An automatic Empty Vehicle Detection system for Airport People Movers applications

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***Abstract*—Automated People Mover (APM) Systems are common at many airports worldwide. The emptiness from passengers must be confirmed before the vehicle enters a turn back facility, a workshop area or any other restricted-access area inside the airport. Since APM vehicles typically run fully automatic without any attendance staff onboard an automatic detection system is required. A new video-based solution to automatically check whether the car has been cleared from passengers and baggage or not is proposed in this paper.**

***Index Terms*—Automated People Mover, security, empty vehicle detection, video image processing, airport**

I. Introduction

Automated People Mover systems today form integral parts of many major airports with extensive terminal facilities. Many of these APM installations serve terminal areas and nearby parking lots. They may also travel between security and non-security areas and of course to and from depots or workshop facilities. Since, these vehicles run without any attendance staff, emptiness from passengers shall be checked before the vehicle enters a turn back facility, a workshop area or even travels from a non-security to a security area. In all cases, people shall be prevented from access to restricted areas. Most often, a manual inspection of the vehicle is performed at terminal stations. This requires considerable personnel effort and is even prone to failure, in case the staff is distracted and does not check carefully enough. Therefore, an automatic Onboard Empty Vehicle Detection (OEVD) system has been developed using video image analysis that can automatically check whether the car has been cleared from passengers and baggage or not. This system could be used to support the security staff and the central control operators and even provide a higher level of security. Basically, the system shall feature:

- detection of helpless people who unintentionally remained inside the vehicle (emergency),
- detection of baggage left behind,
- event-triggered video recording and
- assistance to the OCC staff to trigger camera images event-based.

After a short literature review in Section II, the operational context of the detection system is explained in Section III of this paper. The hardware concept used for development, lab and field tests is described in Section IV and will be complemented with an overview of the detection algorithm in Section V. Finally, conclusions are drawn regarding further improvement of the proposed method.

II. Related Work

Detecting passengers or objects inside vehicles has found broad application especially related to the automotive sector, such as [4]. Near-infrared images taken from outside the vehicle are automatically evaluated to count the number of people. The exact position of the passengers in the front and back seats helps to reinforce certain parts of the image to enhance visibility. Similar approaches based on stereo-image evaluation are proposed, too [1], [3]. Again, single seats inside a car are supervised for the presence of people, e.g., adult, child or baby seat. However, stereo camera imaging requires a higher number of cameras compared to single image processing and more complex algorithms to merge the images of two cameras.

A security-oriented approach to detect and monitor passengers in busses is presented in [2]. It is based on a dedicated recognition of the human's head and tracking the identified head inside the vehicle. The movement profile may be used to indicate suspicious behavior of the person. Detecting and counting of people inside a crowd is explained in [5]. Like most approaches the focus is on dedicated people counting making use of human specific features. The described method is used to supervise groups of people in the open space but not inside vehicles.

Regardless of the field of application, detection systems for people inside vehicles usually focus on passenger counting to get an estimation of the occupancy of the vehicle. However, it is also clear to know that these methods are prone to failure due to insufficient image contrast, varying environmental conditions, e.g., natural and artificial light

