geographical granularities and pan to focus on a certain area of the city. Additional maps such as public facilities can be loaded afterwards. The view displays incidents within the time window specified by the center time-slider. The incidents outside of this period are faded. The users can also apply a geographical bound, by dragging a box around the area of interest. The incidents outside of the bounds will be disregarded by the timeline view and the periodic pattern view.

Periodic Pattern View

The main purpose of periodic pattern view is to provide the CIOs a quick and easy way to search for temporal crime patterns. There are three sub-tools included in this view: periodic pattern tool, histogram tool and line chart tool. The periodic pattern tool is similar to the one used in ReCAP [3], but overcomes some of its shortcomings. In the periodic pattern tool, incidents are summarized by the granularity selected by the user and the crime type. A circle is used to represent the granularity of time that can be a year, month,

week or day. Within the circle are the sectors in the time period. For each sector, the incidents are summarized by crime type and displayed as a spike. The length of the spike indicates the relative number of the incidents. The advantage of this is that the analyst may see different patterns developing over the different time periods. The histogram tool and line chart tool serve as normal charting tools that display crime incidents distribution over time.

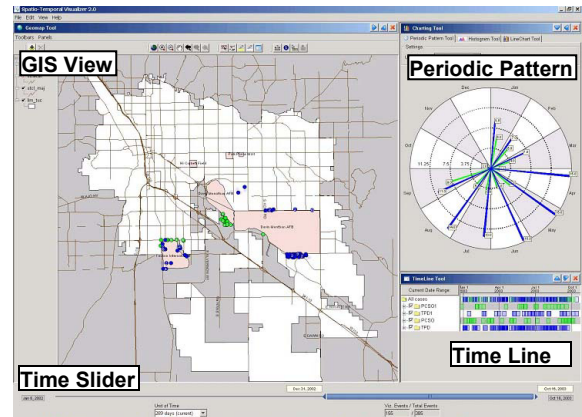


Figure 2. Major components of STV

Timeline View

The timeline view is a two-dimensional timeline with a hierarchical display of the data in the form of a tree. The hierarchical tree of incidents, displayed in the left column, organizes incidents into folders, which represent crime type in a law enforcement context. The right column of the timeline view is a 2D timeline that uses a block of color belt to represent the location of an incident in the time dimension. The block of incidents under the same crime type will be aggregated under that type where the overlap of these color blocks creates an indicator of crime density. This crime density indication helps analysts identify crime clusters. The timeline view also allows analysts to organize incidents into groups and change the representing colors.

Central Time-slider

The time-slider maintains central control over temporal aspects of data. The time-slider illustrates the global time bounds and the time window currently viewed. This time window into the data may be moved and resized, to incorporate new incidents and exclude others. By doing so, the display in the three views changes simultaneously and shows an animated crime incidents pattern over time. This slider was first inspired by Lifelines [4] and revised according to feedback from users. A quick time window selector is added for the analyst to select predefined time units such as week, month, and year to resize the time-slider precisely.

System Architecture of STV

STV is designed as a generic, portable application for spatial and temporal visualization. Architecturally, STV is built upon Java Web Start technology in a modular fashion. This was done with the intent that other types of views would be added in the future with relatively little work by

taking advantage of object-oriented inheritance. In an effort to make STV a generic tool, an open data storage format is designed with XML technology so that STV can be used in any domain as long as data is provided in the designated format. With such design, STV is deployed in the ongoing AI Lab BioPortal project [5] to visualize public health data.

CAN: ASSOCIATION DISCOVERY VISUALIZATION

Identifying criminal associations is important for law enforcement in that a well-established criminal association network can be used to discover conspiracy; build investigative leads, and illustrate the conspiracy to the jury in a court of law. Such a network is especially important in solving organized crimes and narcotic crimes because both have enormous networks to support the criminal activities. For instance, there may be hundreds of people, vehicles and businesses involved in a narcotic crime from production to transportation, selling and consumption. Currently these criminal associations are drawn by crime analysts, either manually or by using some off-the-shelf software. Figure 3 shows an example of a link chart of criminals committing frauds created by a crime analyst at TPD. Drawing a chart like this is a tedious and time-consuming process.

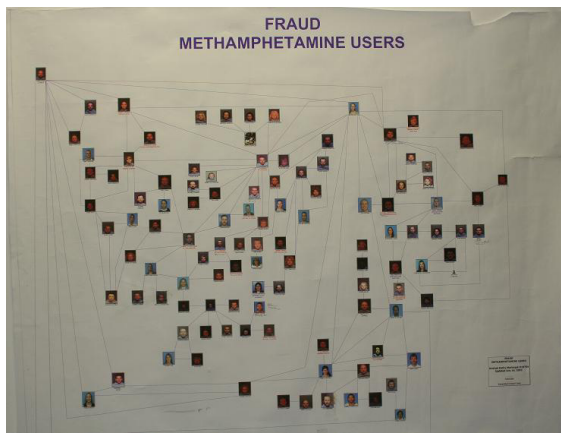


Figure 3. A link chart of criminals committing fraud

Design and Functions of CAN

There are several off-the-shelf software tools that aim at assisting crime analysis and help visualize criminal networks. However, most of them do not have crime database connectivity, a lack which leads to a long and repetitive network creation process. Moreover, none of these off-shelf programs has the ability to analyze the networks and identify groups and roles of members [6]. With these requirements in mind, the CAN system [6] is designed as a client-server application where the server will provide crime database integration and the client supports network editing, navigation and analysis. The CAN system intends to cover the entire crime network analysis lifecycle from network construction, to network editing, navigation and analysis.

