Lessons Learned Implementing Video Analytics in a Public Surveillance Network

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In 2016, the Urban Institute started working with the Milwaukee Police Department (MPD) to optimize its surveillance system, which consisted of 42 cameras across 40 locations. Improvements included software and hardware upgrades, new high-definition cameras, and two video analytic technologies: automatic license plate recognition (ALPR) and gunshot detection technology (GDT). This brief details the MPD's experience with these technologies—including benefits and challenges—and provides recommendations for making them more efficient.

For public surveillance systems to be effective and efficient, it is important that agencies strategically place cameras where crimes are likely to occur or where evidence is likely to be gleaned (La Vigne et al. 2011; Shukla et al. 2020). The MPD added 45 cameras to its public surveillance network, including 24 panoramic cameras and 12 pan-tilt-zoom (PTZ) cameras. Panoramic cameras are stationary and have wide viewsheds that capture large areas, whereas PTZ cameras allow operators to adjust camera angles and zoom in and out.

It is also important for staff to actively and continuously monitor camera feeds (La Vigne et al. 2011), but this can be difficult, even for highly trained camera operators. Video and audio analytics—camera-integrated software that automatically identify persons, objects, and sounds—can aid staff who monitor video recordings or conduct criminal investigations. For these reasons, the MPD added two analytic technologies: PTZ cameras that automatically turn toward the nearest intersection after detecting a nearby GDT alert, and nine ALPR cameras that automatically check license plate numbers against the department's list of wanted vehicles. During this process, Urban observed operations and interviewed stakeholders to identify benefits and challenges as well as key recommendations for integrating video analytics into police public surveillance networks.

Video Analytics in Law Enforcement

Video analytics encompasses a range of software enhancements that law enforcement agencies use to improve public safety and aid investigations. Perimeter, crowd, and object detection, person tracking, and facial recognition are common features of video analytics in surveillance cameras. Video analytics' algorithms detect changes in a video's pixels, alerting law enforcement agencies that the software has recognized a designated object, person, sound, or behavior (e.g., a person crossing a boundary). Video analytics can also be complemented by technologies such as GDT and ALPR.

Integrating Gunshot Detection Technology into a Surveillance System

Gunshot detection technology is a network of outdoor acoustic sensors installed in areas with frequent gunfire. The MPD uses ShotSpotter Inc.'s GDT, which detects gunfire when four or more acoustic sensors discern gunshots from other sources (such as fireworks or weather) through a processing algorithm (La Vigne et al. 2019; Lawrence et al. 2019). The GDT then computes the spatial coordinates within approximately 25 meters of where the gunfire occurred (Aguilar 2015; ShotSpotter 2018). Technicians at ShotSpotter headquarters screen out sounds misidentified as gunshots. Finally, data on confirmed shootings are sent to the law enforcement agency's computer-aided dispatch system, which deploys officers to the scene of the shooting.

Law enforcement agencies can use GDT to measure, respond to, and investigate shootings (Lawrence et al. 2019). The technology can reduce response times and increase the likelihood of identifying suspects, witnesses, and evidence.[1] However, few agencies have used video analytics to integrate GDT into their surveillance systems. Agencies can use analytics to identify GDT alerts occurring near PTZ cameras, which can then automatically turn and zoom toward gunshots or predetermined locations. Although ShotSpotter's GDT uses networks of acoustic sensors to create large coverage areas where shootings can be identified, other GDT systems are camera-specific. For example, GDT attached to a PTZ camera can identify a nearby shooting and ping the camera to turn toward it (Ratcliffe et al. 2019).

We identified 17 PTZ cameras within the Milwaukee Police Department's GDT coverage areas. Early plans had the cameras turning toward shooting events, but we found this would produce footage of building walls, foliage, and other visual obstructions. Instead, the cameras were programmed to turn toward the center of their respective intersections when GDT alerts occur within 500 feet, and to fully zoom out to maximize the chances of identifying fleeing vehicles or people.

Automatic License Plate Recognition

Automatic license plate recognition systems use infrared technology to identify reflective materials, take pictures, and process images through analytic software. Cameras with ALPR technology can be installed on squad cars to create mobile units or on poles, buildings, and other fixed apparatuses along high-use roads and intersections. Such cameras can scan thousands of vehicles during a typical police shift, making them more efficient than the traditional patrol model of crime prevention (Ozer 2016).