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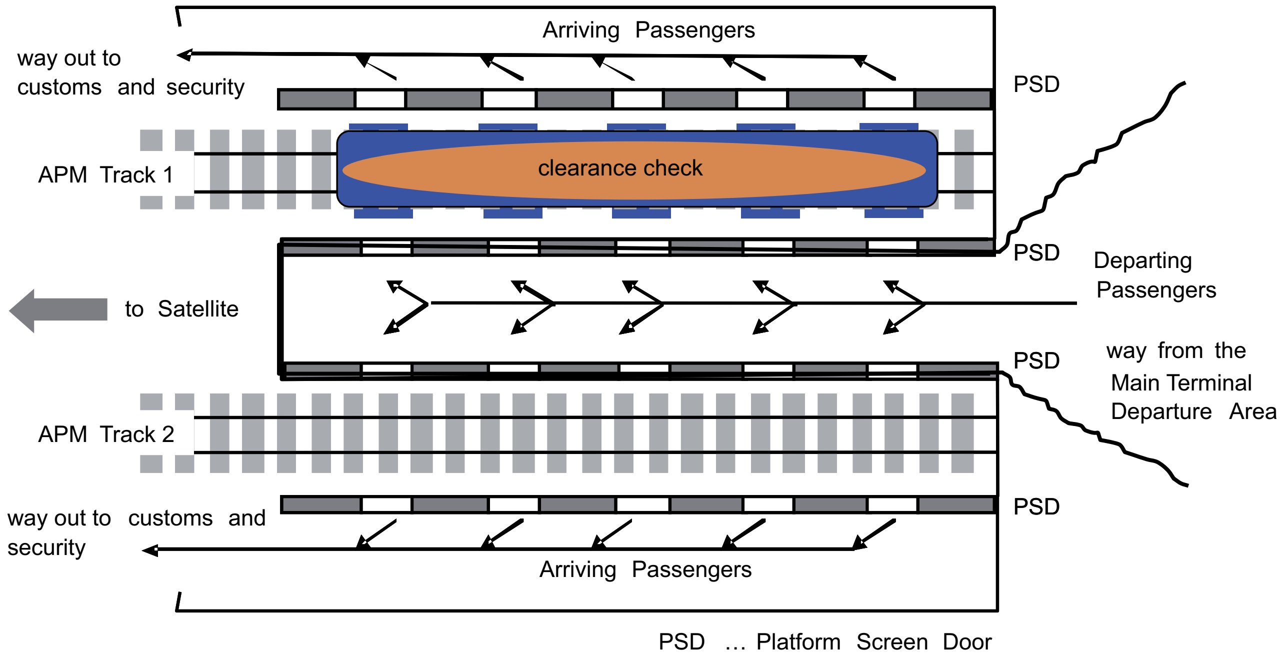

Figure 1. Flow of arriving and departing passenger including Empty Vehicle Detection

or occlusion phenomena by several people. Miscounting of some people may appear but is not critical from the application point of view. Many approaches assume a specific location of people inside the vehicle. This is not the case for empty vehicle detection in an APM vehicle. Thus, the proposed method here does not make use of passenger counting. Instead, a characteristic reference image of an empty vehicle background is compared with captured images in order to conclude the presence of people or objects, in general. However, this status indication shall be provided with a high level of confidence to not assume a vehicle empty, which is not.

III. Operational Context of the OEVD System

The system shall help improve operational processes and enhance security at an airport by detecting people or baggage left behind and providing assistance to OCC staff. A permanent manual inspection of the vehicle is not required anymore. Local personnel must only intervene in exceptional cases. This system could be used in a typical main terminal - satellite configuration of an airport. As an example, the flow of arriving passenger at the satellite and departing passengers at the main terminal could be controlled to keep the passengers separated. All passengers who arrive at the satellite board the APM system and travel to the main terminal. After arriving at the main terminal customs and security checks are applied. Therefore, those passengers shall be kept separate from the departing passengers that use the APM to get from the main terminal to the satellite. By separating the different passenger flows, easier and well-arranged security checks shall be maintained.

The main terminal APM station hosts three platforms (two of which are aside the tracks and one, which is in between the tracks, see Figure 1). All passengers arriving at the main terminal APM station alight the train to one of the two side platforms and then go to customs clearance. The vehicle opens the doors on the respective train side (either left on APM track 1 or right on APM track 2). After disembarkation security staff then checks the train for remaining people or objects. Once the vehicle has been declared empty the train doors as well as the Platform Screen Doors (PSD) close. After a short period of time, the PSDs and train doors on the opposite side open. All departing passengers waiting at the centre platform then board an APM train and leave for the satellite terminal station.

