Enhancing security management in public transport using automatic incident detection

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Abstract

It is often argued that CCTV systems used in security contexts are not exploited to their full potential. This paper reports on the developments underway as part of the EU PRISMATICA project to enhance CCTV systems to provide more extensive surveillance of public transport networks. Firstly, it outlines the techniques of automatic detection applied to CCTV images to identify suspect events, such as abnormal stationarity, intrusion, overcrowding and abnormal movement. Secondly, it examines issues related to the development and deployment of these technologies into transport security control centres.

1 Introduction

CCTV plays an increasingly important role within surveillance and security work within numerous public domains. Cameras can be seen in public shopping malls, football grounds, city streets and, of course, urban transport networks. It has been argued that the public visibility of cameras plays a critical crime prevention role. Additionally, it is known that once a crime has been committed, recordings are available for review in an attempt to pinpoint the exact nature of the incident and those involved. Nevertheless, it is often argued that given the cost of installing...
widespread CCTV coverage, current security operations do not fully exploit the potential of CCTV to support pro-active surveillance and security operations.

Within public transport networks, a great deal of centralised surveillance activities involves members of staff in control rooms, either at the local or network levels, monitoring banks of CCTV images (see Figure 1). Fixed or movable cameras are linked to a control room where staff scan images from the different cameras in order to detect abnormal situations. This kind of infrastructure is wide-spread in public transport networks, such as metros, railway stations, bus stations, airports and so forth.

Figure 1: A Station Operations Room in London Underground

[The CCTV screens are placed along the edge of the desk]

However, the rapid proliferation of CCTV cameras is making it increasingly difficult for individuals to simultaneously and extensively monitor the resulting data. Due to the confines of space in control rooms, at any one time the monitors displaying real-time CCTV images are likely to represent only 5-10% of all cameras deployed in the surveyed area. Additionally operators are usually required to undertake a range of tasks alongside their monitoring duties. These tasks include dealing with incoming calls, logging events, managing mobile staff and so forth. Therefore their opportunities for real-time monitoring activities are restricted. Furthermore, when staff do have the opportunity to study CCTV images, they face general problems of fatigue, “inattentional blindness” (a failure to see unattended items; [1]) and “change blindness” (a failure to notice large-scale changes; [2]).

One aspect of a new EU project called PRISMATICA (PRo-active Integrated systems for Security MAnagement by Technological, Institutional and Communication Assistance) is concerned with enhancing CCTV networks by enabling automatic detection of specific security incidents. It is envisaged that this can facilitate the emergence of more effective and widespread surveillance of transport networks, as staff will be given early warnings of events thereby providing them with opportunities to develop a timely response to those events.

PRISMATICA brings together six urban public transport operators (in Brussels, Lisbon, London, Milan, Paris and Prague) and several research and
technology laboratories from across Europe. It aims to integrate a wide range of technical systems (incl. audio surveillance and individual passenger alarms) with novel operational processes to develop innovative security management systems for transport operators. As such, the project contributes to more general efforts to make public transport systems more attractive to passengers, and more secure for passengers and staff.

Generally, then, the project is concerned with innovating the fields of crime prevention, recognition and management within public transport. This paper, however, will focus on the element of the project concerned with automatic incident recognition via CCTV. This technology is designed to aid the automatic detection of a range of events, such as trespass, congestion, suspect packages, suspect individuals, vandalism and so forth. We firstly describe the techniques that we use to automatically detect events through CCTV images. Then we consider some of the issues associated with deploying such a technology into the workplace.

2 Automatic CCTV Surveillance
There is a strong need to develop processes which enable automatic surveillance of public transport networks, in order to enhance security and automatically detect incidents. Such a process could provide early warnings of security problems in order to efficiently guide response and intervention by mobile staff, security agents, police, medical teams, etc. Therefore, the challenge consists in detecting key incidents while preventing too many false alarms.

In this regard, there has been a steady increase of reports in the public literature of attempts at dealing with public transport environments. A major recent effort has been the work conducted in the FP IV's project CROMATICA [3][4] specifically targeted to a range of operational scenarios in underground railway environments, through extensive on-site validation with large amounts of video data. Efforts such as this have put Europe at the forefront of the state-of-the-art in the field.

