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Improve Safety using Public Network Cameras

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***Abstract*—Surveillance cameras, also called CCTV (closed-circuit television), are widely deployed as one of the solutions to improve public safety. The visual data from these cameras are usually unavailable to the public. In recent years, many organizations have deployed network cameras with diverse purposes such as monitoring traffic congestion and observing natural scenes. The data are available to anyone connected to the Internet, without any password. Although the cameras are not deployed for surveillance purposes, the cameras can be utilized to increase public safety by properly integrating to current surveillance systems. Suspicious activities may be monitored in real-time and coverage can be increased along with CCTVs deployed by law enforcement. Integrating public cameras into a surveillance system has many challenges such as inaccurate locations, diverse sources, and different methods to access the visual data. This paper presents how to discover public cameras from heterogeneous sources and find the accurate locations and orientations of the cameras. We propose a proof-of-concept system to improve public safety by integrating public cameras into our previous visualization tool.**

I. Introduction

Surveillance cameras have been widely deployed as a solution to improve public safety. However,several factors may make surveillance cameras more effective in reducing crime: (1)Active monitoring may stop a crime in progress; (2) Proper recording, indexing, and search of recorded data may help identify and capture suspects, as well as provide evidence for prosecution; and (3) the field of view for the cameras should be well lit to improve the useful content (e.g., recognizable faces).

Traditionally, surveillance cameras are "closed circuits", commonly called CCTV (closed-circuit television). The data are available to only authorized personnel and unavailable to the general public. In recent years many organizations have deployed network cameras for a wide range of purposes. City and state governments deploy cameras along highways and at busy intersections so that travelers and transportation managers can monitor traffic and detect congestion. Some stores deploy network cameras to attract customers. National parks deploy network cameras to observe natural scenery, air quality, and possibly wildlife. Construction sites show the construction progress using network cameras. Figure 1 shows several examples of the types of data from these network cameras provide. The streaming data from many of these network cameras are available to the public and anyone connected to the Internet can see the real-time image or video. Even though these cameras are not deployed for surveillance purposes, the cameras may be used for real-time monitoring of activities if they are properly integrated into existing surveillance systems. The public network cameras could supplement existing closed-circuit security cameras deployed by law enforcement.

Fig. 1. Samples of public network cameras: (a) a shopping mall, (b) a parade, (c)-(d) traffic intersections

Many challenges arise when integrating network cameras into a surveillance system, for example, these cameras are owned by different organizations and there is no single site which lists all available cameras. The cameras from heterogeneous sources may require different methods to access the data. For surveillance purposes, the locations and orientations of the cameras must be precisely known.

This paper extends our previous work [1] by including real-time streams of public (i.e., no password protection) visual data from a diversity of sources. Our previous study demonstrate a visualization tool that can display the location and viewing angles of CCTVs. This paper provides a proof-of-concept system that integrates publicly available sources of visual data in order to further augment and extend the existing CCTV networks. The paper explains the procedure of discovering these cameras and their properties (i.e., metadata, such as viewing angles). The main contributions of this paper include: (1) utilizing public cameras to increase public safety in multiple cities, (2) discovering public cameras from heterogeneous sources, (3) finding metadata such as locations and viewing angles, using the visual contents from the cameras,

and (4) integrating with other sources of information such as crime data and social media contents.

II. Related Work

Many papers conduct research to improve public safety. Timan and Oudshoorn [2] utilize mobile cameras as surveillance cameras. The authors investigate public experience of mobile cameras as a form of surveillance and conclude that mobile cameras can be considered as surveillance. They do not use public cameras to improve public safety. Raty [3] conducts a survey on remote surveillance system by reviewing three different systems. None utilizes public cameras. Kaseb *et al.* [4] utilize live public cameras to provide worldview and route planning. The authors build android application and it allows users to watch tourist attractions and live street view along with their route between a starting point and a destination. They do not utilize public cameras to improve public safety. Our previous work [1] demonstrates a visualization tool that can display the location and viewing angles of CCTVs without including public network cameras. This paper improves the previous work by integrating public cameras and other sources of informations such as crime data and social media in a proof-of-concept prototype.