Nearly 60 percent of large US police departments have implemented ALPR systems, making ALPR one of the most common law enforcement technologies (Lum et al. 2019). To fully realize its benefits, law enforcement agencies must use ALPR strategically and determine who will oversee camera operation, where cameras will be located, and desired outcomes. For example, ALPR can help agencies make more follow-up arrests with fewer officers than business-as-usual policing practices (Ozer 2016). Research has also shown that ALPR may improve police investigations, though it is unlikely that it directly impacts crime (Lum et al. 2010, 2011).[2] Koper, Taylor, and Woods (2013) found that one police department's specialized auto-theft unit was more likely to detect and recover stolen vehicles when deploying ALPR technology, providing evidence that ALPR makes crime detection more efficient. Although agencies often use ALPR to reduce and prevent auto theft, they have also used it to investigate crime patterns (e.g., vehicles identified when and where crimes are occurring), an application agencies consider more efficient than manual monitoring (Lum et al. 2010, 2011; Willis, Koper, and Lum 2017).

Drawing on existing best practice, the MPD installed nine ALPR cameras at five main Milwaukee intersections, targeting areas where vehicles are frequently stolen and recovered. The cameras were programmed to automatically check whether captured license plate numbers are in the department's hot list of vehicle tags. The hot list, which the MPD updates daily, is a database that includes vehicles known to be stolen, involved in crimes, or connected to wanted people. When a camera identifies a wanted license plate, the camera operator receives an alert that the vehicle passed a specific ALPR camera and that they need to follow up by, for example, contacting dispatch or radioing nearby officers.

Methods

We conducted semistructured interviews with staff who use or directly work with the MPD's camera program. This included camera operators (people who monitor camera feeds, look for crimes, or support investigations of crimes occurring within a camera's viewshed), camera program supervisors, shift commanders, crash-reconstruction-unit officers, specialized investigations-division officers, criminal investigations bureau detectives, and civilian managers from the department's communication division (i.e., the 911/dispatch center). We supplemented these interviews with in-depth observations of the MPD's camera operations.

Priorities for data collection included

- collecting information from a diverse and representative sample of stakeholders with experience using cameras (including uniformed and civilian staff with different responsibilities and from different shifts and departments), and
- understanding officers' perceptions of the camera upgrades and new video analytics, including benefits, challenges, and investigative utility.

We conducted interviews and observations in May 2019, a year and five months after the department finished upgrading its cameras and integrating the video analytics, and a year after it moved the camera program from its communication division to its fusion center (the department's real-time

crime investigations division). Our goal was to gather information about staff members' knowledge of and experiences with the cameras, how the upgrades benefited investigations, challenges staff experienced, and suggestions for improvements. We summarized and noted responses and observations manually, and we synthesized the data for key themes.

Challenges with Video Analytics

Integrating video analytics into a surveillance system raises operational and implementation-related limitations that can impact their investigative effectiveness. This section outlines some of the challenges the MPD encountered.

Poor Gunshot Detection Technology Integration

The MPD requested that the camera vendor program its PTZ cameras to focus on the centers of respective intersections and to zoom out to capture surrounding areas when GDT alerts occur within 500 feet. Although the department considered the GDT integration promising, implementation-related problems made the technology challenging to use efficiently. First, camera operators reported a delay when the GDT software alerted the camera program's software, making cameras slower to turn (and thus slower to capture potentially useful footage). Second, operators reported that the cameras were incorrectly zooming *in* to the centers of intersections, producing footage of pavement that did not help follow-up investigations. Finally, when cameras did automatically turn and zoom in, the camera program failed to reset to its previous settings. Operators often returned to their workstations to find cameras focused on the ground after alerts had caused them to turn, rendering footage unusable.

Operators also observed some technical difficulties with GDT alerts on their computer screens. When shots were detected, operators received alerts with shooting locations on a map within the camera software; however, these alerts disappeared after a few seconds, and operators did not have enough time to collect additional information. When operators were not near their computers or paying close attention, they missed valuable location information.

Gunshot detection technology is integrated into the surveillance system, so the nearest camera automatically faces towards the nearest intersection [when gunshots are detected]. It's helpful on occasions and sometimes it's not. It can take control over what we are doing.
—MPD camera operator

Disruptive ALPR Alerts

The MPD also experienced challenges with ALPR, primarily involving alerts. The department found it challenging to combine its vehicle hot list with the camera software and had to work closely with the camera vendor to rectify this. The vendor had little experience with this problem, exacerbating the challenge.