The OEVD system shall perform the clearance check before the train doors open to let departing passenger in. The principle flow of activities is shown in Figure 2). All passengers arriving at the main terminal APM station alight the train (see Figure 1) and then go to customs clearance. Once the vehicle has entered the APM station, it opens the doors on the respective train side. After a fixed period of time, e.g., 30 seconds, the disembarkation process is assumed finished and the vehicle doors as well as the PSDa shall close. Once, all doors are closed the video analytics of the OEVD scans the car and report the status to the onboard ATC. If the OEVD confirms the vehicle to be empty, the train doors as well as the PDS on the opposite side of the vehicle open.

The departing passengers can board the train and the trains leave for the satellite station after a defined period of time. In case the EVD reports the vehicle as non-empty

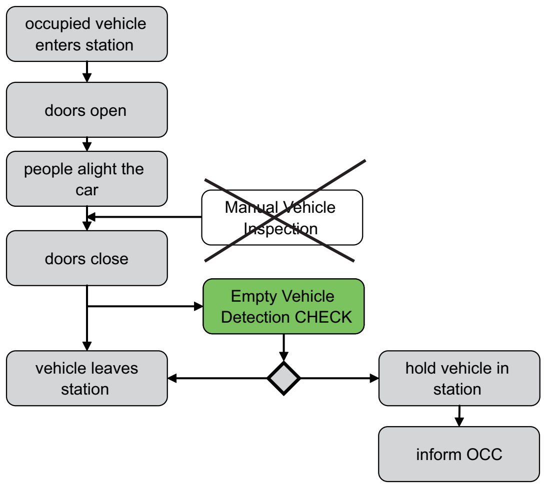

Figure 2. Operational activities for empty vehicle inspection

the whole cycle shall be repeated, security staff or central control operators must be informed.

IV. Hardware Concept

The system is based on intelligent video image analysis and it comprises of two cameras and a Network Video Recorder (NVR). The NVR is interfaced to the onboard Automatic Train Control (ATC) system via a relay contact. It receives status information, such as the train door open/close signal and a scan trigger pulse from the ATC. In the same way, the ATC receives the scan result of the vehicle's interior and self-diagnostics data from the detection system.

Typically, each train car is equipped with one pair of cameras facing in opposite direction to allow complete supervision of the car's interior. The camera position and the field of view are indicated in Figure 3.

The cameras are mounted and aligned in such a way as to provide a most suitable field of view for the video analytics software. For example, they are placed strictly in line with the passengers' handrails and therefore allow maximum visibility even of more distant parts of the vehicle (see Figure 5)

The video analytics shall operate upon external request only. Therefore a command (2-wire 24VDC) is send to the EVD system to activate the analytics. In parallel the door status is transmitted and the EVD system will only start in case the doors are reported closed. Having closed doors

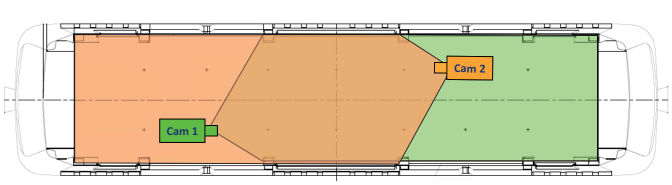

Figure 3. Camera position and field of view for Empty Vehicle Detection, ©Bombardier

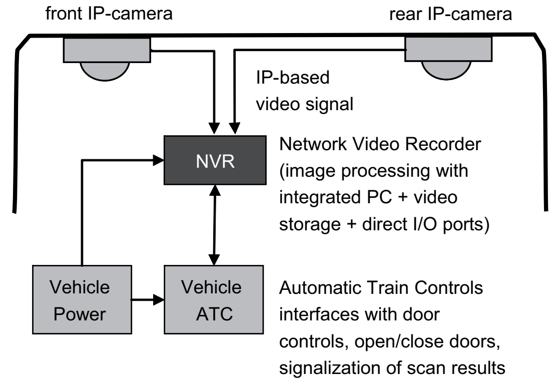

Figure 4. Hardware architecture for prototype tests

is essential to increase detection accuracy and reliability and to limit the interference from, e.g., strong and fast changing sunlight.