III. Network Cameras for Public Safety

To build a tool that integrates network cameras for public safety, several important steps must be taken. First, we have to discover the network cameras from existing online sources. After finding the cameras, it is crucial to acquire metadata such as locations and orientations. This section explains these two steps and how the network cameras are integrated into a visualization tool.

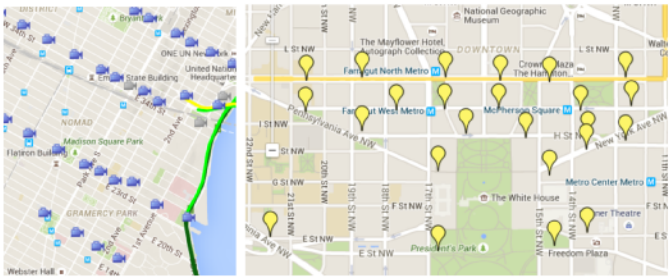
A. Challenges

Many challenges arise when integrating network cameras into a surveillance system. For example, these cameras are owned by different organizations and there is no single site which lists all available cameras. Maintaining the up to date data is also a difficult problem. The IP address of a camera may change because the owner re-deploys the camera. A camera may be disconnected; this may occur if a camera monitors a construction site and the construction is completed. Sometimes, a camera is out of order. The cameras from government agencies (such as departments of transportation) may be added or removed. Accordingly, we have to update the cameras periodically. Each government agency has it own website format. Efforts must be taken to retrieve the data from heterogeneous sources. Also, there is no standard among different brands of cameras. For surveillance purposes, the locations and orientations of the cameras must be precisely known but few camera owners provide the information. Even when the information is provided, the information may be wrong and it is desirable to have a method that can automatically verify the information.

Most network cameras provide web interfaces for human viewing. Different brands of network cameras, however, have different formats for the HTTP pages. For some cameras, the streaming data can be retrieved by using specific paths in the URLs. For the others, the data must be retrieved by repeatedly sending requests to the cameras. Some network cameras provide only Motion JPEG due to the lower computing demands (no motion detection) and some other cameras provide MPEG streams. If the data streams are consolidated on web servers (most departments of transportation do so), the data must be retrieved from the servers. Some servers define programming interfaces for data retrieval but the others do not. For the latter, it would be necessary to reverse engineer the structures of the web pages to determine the methods for data retrieval. Due to these reasons, using public network cameras for surveillance requires significant effort.

B. Camera Discovery

Public network cameras can be found in many different ways. One obvious approach is to use search engines. This method has low success rates because search engines tend to find vendors of network cameras, not live data streams. Sometimes, websites collect public network cameras and we can parse the website to gather visual data. Another approach is to search government agencies (such as departments of transportation) in different states. Many states have their own websites and provide live traffic cameras to the public. Figure 2 shows street cameras from the department of transportation in New York and Washington DC. The cameras are deployed in major intersections and the locations are provided. The websites are built with different formats and efforts are needed to obtain the data. Another approach uses crowdsourcing [5]: people can enter sources of live data streams and their locations. Croudsourcing has great potential to increase the number of available cameras, especially if community-based policing groups could be engaged (e.g., NextDoor, neighborhood watch groups).



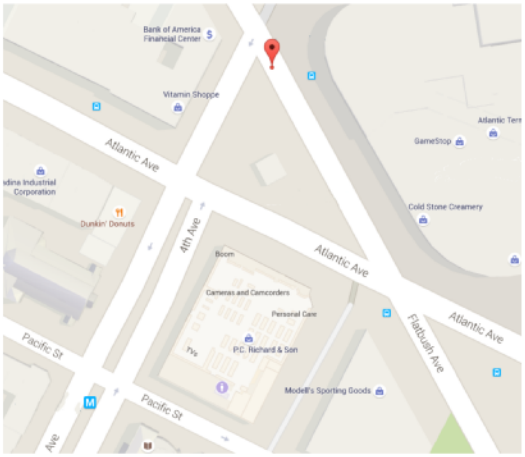
(a) (b)

Fig. 2. Traffic cameras from departments of transportation (a) New York. (b) Washington DC.