After the department integrated its hot list with the software, the camera operators were overwhelmed by the number of alerts appearing on their computer screens. These alerts appeared in the center of their screens, hiding other ongoing tasks and forcing them to pause their work to respond to the alerts. Operators had to click on the alerts, acknowledge notifications, and close out. They considered this process a huge time investment that occasionally disturbed high-priority and time-sensitive tasks.

Operators also reported a software bug that reset their customized camera feeds. After operators acknowledged alerts, camera feeds reverted to default settings rather than to the customized setups operators created for their shifts. This caused operators to lose custom settings, including the directions cameras were set to face and how windows were set up on their computer screens.

Other Challenges

Camera operators reported a lack of training opportunities. Before the upgrades, most camera operators learned how to use equipment from more experienced colleagues who had also been trained by colleagues, and so on and so forth; the knowledge that had been passed down was therefore dated and only covered the bare minimum of software capabilities. After the upgrades, the vendor conducted an in-depth training with all operators on the camera software's functions, but many operators found the new information difficult to comprehend or raised more questions than the vendor could answer, causing operators to revert to old habits. Some respondents agreed that although they knew enough to do their jobs, they wanted to learn more about features that would make it easier for them to use the software.

Interviewees also reported a lack of awareness about the camera program. Many interviewees who could have benefited from using camera footage in their day-to-day work mentioned that they had only recently learned about the department's camera program and video analytics. They also emphasized that few other officers in the field were aware of the program. They also had limited knowledge about who to contact within the MPD to access captured footage.

There are also some inherent technical limitations to ALPR and GDT. For instance, although ALPR increases efficiency, its effectiveness depends on whether it reads license plates correctly and produces data that help law enforcement detect auto-related crimes. Similarly, GDT systems do not always accurately detect gunshots, particularly when gunshots occur indoors or in vehicles or are muffled by other sound barriers. They may also misidentify sounds (e.g., fireworks or car backfires) as gunshots, even though their algorithms were created to discern gunfire's specific acoustic signature.

Benefits of Analytic Tools in Milwaukee

Despite challenges, MPD staff also reported that the video analytics benefited the department in several ways. We elaborate on these advantages below.

Improved Camera Quality

Although not specific to the integrated analytics, most interviewees commented that the new high-definition cameras were a helpful addition to, and an improvement over, the old cameras. Staff have found that the PTZ and panoramic cameras have unique benefits, and they were particularly impressed by the cameras' recording quality. One officer explained that while investigating a car crash, he used a new PTZ camera (located a block and a half away) to zoom in to the scene of the crash. Despite the distance, the recording was clear and helped the investigation. Staff also mentioned that the panoramic cameras' ability to capture all of an intersection with few blind spots was useful.

Officers also expressed that placing both types of cameras in the same intersection produces footage with unique investigative advantages (see Robin, Peterson, and Lawrence 2020). Panoramic cameras' wide viewsheds help officers locate incidents, and PTZ cameras enable them to zoom in to incidents' specific locations to identify and track witnesses and suspects.

In Milwaukee, both camera types serve a proactive function (i.e., identifying and responding to crimes in real time) and a reactive function (i.e., supporting investigations of crimes occurring within the vicinity of cameras). The district attorney's office also used camera recordings for trials. Prosecutors in particular use video evidence in court to establish timelines of events for juries and judges.

Potential Benefits of Gunshot Detection Technology

Although there were some challenges integrating GDT in Milwaukee's camera program, respondents agreed that the technology could benefit investigations. For example, although footage was practically useless when cameras zoomed *in* to nearby intersections after gunfire was detected, camera operators nonetheless appreciated being notified of the shooting locations. Because operators had direct access to every camera in the city, they could use this information to review nearby cameras' footage. Before the GDT software was integrated into the camera system, operators could not know that a gunshot was detected in a camera's vicinity unless another officer specifically requested that they review footage for investigative leads.

We also found that although MPD patrol officers had direct access to the department's GDT software on their phones and squad car computers, camera operators could only access it indirectly through the camera software (e.g., when a GDT alert pinged a nearby PTZ camera). This delayed operators reviewing camera footage for useful intelligence. Directly installing the GDT software on operators' computers would have simplified this process and allowed them to review and investigate leads themselves.