2.1 Mechanisms of detection
It is very difficult to devise an exhaustive list of potential and operational applications in artificial vision because this technology is able to adapt in order to respond to many needs and applications. Whatever the application envisaged, however, the optical information processing is based on the same principles[5].

Roughly speaking, one can consider that the machine must analyse raw information, which is very heavy and difficult to manipulate, in order to describe and interpret its content.

In static image analysis, it is common now to describe methods, according to the level of abstraction they use in order to represent the information. According to this hierarchy principle, one can distinguish three levels of complexity. The "low level" for which the image is a set of pixels. The "high level" where the information included in the image is described in terms of objects. The "intermediate level" makes the connection between the two precedent ones [6].
If we transpose this classification to dynamic image analysis, we discover that the movement analysis in image sequences could be envisaged in different ways:

- **High level**: Certains features of the objects present in the images (position, size, shape, etc.) are analysed in terms of evolution in the image sequences.

- **Intermediate level**: Some processing is carried out on the image sequences, which can combine local characteristics (for instance the evolution of the greyscale of the pixels in a region of the image) and global characteristics (evolution of the illumination of the scene observed), to segment the image into homogeneous zones regarding the movement.

- **Low level**: Local treatments, involving both the spatial neighbourhood of a pixel and its temporal neighbourhood (pixels located at the same position in the other images) lead to a new image in which the pixels affected by the movement are different from those included in stationary zones.

The first level contains mainly approaches qualified as structural methods or **token-based** methods. The second level gathers methods based on the analysis of the movements or **optical flow**. The third one lies on the local illumination variations of the image, sometimes called **motion-based** methods.

Figure 2 shows the processing of an image based on the third level of analysis. From an original image, the moving edges are calculated. This enables us to follow the movements of the pedestrians.

![Moving edges detection](image)

Figure 2: Moving edges detection (left: original image, right: moving edges)

### 2.2 Examples of two potentially dangerous situations

#### 2.2.1 Abnormal stationarity detection

Most abnormal stationarity situations are generated by itinerant salespeople, musicians, beggars, drug dealers, or robbers looking for their victims. They are characterised by one person waiting in a corridor for a "long" period of time. We can have the same kind of pattern when a person falls on the floor (slippery floor, collapses) or when an object is unattended.
Recent user needs investigations revealed that this kind of information is required by 79% of the public transport operators and the detection of stationary objects by 75% [7]. So, it is envisaged that such information will reduce the operators' monitoring workload giving them directly the location of a problem and, as a by-product, improving the network safety by increasing the number of detected abnormal situations, and decreasing the detection delay.

Figure 3 shows two different scenarios of suspicious stationary situations.

![Figure 3: Detection (left frame) of a stationary person on the stairs, (right frame) of an object left on the ground](image)

### 2.2.2 Intrusion detection in forbidden areas

The aim of this application is to improve security in public transport by automatically detecting unauthorised people entering forbidden areas, such as tunnels, tracks or private offices.

Figure 4 shows that from the original image (left frame), the moving edges on the images are calculated in real time (central frame); this enables us to have the size of the moving area and to decide if it represents a danger or not.

The size of the moving area is calculated by the geometrical shapes in which it is encapsulated (octagons on right frame). If the moving area is large enough, according to a threshold, an alarm is triggered in real time in the control room and the operator has the opportunity to see the image sequence of the incident.

![Figure 4: Intrusion detection in tunnels](image)
2.3 The overall detection system for Prismatica

At the present time, the developed solutions have significant limitations. They have only been tested as single-sensor schemes. They require improvements for important situations (e.g. aggression) and locations with low camera positions (platforms, on-board vehicles). Transport networks require further “situation assessment” capability in areas covered by multiple sensors (e.g. the full length of a train platform and its access passageways). Valuable information used by human operators to raise their awareness and confirm the need for action has not been routinely fused to visual analysis. Typical examples include service information (e.g. expected time of arrival and occupation state of the next passenger carrier), multiple views (e.g. feeds from an adjacent different mode of transport), environmental conditions (time of day, weather) and audio cues. Voice recognition in a noisy environment is not yet robust enough. A more promising approach, not yet fully explored in this field, is the analysis of sound levels and spectra. In short, data fusion plus the ability to learn in what are complex and varied conditions are necessary and underdeveloped components that need to be added to the available single-signal detection mechanisms.

