COPLINK

Arming Law Enforcement with New Knowledge Management Technologies

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Abstract: The problem of information and knowledge management in the knowledge intensive and time critical environment of law enforcement has posed an interesting problem for information technology professionals in the field. Coupled with this challenging environment are issues relating to the integration of multiple systems, each having different functionalities resulting in difficulty for the end-user. The COPLINK project ties together the law enforcement domain expertise of Tucson Police Department with the research and technical background of the University of Arizona's Artificial Intelligence Lab. Working closely together as a user-involved project, we have collaborated at all levels of development (design, testing, and implementation) and the result of our efforts are the COPLINK Connect database, Detect criminal intelligence and Collaboration applications. COPLINK offers a cost-efficient way of web enabling stovepipe law enforcement information sharing systems by employing a model for allowing different police departments to more easily share data amongst themselves through an easy-to-use interface that integrates different data sources. This chapter highlights the technologies created as a result of our collaboration.

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1. INTRODUCTION

The challenges of being a law enforcement officer are many and exist at different levels. There are, of course, the dangers on the street, being the front line as protectors of the community. There is also a large workforce of law enforcement personnel working to solve crimes by searching for critical information. Unlike the popular view propagated by the television and film industries, law enforcement agencies are anything but cutting-edge in their use of information technologies for information sharing and criminal intelligence analyses. In reality, many officers, investigators, and crime analysts are minimally armed with large disparate datastores within their own agencies, which are often times difficult to use and have limited access. This, coupled with little or no information sharing between agencies, makes investigative tasks difficult and time consuming. In a field where time to locate and apprehend a suspect is critical, there is no room for error or for delay.

Under the umbrella of digital governments, the development of cutting edge knowledge management technologies for law enforcement is an important and challenging endeavor. Focusing on a previously neglected domain, issues of dealing with huge amounts of information, different types of legacy systems, security, end user needs and user characteristics all lead to the potential for significant impacts to digital government research and its influence on society. Funded by the National Institute of Justice and the National Science Foundation, the University of Arizona's Artificial Intelligence Lab has teamed with the Tucson Police Department (TPD) under the COPLINK project, focused on the development of different knowledge management technologies, including the Connect Database, Detect Criminal Intelligence Analysis, and Intelligent Agent applications.

The COPLINK project directly targets the problems of information sharing and criminal analyses within and between law enforcement agencies. The approach of this project is not merely one of user-centered design but one of user-involved design. To leverage law enforcement domain expertise and the University's research and technical capabilities, the COPLINK project revolves around the participation of Tucson Police Department law enforcement personnel serving as active members of the development team. This chapter details our story, in terms of law enforcement needs, technology development, collaboration efforts and results from the perspectives of both the University of Arizona's Artificial Intelligence Lab and the Tucson Police Department. It is our hope that by sharing our case study, we can persuade other organizations to create a similar synergistic bond between research efforts and application of technology in digital governments.

The COPLINK Connect Database, COPLINK Detect Criminal Intelligence Analysis and COPLINK Collaboration applications were

developed to specifically deal with the problems and issues with information sharing and criminal intelligence analysis facing law enforcement agencies. We utilized a user-involved design methodology that led to the resulting design decisions, including data source identification and functionality. Design principles of platform-independence, stability, scalability, and an intuitive graphical user interface are the underlying foundations of the COPLINK systems.

2. KNOWLEDGE MANAGEMENT PROBLEMS IN LAW ENFORCEMENT

The general area of knowledge management (KM) has attracted an enormous amount of attention in recent years. Although it has been variously defined, it is evident that knowledge management exists at the enterprise level (see (Davenport & Prusak 1998) and is quite distinct from mere information (e.g. see (Nonaka 1994; Davenport & Prusak 1998; Teece 1998)). Also apparent in this area are the challenges that knowledge management poses to an organization. In addition to being difficult to manage, knowledge traditionally has been stored on paper or in the minds of people (Davenport 1995; O'Leary 1998). The KM problems facing many firms stem from barriers to access and utilization resulting from the content and format of information (Jones and Jordan 1998; Rouse, Thomas et al. 1998). These problems make knowledge management acquisition and interpretation a complex and daunting process. Nevertheless, knowledge management information technologies have been developed for a number of different applications, such as virtual enterprising (see e.g., (Chen, Liao et al. 1998)), joint ventures (see e.g., (Inkpen and Dinur 1998)), and aerospace engineering (see e.g., (Jones and Jordan 1998)).