Network Construction

Building a large criminal association network from scratch is a long and repetitive process that needs technology's assistance. The CAN system provides three major functions

to help construct the network: 1) identify entities in the database and retrieve information on the target entity; 2) expand the network by retrieving the associations around the selected target; 3) build the association path between selected criminal targets. These functions are performed by automatically searching police reports. The CAN system supports six types of entities including people, vehicle, weapon, location, business and phone number and five types of relations including family, friends, criminal records, phone tabs, and miscellaneous.

Network Manipulation

Criminal investigation relies heavily on undocumented domain knowledge as well as on intelligence stored in information systems. Thus, it is essential to allow crime analysts to add extra information by manipulating the system-generated networks. The CAN system supports network editing in various ways such as: 1) adding and removing entities and associations in the network; 2) creating virtual groups of entities that share similar characteristics such as gang members and multi entities of the same person; 3) filtering the network by entity type, relation type and time period to reduce information overflow. The CAN system also provides a tabular view where the crime analyst can sort, select, hide and delete entities and associations. The changes are reflected in the network immediately.

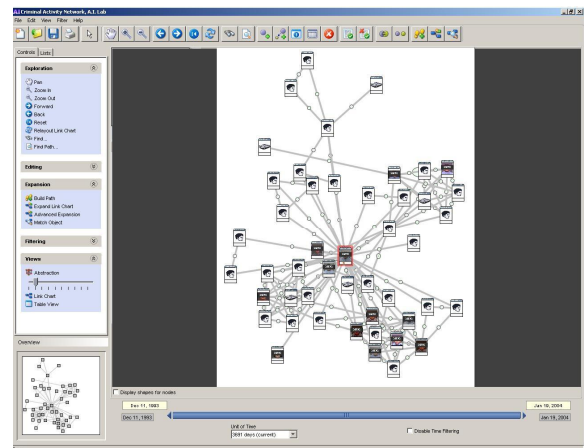


Figure 4. CAN system screenshot

Network Navigation

The network navigation component in the CAN system provides comprehensive navigation functions similar to a GIS system. It first renders the association network onto a two-dimensional map using customized spring-embedded algorithm. The crime analysts can zoom and pan the viewable area of the network to gain a birds-eye view of the network and not miss the details. The CAN system also provides the crime analysts an overview of the network with which they can always keep a global view, providing a focus+context interface. When facing a complicated association network, the crime analyst can do keyword search on the items in the network and bring the investigation target to the center of the view area.

Network Analysis

The CAN system provides two network analysis methods to help crime analysts capture critical associations: 1) association path searching and; 2) social network analysis to identify clusters. The association path searching is implemented using breadth first search to find the shortest paths. Social network analysis includes two steps: cluster recognition and structural analysis. The cluster recognition process is done by a reciprocal nearest neighborhood-based complete-link algorithm. The heuristics of relation weight calculation are based on the type of associations and the number of associations [7]. The key approach of structural analysis is blockmodeling [8] to discover the roles of each entity in the cluster such as leader, outlier or gatekeeper.

USER FEEDBACK AND CONCLUSIONS

STV has been deployed at TPD for over a year. Feedback from users showed that using STV has many advantages over their current analysis tools in both speed and effectiveness. Without STV CIOs create the investigative reports for the detectives in a week and with STV, this task takes less than two hours, which is a 20 times improvement. STV integrates with the COPLINK system and with other formats of data. The CIOs can leverage the advanced query functions in the COPLINK system to collect all possible incidents related to the investigation and load them into STV.

With STV, the CIOs can detect emerging crime patterns much faster and manage police resources more effectively. For example, one of the CIOs used STV to plot recent burglaries for the past month and used different colors to indicate newer and older cases. With STV, the CIO was able to identify a spatial trend of the burglary cases and to locate the trouble area. With enhanced police patrol in the area, a police officer found a suspicious vehicle and this vehicle led to an arrest. This investigation took 2 hours and the suspect was arrested 2 days later. Without STV, the CIO would have had to read hundreds of police reports and the process would have taken over a week.

The CAN system is not yet fully deployed at TPD at the time of writing. As a preliminary experiment, we provided TPD with criminal networks of a set of individuals involved in a conspiracy case. The crime analysts were working on a very large, complex criminal syndicate investigation: over 30 investigative targets. Historical data needed to be incorporated into several different documents. The crime analysts used some of the networks we provided to expeditiously determine which case reports are needed to be pulled, reviewed, and summarized. The CAN system assists the investigators with confirming suspected relationships and identifying additional targets. The generated criminal networks were used to prepare documentation necessary to obtain federal complaints for some of the suspects and in other various affidavits.

The law enforcement community can greatly benefit from automatic visualization techniques and tools. STV and

CAN have shown to be promising visualization tools towards this goal.

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