System architecture aspects are not sufficiently developed. There is the need for further progress in the synergetic integration of automated systems to the human-supervised control environment (control rooms, vehicles) so that these systems act as semi-intelligent assistants to support decision-making tasks.

Moreover, and equally important, it is necessary to revise and re-engineer the operational processes so that they can make effective use of the new tools. Most major operators are doing this (e.g. PC2000 in Paris, NCC in London), but mostly independently. There are mutual and EU benefits to be gained by the dissemination and transfer to smaller and less-developed operators.

3 Issues for development and deployment

The developments that we discuss above raise various possibilities for the configuration of an actual technology that could be deployed into the control rooms of transport operators. However, the success or failure of the technology will in part rest upon the ability to tailor it to the demands and contingencies of security work as it is undertaken at present. All too often technologies have failed due to a lack of understanding of the practical problems faced by staff everyday in the workplace [8]. Indeed, many detection/control systems have been developed in isolation from the security staff, and as a result have, in some cases, even increased the workload on those human operators.

Therefore, as part of the PRISMATICA project, we are undertaking field studies, and interviews with staff, in the various operational contexts to develop our understanding of the practicalities of security control work. There are various ways in which we envisage these studies can inform the development and deployment of the technology, but here we will outline three: i. learning from existing practices to inform automatic detection techniques; ii. tailoring event
notification to local operational contexts; iii. examining the potential for specific ‘automatic’ responses.

3.1 Practices of Incident Identification
In configuring technologies to detect particular events, we are able to learn from the current ways in which these events are detected. For example, staff who routinely monitor CCTV images become expert in spotting ‘unusual’ human behaviour, behaviour that often turns out to have organisational consequence. Take, for instance, bus drivers who notice pick-pockets because they often look directly into the driver’s mirror to see if they are being watched. Alternatively, consider how gate ‘doublers’ (those who sneak through the gate behind a fare paying passenger) are often spotted, because rather than head directly for the gates, they tend to walk in an arc towards the gate in order to slip in behind another passenger.

These ‘tricks of the trade’ could be adopted to configure technologies to detect more complex events, indeed even events that take place off-camera. Given that cameras are distributed throughout stations, individuals will often undertake illegal activities purposefully out of the gaze of cameras. This may seem to be a problem both for automatic detection technologies and also staff currently monitoring CCTV images. However, Luff and Heath have shown that staff are sensitive to this problem and have found a solution [9], a solution that could be adopted by the technology. Staff are aware that buskers (illegal musicians) and beggars attempt to position themselves in CCTV blind spots, but can still often spot them by virtue of what they are able to see on screen - that is, by watching the passenger behaviour. If there is a busker or beggar at the bottom of an escalator, for example, passengers will often swerve to avoid them, one-by-one turn towards them, or stretch out their hands to give them money. Each of these actions is a tell-tale sign of the presence of an ‘undesirable’ for the watching staff.

3.2 Event Notification
Once an event has been detected, it is critical that staff are informed in an appropriate and timely fashion, such that they can decide whether or not it is organisationally relevant, and if so, how to respond. CCTV monitoring work in control rooms is routinely interleaved with competing demands for staff members. The control staff are often engaged in dealing with incoming calls, checking-in staff, attending to queries, and so forth. So it is important that notification alarms are somehow configured or configurable to indicate the urgency of an event. Within many workplaces it has been found that if alarms are triggering regularly to mark relatively minor events, they will increasingly be ignored. Therefore, it would be worth distinguishing between the type of incident recognised by varying the alarm signalling mechanism.

Furthermore, the relevance of an incident is determined by staff in relation to other information available in the control room. For example, ‘overcrowding’ is currently identified as a problem not simply by virtue of the shear numbers of
people on a platform, but also a variety of other variables, for example, whether there is a train due in the next few moments, whether there are people moving into spaces further down the platform, whether the escalators are full of people, whether the lobby at the top of the escalators is filling up, etc. All of this information is critical to establishing the relevance of an ‘event’ and what sort of action should be taken. These changes may be useful to consider linking the PRISMATICA tools to additional information (e.g. traffic information) to reduce unnecessary alarms.