The same problems of knowledge management and information access exist at the specialized organizations of law enforcement. Federal, state, and local criminal justice entities possess vast repositories of information, but the explosive growth in digital information and the need for access within government agencies have made information overload increasingly significant.

A function of the daily routine of many crime analysts and detectives at TPD is to create knowledge from information by analysing and generalizing current criminal records that consist of approximately 1.8 million criminal case reports containing details from criminal events dating back to 1986. Although investigators can access large data stores of criminal data to tie together information needed to solve cases and crimes, they must manually search for connections or relationships in existing in the data. Combining information to create knowledge is often hampered by voluminous

information examination of which requires exorbitant time and effort on the part of the investigator. Compounding this problem is the variability of individual investigator's ability to locate relevant information. The problem is not necessarily that the information has not been captured—any officer who fills out up to seven forms per incident can attest to that. The problems are database integration and access to information. Typically, law-enforcement agencies have captured data only on paper or have fed it into a database or crime information system. If the agency involved has more than one of these (that are possibly incompatible), information retrieval can be difficult or time-consuming.

2.1 Database Integration

One important aspect of problem solving is the ability to cluster related information to permit querying across many different data types and sources. This requires the ability to integrate and access the vast number of law enforcement data sources (Sparrow, 1991). In many local law enforcement agencies, criminal information databases exist as isolated stand-alone systems. While many law enforcement agencies depend heavily on crime-related information systems, most of their systems are not networked together; thus deterring collaboration (Pliant, 1996). Inability to share information with other systems prevents an agency's receiving timely information that could be used with that from other data sources to increase the efficiency of crime prevention and investigations (Tucson Police Department, 1997).

2.2 Access to Information

Similarly, law enforcers often have a problem accessing valuable information sources. Because time can be such a crucial factor in the completion of an investigation, access to information in a timely fashion is critical. Obstacles to acquiring information promptly can include restricting access to some systems to certain types of officers and long wait times for query returns. Although a detective may need information within 3-40 hours, he or she may have to wait a few weeks to a month before receiving it. Likewise, secure remote access to textual and multimedia databases is not currently available at many agencies (Tucson Police Department, 1997).

Potent information retrieval tools can provide information sharing abilities as well as alleviate crime analysts' information overload, reduce information search time required for analysis of available criminal records, and advance the investigation of current cases. This chapter introduces three knowledge management systems that can provide the ability to access data

from different systems as well as provide the functionality of intelligence analysis and collaboration that currently does not exist in the traditional records management system.

3. TUCSON POLICE DEPARTMENT CASE STUDY

The Tucson Police Department (TPD) recently evaluated its information technology and identified problems of lack of information sharing, integration, and knowledge management. The department agreed to participate in research to investigate the potential of current state-of-the-art, near-term, and cost-effective database, Intranet, and multimedia technologies to make computer justice information database integration, management, and access more effective.

Similarly to systems at many other law enforcement agencies, TPD's current records management system (RMS) has many problems pertaining to its interface, access to information and lack of knowledge management. Although users are able to search on name queries, location queries, vehicle queries, etc., they are not able to search multiple fields simultaneously. In addition, users of RMS complain that, depending on the type of query, RMS can take from a few minutes to a few hours to return its results.

The COPLINK project attacks several problems existing in many law enforcement agencies, including TPD, by developing a model integrated system that allows law officers both within and between different agencies to access and share information. An additional goal of COPLINK is to develop consistent, intuitive and easy-to-use interfaces and applications that support specific and often complex law enforcement functions and tasks. While the scope of this project includes a multilevel development plan incorporating different information technologies, the focus of the research reported here is not only on the development of a multimedia database system to promote information sharing, but also the improvement of criminal intelligence analysis.

4. COPLINK CONNECT DATABASE APPLICATION

After analyzing user requirements dealing with the problems of information integration and ease of access, we created the COPLINK Connect application, employing a consistent and intuitive interface which integrates different data sources, such that the multiplicity of data sources remains completely transparent to the user, allowing law enforcement personnel to learn a single, easy-to-use interface. In addition to the interface

design, we also developed a model that allows for information sharing both within and between law enforcement organizations.