C. Cameras' Locations and Viewing Angles

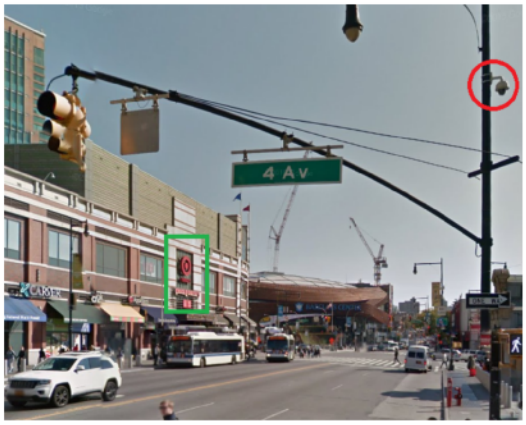
Locations, viewing angles, and orientations of cameras are important for surveillance purposes. Some camera owners provide precise locations but many provide only approximate locations or no information about the locations at all. We find the cameras' locations using various methods, such as using a

(a)



(b)

(c)



(d)

Fig. 3. The location provided by a camera owner (a) is different from our estimate (b)at our estimated location (c)The visual data from the camera (d) matches the Google Street View.

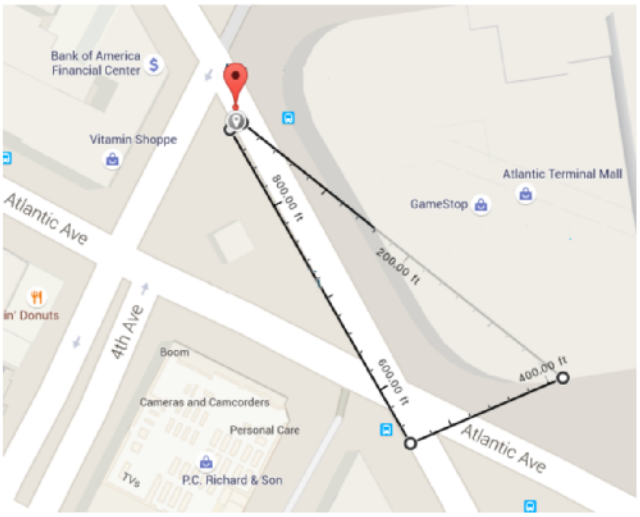


Fig. 4. Viewing angle measurement

camera's IP address to look up its geographical location. This is, unfortunately, not always successful because many organizations consolidate multiple data streams into a few file servers and the file servers' locations do not reflect the locations of the cameras. The cameras deployed by government agencies usually have locations on their websites; however, sometimes the provided locations are inaccurate. Figure 3 shows an example. Figure 3 (a) is the location from the camera owner, on top of a building. By examining the visual content, shown in Figure 3 (c), we estimate the camera's actual location, as shown in Figure 3 (b). Then, we validate our estimated location by comparing it with the Google Street View at that location, shown in Figure 3 (d). After we find the precise locations of cameras, we use a similar method for finding the viewing angles. By comparing the visual data from the camera and a Google Street View, we mark the visible distance on Google Maps as shown in Figure 4.

D. CAM^2

Continuous Analysis of Many CAMeras (CAM^2, `https://cam2.ecn.purdue.edu/`) is a system that provides visual data more than 80,000 public network cameras. Approximately half of the cameras are in the USA, geographically distributed in many states as shown in Figure 5 in page 4. CAM^2 hides the heterogeneity of the cameras behind a web interface. As a result, users can treat all cameras in the same way. CAM^2 has an application programming interface (API) through which the data can be analyzed in real-time. CAM^2 uses cloud instances as the computing engines and can process large quantities of data (five millions images per day [6]). CAM^2 has been used for image-guided navigation [4] but using CAM^2 for for public safety has not been explored.