V. Detection Approach

Apart from video recording capabilities, the NVR provides a computing unit for the image processing tasks as well as dedicated I/O interfaces to connect the system to the onboard ATC. The software and algorithms implemented are easy to tune. Highly sophisticated image processing algorithms requiring expert knowledge for installation, parameterization and maintenance have not been used. Instead, the approach bases on very simple and unique artifacts of airport APM cars.

Thus, only a very limited subset of typical image processing methods is used such as edge detection algorithms (see Figure 5). The evaluation of detected image features focuses clearly on the operational context and the specific environment of the Empty Vehicle Detection application. This makes however, the system robust enough to work in more challenging APM environment. Characteristic image features from an empty vehicle are compared with each image which is to be analyzed. Significant differences indicate in red in Figure5 elements which do not correspond to an empty vehicle reference image are then detected based on edge detection principles.

The system outputs two signals, first the clearance status of the vehicle either upon request by an operator from OCC or fully automatic by the system. Whenever the vehicle has stopped in a station a trigger pulse from the onboard ATC will initiate the OEVD software to scan the vehicle interior. If found empty a clearance signal is send to the ATC otherwise the vehicle is indicated occupied. In this case visual inspection either from OCC or by local staff is necessary to remove baggage or ask people to leave the vehicle. The second output is a health signal indicating proper functioning of the OEVD software and hardware. This includes, for example, check for acquisition of valid image data (no frozen image, no moved camera position, minimum and maximum brightness of image).