4.1 Design Criteria

The main design criteria considered for the COPLINK project includes:

- **Platform independence**: Because not all police departments utilize the same hardware or software operating systems, platform independence was critical.
- **Stability and scalability**: The system also had to offer room for system growth and expansion.
- **Intuitive and ease of use**: The front-end user interface should be intuitive and easy to use, yet flexible enough to meet the equally demanding investigative needs of detectives and officers.

Typical law enforcement applications usually are legacy systems having out-dated performance and capability. For example, TPD's RMS took 30 seconds to answer simple requests and up to 30 minutes for more complex queries. Improved response time was critical to restoring departmental efficiency. To ensure application speed, issues of data and network communication, disk access and system I/O needed to be addressed. This also meant carefully distributing logic where it could be most quickly and efficiently executed, i.e., all user-input error checking should be done in the front end, and all database access logic achieved through pre-compiled stored PL/SQL procedures in the database.

Another critical issue, especially in designing a system that could be deployed across multiple law enforcement agencies, was acknowledging that no two agencies would store their incident data in exactly the same way. Therefore, it was important to come up with a data organization design that was flexible enough to be applied to any underlying data set. The database team designed a series of standardized "views" that fitted typical information search and presentation situations. For example, most of the data in the TPD systems were related to "Person," "Location," "Vehicle," or "Incident" information. A set of views was developed for each of these areas of interest, with the underlying data sets mapped to those standard views, making the system more portable to other law enforcement agencies.

4.2 Database Design

Based on the criteria established and after much investigation, the COPLINK team decided upon a three-tier architecture:

- **Front-end interface:** The front-end should be a thin client, consisting of a series of user-friendly query screens matching the four main areas previously discussed (Person, Location, Vehicle, and Incident). The front-end would generate query requests.
- **Middle-ware application server:** The middle-ware would handle secure requests from multiple clients, and execute the stored procedures in the database.
- **Back-end database:** Results from the database would be processed by the middle-ware, and be formatted into return data strings. These return strings would then be sent to the front-end where they would be parsed and displayed to the user.

There are four main query screens, each resulting in a summary listing of information related to an initial query. Figure 1 illustrates relationships among queries. For example, if a user initiates a search on a particular first-name/last-name combination, a summary table is presented as a result of a dynamic SQL query, listing all possible matches, as well as the number of incidents associated with each individual match. From there, the user can select either a secondary listing of incidents related to a particular individual or can access a more detailed summary of the personal information on the individual. For an incident summary, all the pertinent case detail information on a particular incident is presented. For a detailed person summary, the user can select the incident summary for that individual, and from there obtain case details for any incident listed.

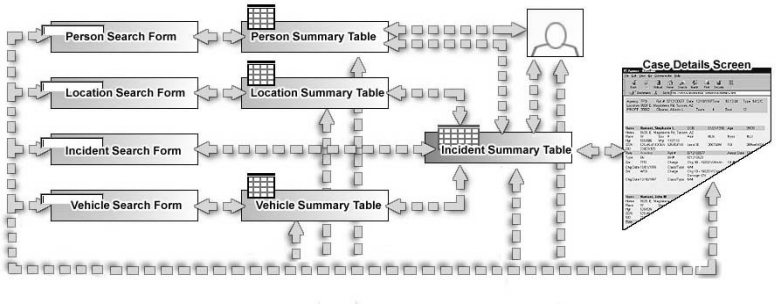

Figure 1. COPLINK Connect Search Schema

4.3 User Evaluations for the COPLINK Database Application

A usability evaluation, involving 52 law enforcement personnel, was conducted to assess the achievement of a number of the goals that guided the

design and development of the COPLINK Connect. Items on the questionnaire used to assess and compare the COPLINK and RMS systems were based upon user perceptions of such widely used measures of usability as: *effectiveness* (impact of system on job performance, productivity, effectiveness of information, and information accuracy), *ease of us*e (measures of effort required to complete a task, ease of learning how to use the application, ability to navigate easily through the different screens, and satisfaction with the interaction), and *efficiency* (speed of completing tasks, organization of the information on the screens, ability to find information and the interface design itself) (Hauck, 1999).

From both questionnaires and interviews, participants indicated that the quality and quantity of information from COPLINK Connect surpassed those of RMS. In a review of current RMS practices, a number of detectives and officers were actually unable to use RMS but were able to use COPLINK DB to conduct searches. It is evident from this evaluation that COPLINK DB allowed a population of TPD personnel to access information that would have been quite difficult for them to acquire using the RMS system. From both the questionnaire and the interview data collected from this evaluation, it is evident that many participants rated the information found in COPLINK as more useful than the information in RMS.