E. Case Study

This section demonstrates our visual analytics system that utilizes real-time streams of network cameras for improving

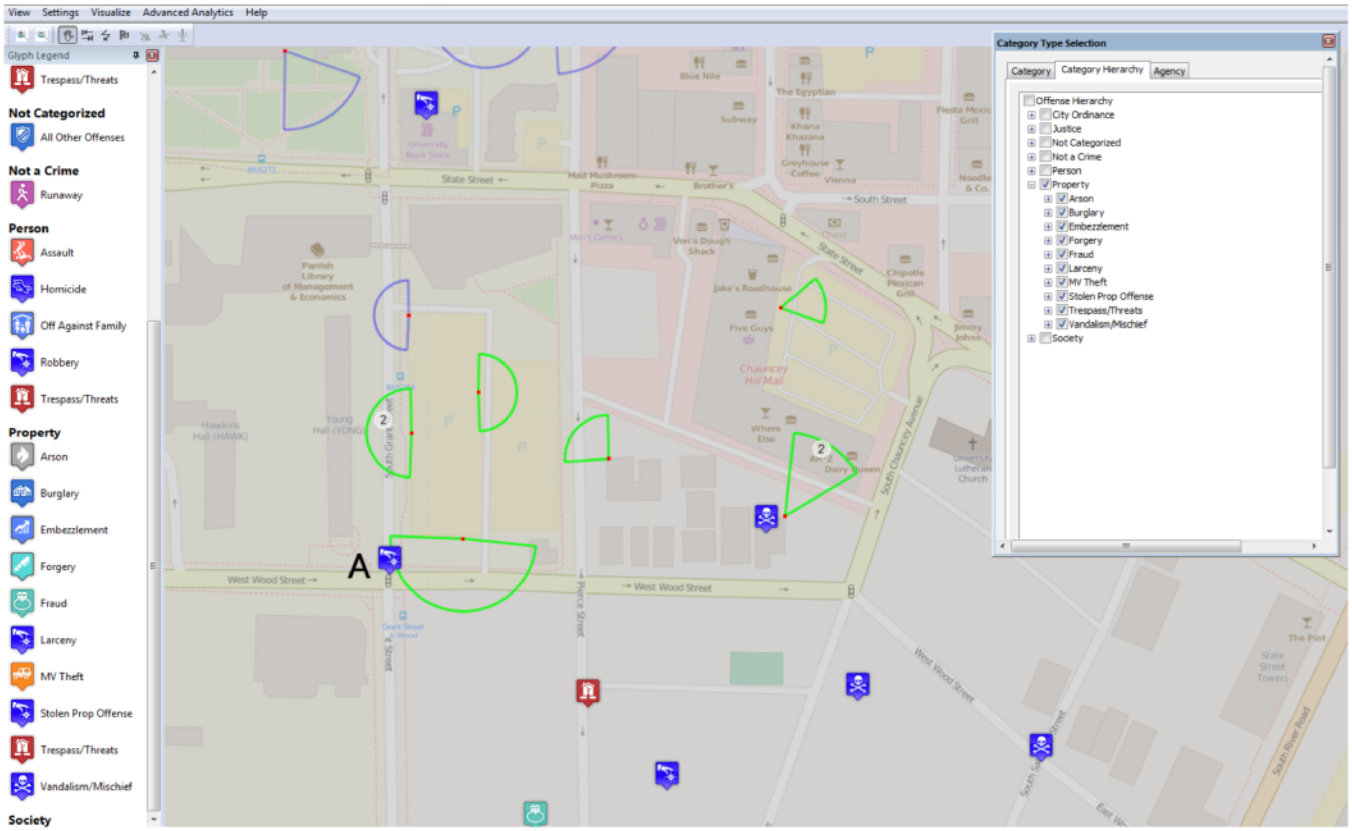


Fig. 6. Our visualization tool.The camera viewing angles in green are police cameras and the camera viewing angles in blue are public cameras.

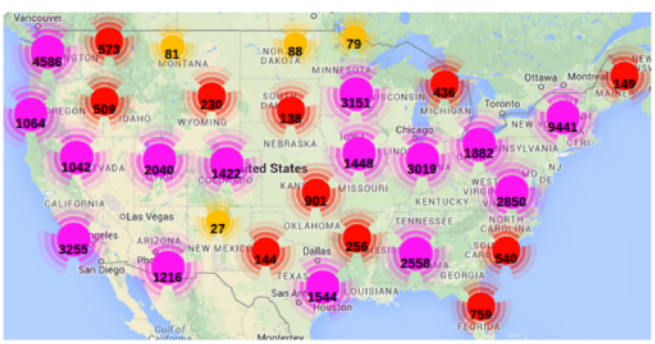


Fig. 5. CAM^2 system

public safety. Our system has been designed as a framework for exploring multi-variate spatiotemporal data. The system can superimpose data from reported crimes, traffic, and civil data from US cities, along with the camera coverage data obtained from the local police departments or the public cameras. In this example, we randomize the police camera coverage in order to protect the non-public information of the actual locations and viewing angles of these cameras. We also utilize social media data (e.g., Instagram, Twitter) in order to further enhance situational data for law enforcement agencies.