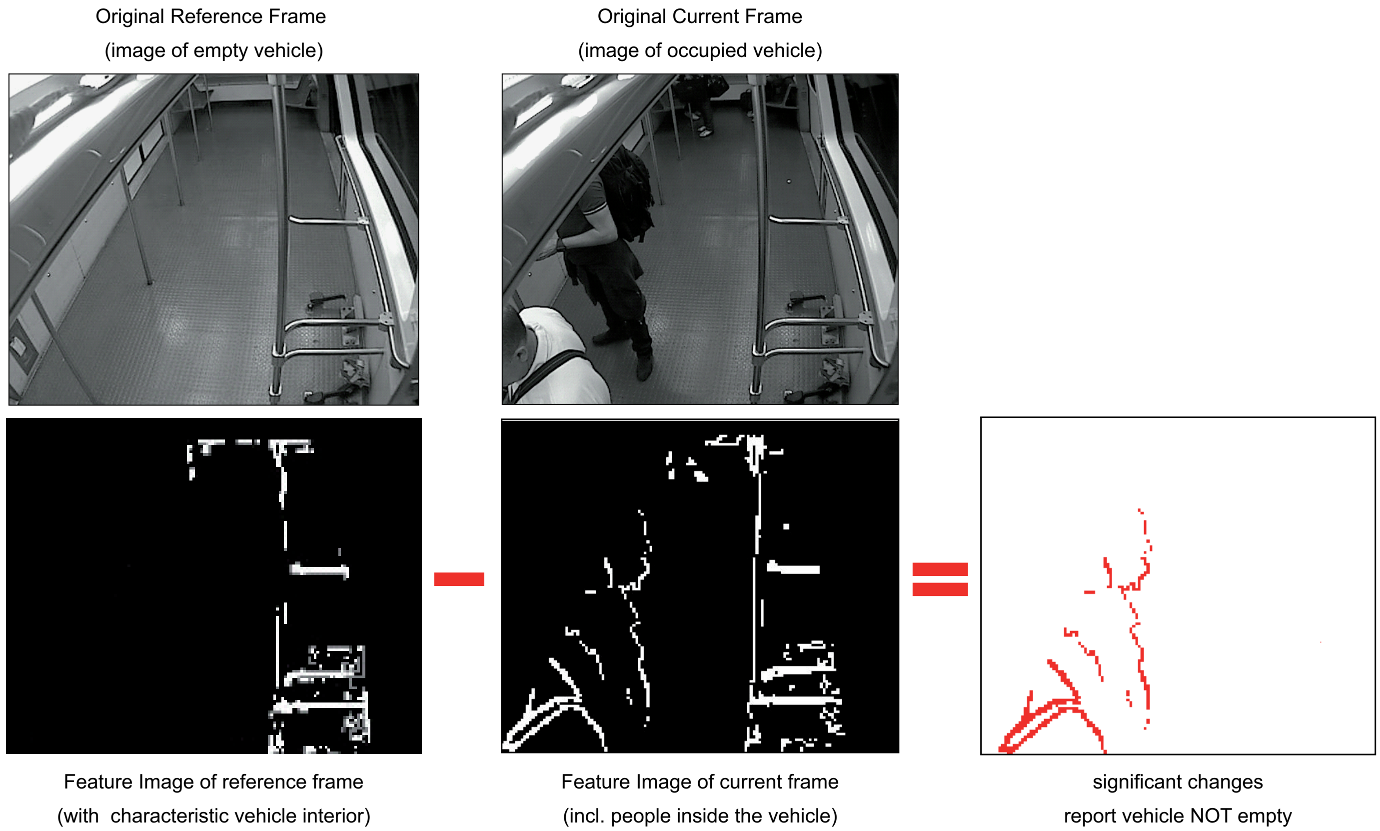

Figure 5. Empty vehicle and vehicle with passengers; distortion of the background feature image

VI. System Tests

The detection system had been tested in different laboratory installations and using real world video sequences from an international airport before going into a field installation. Extensive data had been collected from an on-site field installation at the Rome International Airport in Italy. Various test scenarios with people and baggage were performed to check reliable detection of Empty or Not Empty status of the vehicle. Figure 6 shows two example detections with people sitting near the rear window and only produce minimum changes to the background reference image. No detection failure had been recorded and the system identified each occupied vehicle correctly as Not Empty.

Figure 6. People sitting in front of the rear window are detected reliably

VII. Summary

The developed detection system for Airport People Mover Systems can automatically check the interior status of a vehicle. It shall detect whether the vehicle is empty or not in order to prevent people or left luggage to be taken to restricted areas, e.g., workshop or depot facilities or even secured parts of an airport. The approach bases on video-image processing using onboard video cameras installed in the vehicle's ceiling. The system can help improve security at airports. It had also been installed in an existing APM to capture and work with real life data. For further improvement, tests that are more detailed need to be performed under various environmental conditions, e.g., summer, winter, sunshine, night, etc. Next steps may include adapting the system to work with different vehicle types, e.g. metro cars and to check usability for urban applications.

References

[1] W. Yao: Method for detecting passenger object based on three-dimensional information. Shanghai Yaowei Industry Co Ltd.; Patent Publication CN101281647, 2011

[2] B. C. Chee, M. Lazarescu and T. Tan: Detection and Monitoring of Passengers on a Bus by Video Surveillance. Image Analysis and Processing, 2007. ICIAP 2007. 14th Int. Conference, pp.143-148, 10-14 Sept. 2007, doi: 10.1109/ICIAP.2007.4362771

[3] M. Devy, A. Giralt and A. Marin-Hernandez: Detection and Classification of Passenger Seat Occupancy using stereovision. Proceedings of the IEEE Intelligent Vehicles Symposium 2000; Dearborn (MI), USA October 3-5, 2000

[4] I. Pavlidis, P. Symosek, B. Fritz: Automatic detection of vehicle passengers through near-infrared fusion. Intelligent Transportation Systems, Proceedings. 1999 IEEE/IEEJ/JSAI Int. Conference on, pp.304-309, 1999. doi: 10.1109/ITSC.1999.821071

[5] S. Choudri, J. Ferryman and A. Badii: Robust background model for pixel based people counting using a single uncalibrated camera. Performance Evaluation of Tracking and Surveillance (PETS-Winter), 2009 Twelfth IEEE Int. Workshop, pp.1-8, 7-9 Dec. 2009. doi: 10.1109/PETS-WINTER.2009.5399531