5. COPLINK DETECT CRIMINAL INTELLIGENCE APPLICATION

In order to provide investigative support through data mining techniques, a knowledge management tool, COPLINK Detect, was specifically designed to aid law enforcement investigators and detectives in criminal intelligence analysis, helping to improving efficiency and effectiveness. A statistics-based, algorithmic technique, called a concept space or automatic thesaurus, was used to identify relationships between objects (terms or concepts) of interest (Lesk, 1997). The technique has been frequently used to develop domain-specific knowledge structures for digital library applications.

A concept space is a network of terms and weighted associations that represent the concepts and their associations within an underlying information space that can assist in concept-based information retrieval. In addition, co-occurrence analysis uses similarity and clustering functions (Chen & Lynch, 1992) to weight relationships between all possible pairs of concepts. The resulting network-like concept space holds all possible associations between objects, which means that every existing link between every pair of concepts is retained and ranked. The concept space was used as the basis for the COPLINK Detect application.

In COPLINK, detailed case reports are the underlying space and concepts are meaningful terms occurring in each case. Detect provides the ability to easily identify relevant terms and their degree of relationship to the search term. The relevant terms can be ranked in the order of their degree of association so that the most relevant terms are distinguished from inconsequential terms. From a crime investigation standpoint, Detect can help investigators link known objects to other related objects that might contain useful information for further investigation. For instance, like people and vehicles related to a given suspect.

Information related to a suspect can direct an investigation to expand to the right direction, but a case report that reveals relationships among data in one particular case fails to capture those relationships from the entire database. In effect, investigators need to review all case reports related to a suspect, which may be a tedious task. In the COPLINK project, we introduce Detect based upon the concept space algorithm as an alternative investigation tool that captures the relationships between objects in the entire database.

To date, we have successfully adopted our techniques to create COPLINK Detect based on a collection of 1.5 million case reports from the current Tucson Police Department Records Management System. These cases span a time frame from 1986 to 1999 (the entire case record collection for the City of Tucson). Based on careful user requirement analysis, five entity fields from the database were deemed relevant for analysis: Person, Organization, Location, Vehicle, and Incident type. The purpose of this tool is to discover relationships between and among different crime-related entities. It is important not only to know that there is a relationship, but also to know what each relationship is.

5.1 System Design

In general, there are three main steps in building the domain-specific Detect concept space. The first task is to identify collections of documents in a specific subject domain; these are the sources of terms or concepts. For Tucson Police Department, we are using the case reports in the existing database. The next step is to filter and index the terms. The final step is to perform a co-occurrence analysis to capture the relationships among indexed terms. The resulting output is then inserted into a database for easy manipulation (for a more in-depth analysis of the Concept Space algorithm, see Chen & Lynch (1992)). The last two steps have been customized for COPLINK Detect. After optimising the code and tuning the database, we found that the total time required for building COPLINK Detect is approximately five hours, which is acceptable in the given situation.

5.1.1 Term Filtering and Indexing

Due to the nature of the data residing in TPD's database, each piece of information is categorized in case reports and stored in well-organized structures. Theoretically, a concept space can contain any number of term types (e.g., person names, organizations, locations, crime types, etc.). In practice, however, the size of the database, the time required to build the Detect concept space, and the response time of queries are major constraints that limit the number of term types. With the collaboration of personnel from the Tucson Police Department, we identified and created a set of term types for the COPLINK Detect in order to balance performance and comprehensiveness. The index maintains the relationship between a term and the document in which it occurs. Both index and reverse index are required for co-occurrence analysis. The index contains the links from term to document; the reverse index contains the links from document to term.

5.1.2 Co-occurrence Analysis

After identifying terms, we first computed the term frequency and the document frequency for each term in a document, based on the methodology developed by Chen and Lynch (1992). In general, some term types are more descriptive and more important than others and deserve to be assigned higher weights so as to ensure that relationships associated with these types are always ranked reasonably. In COPLINK Detect, crime types are assigned comparatively higher weights. We then performed term co-occurrence analysis based on the asymmetric "Cluster Function".