1) Situational Awareness - Using Crime Data for Investigative Analysis: Figure 6 showsour visualization tool. Our system can specify the date of interest, select the types of incidents, and show the camera's coverage overlaid on the same map. In this example, we provide a hypothetical scenario for using Figure 6. An analyst is interested in investigating the crime data from a city in the U.S. in order to increase their information and situational awareness of their area of responsibility. The analyst is specifically interested in investigating a string of burglaries that occurred in the past few months. The analyst begins by using our system and selecting crimes against property using the category selection menu (top right in Figure 6). This action displays all the selected incidents on the map. Next, the analyst uses the region selection tool in our system to obtain more details about the incidents and observes that the burglaries had the same modus operandi. The analyst visualizes the police camera coverage layer using our system (shown as green arcs) and identifies the CCTV cameras that may have potentially captured some aspects of the crimes. After watching the video footage cameras these cameras, the analyst uses our system to obtain the public cameras for locations of interest. These cameras have been shown in blue arcs. As can be seen in the figure, our system significantly increases the coverage area. Our system allows investigative analysis in areas that would have been previously unavailable by using the police CCTVs only. For instance a larceny crime is in near the coverage of two public cameras, so the officer can review the camera footage near the time of the incident for potential pictures of the perpetrator (marked as A in

Figure 6). Similarly, one of the vandalism incidents approach or exits could have been captured by 3 of the public cameras, demonstrating how our system can provide easy access to potentially significant information during investigations.

2) Situational Awareness using Social Media Data: The second example demonstrates how to use our system for enhancing situational awareness by integrating social media data as shown in Figure 7. A security officer is interested in monitoring an event for safety and security. This officer uses our system to monitor the geo-tagged social media data in real-time. The officer sets a list of keywords that pertain to the event in order to filter out the unrelated social media posts. During the event, the officer finds several posts that suggest attempted burglaries during the event. After analyzing the contents of these messages using our system, the officer discerns the possible locations of the crime. The officer uses our system and obtains a list of public cameras to further monitor the event and even retriever previous video data for later analysis. The integration of real-time social media data and real-time network camera data can significantly increase actionable information as well as situational awareness during events for public safety and law enforcement agencies.

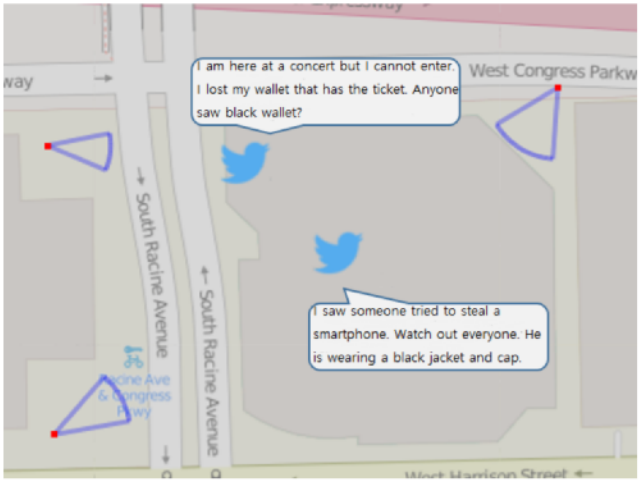


Fig. 7. Our visualization tool integrated with real-time social media data.

IV. Conclusion and Future Work

This paper presents a system to improve the public safety by utilizing the visual data from network cameras. The public cameras are discovered from heterogeneous sources and the metadata such as locations and viewing angles are determined using the visual content from the cameras. Our system can be used to improve the safety in multiple cities. We demonstrate the system using two case studies: (1) using crime data for investigative analysis and (2) enhancing the situational awareness using social media content. As part of the future work, we plan to extend our system to monitor multiple cities. We also plan to automate the process of determining the metadata information.

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