In addition, operators noted that the GDT integration allowed them to see gunshot alerts almost instantly after incidents. This allowed them to respond to shooting events quickly and use cameras to identify potential victims, witnesses, and suspects. The GDT alerts gave operators useful information that helped them review footage to help investigating officers find casings. Finally, the MPD staff we interviewed agreed that the integration would have been more successful (and could have yielded better investigative leads) had the cameras zoomed *out* at the intersections. Staff indicated that people and cars fleeing crime scenes often travel through these major intersections, and that integrating GDT with PTZ cameras correctly could have produced critical information.

Investigative Leads from ALPR Cameras

All interviewees reported that the ALPR cameras were used throughout the MPD for finding wanted cars and people, especially after the department integrated its vehicle hot list into the system. Moreover, although the ALPR alerts were initially disruptive, staff found the technology itself easy to use. They reported that using the license plate recognition software to pull information about alerts and wanted vehicles was straightforward.

Unsurprisingly, interviewees mentioned that the department mostly used ALPR cameras in investigations of motor vehicle thefts and car accidents. However, they also reported that staff used the technology in investigations of homicides and other violent crimes by (1) generating investigative leads by identifying cars where offenses occurred, or (2) helping MPD personnel track and find people or cars suspected in or linked to these offenses. Because of these benefits, most staff recommended adding ALPR cameras across Milwaukee.

The new cameras and ALPR technology are very effective. A stolen car was recovered and there were drug-related arrests in the first week or two of implementation.
—MPD camera operator

Takeaways and Recommendations

Staff perceptions of the MPD's upgraded surveillance system were largely positive. Respondents all agreed that the new PTZ and panoramic cameras were useful, particularly when used with video analytics. Interviewees commonly recommended that the department purchase more cameras (especially ALPR cameras), as the department had relatively few given the city's size. Although staff viewed the video analytic technologies favorably, implementation- and software-related challenges made these technologies less efficient. The recommendations that follow are relevant for law enforcement agencies using or planning to integrate video analytic technologies in their surveillance systems.

First, agencies should collaborate closely with their technology vendors, especially during initial implementation stages. An agency can better ensure success by clearly setting expectations of new technologies early on. Even well after implementation, departments need to frequently communicate and actively report issues to vendors so corrections can be made as quickly as possible.

Second, vendors can provide useful trainings, especially on efficiently using new technologies to enhance investigations. Depending on their needs, departments should consider working with vendors to design trainings and refresher courses for camera operators and other staff who work with cameras. Because these trainings can be expensive, departments should tailor them to staff members' needs. For instance, camera operators need substantial training on surveillance software's features and on integrated video analytics, whereas staff who simply rely on footage or leads generated by camera operators will likely only need to understand the program at a high level. We strongly recommend that departments enable staff to help plan training to tailor it to their needs and perceived knowledge gaps.

Third, departments using ALPR cameras may benefit from working with their software service providers and from charting plans to prioritize alerts. Ensuring vehicle hot lists focus on high-priority vehicles (such as those involved in violent felonies) can shorten response times. Alerts can also be color-coded by priority level or crime type so operators can distinguish between alerts that require immediate attention and those that do not.

Finally, departments should ensure all staff are aware of the available technologies and know how to use them to aid investigations. Disseminating information about camera programs to field officers and incorporating it into academy training are easy ways of accomplishing this. The MPD chief also sent a roll call video to patrol officers and created maps with camera locations for each district office. However, many officers were nonetheless unfamiliar with the camera program and new video analytics. Thus, departments should develop initial internal communications campaigns when they implement these technologies and follow up with regular refreshers and/or trainings to ensure the information is widely known and used.

Notes

[1] See Carr and Doleac (2016), Choi, Librett, and Collins (2014), Irvin-Erickson and coauthors (2017), Mazerolle and coauthors (1998, 2000), and Watkins and coauthors (2002).

[2] Russell A. Neville, "Cincinnati Regional Automatic License Plate Recognition Technology Project," *Police Chief Magazine*, accessed December 27, 2019, https://www.policechiefmagazine.org/cincinnati-regional-automatic-license-plate-recognition-technology-project/.

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