5.2 User Evaluations for COPLINK Detect

We conducted user evaluations to examine the effects of COPLINK Detect on law enforcement investigation and work practices (Hauck & Chen, 1999). Twelve crime analysts and detectives participated in the four-week longitudinal evaluation, during which they were asked to complete journal entries on searches they had conducted using COPLINK Detect. By utilizing data collection methods of documentation, structured interviews, and direct observation, we were able to evaluate the function and design of the COPLINK Detect system. The journals and interviews revealed that COPLINK Detect provided support for intelligence analysis and knowledge management in the areas of link analysis, summarization, and efficiency.

5.2.1 Link Analysis and Summarization

Participants indicated that COPLINK Detect served as a powerful tool for acquiring information and cited its ability to determine the presence or absence of links between people, places, vehicles and other object types as invaluable in investigating a case (Harper & Harris, 1975). The impact of link analysis on investigative tasks is crucial to the building of cases. An officer assigned to investigate a crime has to have enough information to provide a lead before he/she can begin working. Too many cases have to be closed because of lack of information or inability to utilize information existing elsewhere in the records management system. Detect manages all the data in the records system in such a way that it can be used as knowledge about the suspect.

5.2.2 Efficiency

Perhaps one of the most crucial benefits of the use of COPLINK Detect in law enforcement is its speed. As one of our participants explained, identifying a suspect between 48 to 72 hours after a crime is difficult. Beyond this time frame, a suspect is able to destroy evidence that may tie him/her to the crime or change his/her appearance to avoid identification. Witness/victim memory of the suspect's appearance also fades within this period. Identification of the suspect ideally should occur within 48 hours of the crime, so establishing useful links for identifying and locating the suspect is a crucial step. A number of interviews and journal comments indicated that use of COPLINK Detect increased productivity by reducing time spent per information search.

6. COPLINK COLLABORATION SYSTEM

The rapid advancement of information technologies and the Internet provides great opportunities as well as challenges for law enforcement. These technologies allow better use and sharing of information. With the growing popularity of the Web, information can be shared among agencies or made accessible to the public more easily than ever. On the other hand, however, there are many issues and challenges, which are not yet completely resolved. In this section, we report on our experience in designing a collaborative information-sharing infrastructure in the law enforcement domain. We also review some of the major challenges we encountered. Our project is built on the COPLINK infrastructure at TPD, and given the success of COPLINK Connect and COPLINK Detect, we identify some areas that can be further improved.

6.1 Design Goals and Challenges

6.1.1 Information Access and Monitoring

Besides the data sources incorporated in COPLINK Connect, there are many other external sources that need to be inquired frequently by police officers. These data sources include information or search services that are available on the Web. Examples include search services such as Property Assessor Information, Map Guide, People Search and Reverse Lookup. Without substantial experience and knowledge, it becomes difficult to locate important and accurate information. These resources employ a wide range of different hardware platforms, database systems, network protocols, data schemas, and user interfaces. This poses a great challenge for managing and combining these data sources. Several research groups have proposed the use of distributed ontology or agent technology database to deal with this problem (e.g., Ambite et al, 2001; Bouguettaya et al, 2001). Although these systems can effectively manage multiple data sources, they do not allow users to add a new resource easily or to rate the quality or credibility of an existing data source.

In addition, most of the data sources are passive and lack the ability to push useful information to the users. Police officers often have to track the activities of a particular suspect or the whereabouts of a vehicle. These monitoring functions are usually not available in most search systems. As a result, the data sources have to be checked manually on a regular basis, resulting in heavy mental effort for the user.

6.1.2 Personalization and Collaboration

Personnel with different job duties and geographical locations have very different information needs. Given the large number of data sources, police officers face the problem of finding the right data sources that are relevant to their jobs. One main goal of our design is to provide customizable and personalized information to the users.

Effective collaboration among law enforcement personnel is another important goal in our design. A police officer may obtain some knowledge from the observations during patrol, while a crime analyst may get some particular insights when doing an investigation. Such knowledge however, is tacit and not efficiently shared. When a police officer needs some particular information, he/she does not know whom to contact. We find that there also are situations where two different units are working on two closely related cases (e.g., related to the same person), but none of them know that another unit is working on a related case. As a result the two units are not able to collaborate and share their findings. The issues of sharing knowledge in a

collaborative manner and linking together people working on similar cases are to be addressed.

6.2 System Architecture

Taking into consideration the above issues and challenges, we propose the COPLINK Collaboration system, an infrastructure which tries to address those problems to a certain extent.