3.3 Enhancing Organisational Response
Although most security incidents will require human intervention, there may be certain possibilities for the detection system to be developed to trigger an initial automatic response. In considering how this might be done, current staff practices are useful. For instance, once a suspect package has been found in London Underground, staff routinely make a passenger announcement like ‘please keep your possessions with you at all times’. Similarly when the face of a known pickpocket is recognised, staff will announce ‘Pickpockets are known to be working in this area’, or when a person is seen smoking, staff will remind passengers ‘London Underground is a no-smoking area’. Thus, these public announcements are routinely occasioned by specific noticed events. They work both as a general reminder to the public, but also may remind a specific person that they have left their bag a few feet behind them; discourage a pickpocket; or result in an individual putting out their cigarette. Therefore, triggering standard announcements following the detection of particular events may be a useful initial automatic response.

Also, at present, few transport companies record all of their camera images in real-time. Usually only when an incident is reported will a real-time recording be made (time lapse recordings are used otherwise). If it has been reported, it is usually because a ‘suspect’ is being interviewed by mobile staff. Therefore, a vital delay can be caused where material is not on film. That delay could be reduced by automatic recording being triggered early. Thus, the PRISMATICA tools could include the ability to automatically start video recording when certain types of incident are identified (e.g. trespass). Indeed, there may be possibilities not just to start recording on that one camera, but on different cameras that cover the same general area. This would mean that the best view of the event may be recorded from the outset.

Studying current practices therefore points towards ways of developing the PRISMATICA tools to provide useful ‘initial’ responses to specific detected events.

4 Conclusion
This paper considers ways of enhancing the wide-spread deployment of CCTV within public transport networks in urban areas. In particular, it has described technological tools that can use those CCTV systems in order to provide early warnings of specific security incidents. These automatic detection methods can
be applied to numerous events, such as abnormal stationarity, trespass, overcrowding, unusual movements (e.g. going the wrong way down a corridor, etc.), and many more besides. However, these tools raise possibilities rather than immediate solutions. In order to successfully deploy this enhanced security system into transport security control centres, there is a need to consider the impact on the work of staff within those control centres.

Therefore, we have attempted to outline the benefits and importance of analysing existing work practices in order to inform the development and deployment of the automatic detection tools. The benefits highlighted included the use of existing ‘tricks of the trade’ to inform automatic detection methods; the use of an understanding of workplace demands in order to reduce false or unnecessary alarms; and the use of existing ‘responses’ to different events to inform the design of additional functionality, such as automatic recording or automatic announcements. So, we are keen to use our field studies to reduce the possibility of the technology gathering dust in a control room corner. The solutions that we develop then will not simply be technological, but will rather display a sensitive to workplace demands and to the ‘roles’ of technologies and human operators.

As part of this sensitivity to the workplace, we are well aware that different operators and different stations or locations within transport networks have different demands for automatic detection technologies. As a gross example, for instance, surveillance work at station level in London Underground has a different range of concerns than at network level in STIB, where the security control centre surveys some 63 stations. These different demands will also raise organisational questions about the activities of the staff and the role of the new system.

Moreover, the types of event that are seen as critical, change from station to station, between different parts of a single station, and throughout the course of year, the week, the day and even the hour. For instance, some stations have more problems with beggars than others, some parts of a station are more likely to suffer from overcrowding or trespass, special events such as football matches may cause additional short-term problems; overcrowding may only be an issue between certain hours of the day; and so forth. Therefore, the character of events that need to be spotted is ever changing. Therefore, the project will be considering how to make the deployed technologies flexible enough to adapt to different situations and enable the staff themselves easily re-configure them to emerging events.

This issue of tailoring general solutions to specific operational contexts reverberates throughout the PRISMATICA project, as we attempt to develop technological solutions (image recognition, audio detection, etc.) alongside innovative organisational processes (new forms of staff training, communication with passengers, etc.) to enhance security prevention and management across European public transport networks.
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6 References