6.2.1 Linking People Together

We adapt an approach based on collaborative filtering in our system. Collaborative filtering is defined as the collaboration among people to help one another perform filtering by recording their reactions to the information they read (Goldberg et al, 1992). While traditional collaborative filtering relies on documents read (e.g., Konstan et al, 1997) or items purchased by users (e.g., Amazon.com), we make use of the users' search actions and search histories.

The rationale behind this is that when two users search for the same information, it is likely that the users have similar information needs and that they may possibly be working on two related cases. When a user performs a search query through COPLINK Collaboration, the search query will be forwarded to the corresponding data sources. Our system will return the search results to the user and store the search session in the user profile database for further analysis. Collaboration will be performed by applying data mining techniques on these user search profiles. Our previous research has shown that machine learning and data mining techniques such as ID3, genetic algorithms and relevance feedback can be applied in inductive search query analysis (Chen et al, 1998). Using these techniques, the system tries to (1) recommend similar cases to users and (2) identify police officers with similar information needs. If the system finds that two police officers have performed similar searches (e.g., similar search keywords or search criteria), it will alert both users and provide a way for them to contact each other for further collaboration. Since no extra effort is required from the users, we expect them to be more willing to share information. Figure 2 shows a simplified version of the system architecture.

6.2.2 Finding Useful Data Sources

Another measure we use for collaboration is users' ratings of data sources. Users can give ratings to or write reviews for the data sources they use. Our algorithm is based on a hybrid approach, which combines content-based filtering and collaborative filtering (Balabanovic & Shoham, 1997).

Data mining techniques are also applied in our filtering algorithm. Useful information sources will be recommended to a user based on one's past search sessions and the recommendations of other users who have similar information needs. This allows users to have a personalized list of data sources they need while irrelevant sources are filtered.

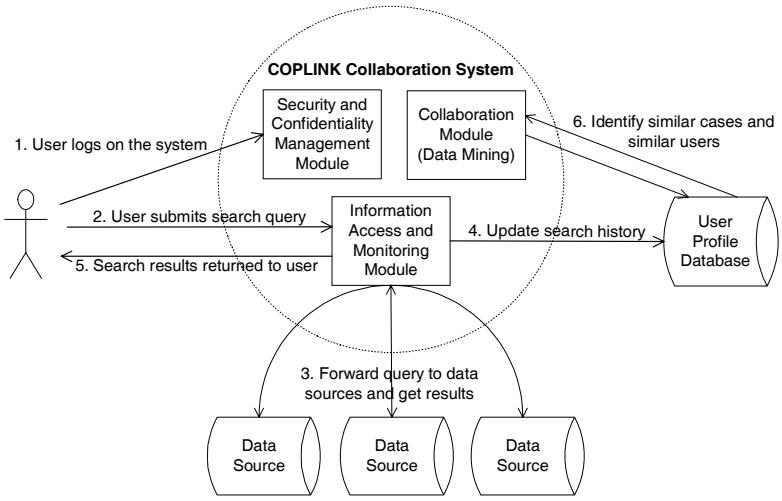

Figure 2. Proposed system architecture to support information sharing and collaboration

6.2.3 Information Monitoring

Users can also set up monitoring tasks through the system. If a user wants to monitor a database for a particular query, the system will store the monitor task in the user profile database and check the corresponding database periodically. When relevant data is updated or inserted into the database, the system will send an alert message to the user through the user interface, email, voice message or cellular phone.

7. CONCLUSION

Criminals do not bound themselves by county borders or jurisdictions. Furthermore, criminals are creatures of habit and being able to understand their habits and close associations is important (Joyce, 1996). The COPLINK applications take advantage of these characteristic by not only promoting information sharing and collaboration between stovepipe information sources and different agencies, but also by capturing

connections between people, places, events, and vehicles, based on past crimes. Our evaluation of these knowledge management and intelligence analysis applications support its potential for transforming law-enforcement practices in this age of digital governments.

In this chapter, we have identified the major challenges in designing an information sharing and collaboration infrastructure within the law enforcement domain to promote criminal intelligent analysis and knowledge management. We have proposed and are implementing an architecture that addresses some of the major issues. Currently, the COPLINK Connect database system is fully deployed at the Tucson Police Department, while final user evaluations and modifications on COPLINK Detect are being conducted. A prototype of the COPLINK Collaboration system is being developed. We are excited about the results of the COPLINK project, from both the potential impact in the research community as well as in application as an example of digital government technologies being used to help the general community. We hope our experience can provide useful insight to other digital government research projects.

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