Security Components in a One-Stop-Shop Border Control System

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***Abstract*—Each year the number of passengers travelling around the world is steadily increasing. Hence, the efficient handling of border crossings while maintaining a high security is a demanding challenge for the future. In this work we present the key security components for a novel proposed one-stop-shop (OSS) border control system, which tries to achieve greatest throughput of travelers while applying highest security measurements. We collect the main stakeholder's requirements for an OSS system and provide an overview of state-of-the-art security technologies. The goal of this work is to assembly the necessary technological solutions so that the proposed OSS system can be operated at all kinds of borders. Thereby, the selected technologies are evaluated and current limitations and constraints described.**

***Keywords*—border control, requirements, security components, sensors, facilitation**

I. Introduction

The 9/11 terrorist attacks fundamentally changed the term "border control" and its relevance. Before the attacks the term was only rarely used but nowadays the terms meaning has changed and border security becomes even more importance. To achieve highest security at all different border types like at airports, streets and railways at land borders, and cruise ships at sea borders, many different processes have been established. Such processes are deployed for customs control, security control and border control.

In the last years Europe's borders (e.g. Italy and Ukraine) are getting unstable due to immigration problems caused by the Syria conflict and the inner conflict in the Ukraine and therefore the relevance of secure border processes of travelers is getting more important. Additionally Europe's economic significance and legal requirements of the Schengen Code that asks for freedom of passenger's movement result into an increasing passenger flows at external border crossings of the EU and are expected to increase even more in the future. In 2011 645 million border crossings were reported and forecasts for air border crossings expect to increase by 80% from 400 million in 2009 to 720 million in 2030 [14]. Due to this important fact the demand on passenger facilitation is additionally needed to overcome future problems with border crossings. Automation (see Figure 1) seems to be one option to mitigate the passenger flow problem, however, first test installations and even operational installations show multiple difficulties associated with the fact that the redesign of a complex security process in a multi-stakeholder environment has to be accomplished.

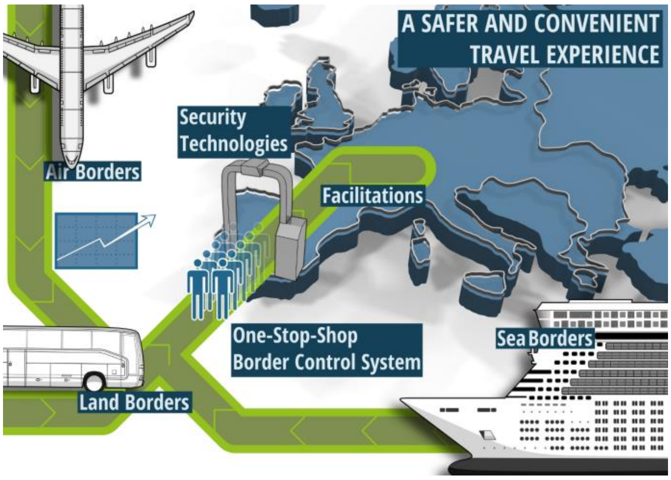

Figure 1: The novel OSS border control system is presented with an emphasis on security technologies and facilitations. The different types of borders such as air, land and sea are covered by an OSS system designed for pedestrians and another for vehicles.

Frontex, the European Union agency for external border security, supports Europe's member states in the introduction with such automated systems and is therefore the main driver for innovation. Frontex proposed best practice guidelines [15] and also the innovation potential in [16]. Furthermore prototypes for such automated border control (ABC) solutions are deployed at airports but one cannot find any harmonized European solution for land border crossings or sea ports in the world yet. For this reasons the EU is moving towards a more modern and efficient border management by using state-of-the-art technology. The European Commission proposed a 'smart border package' to speed-up, facilitate and reinforce border check procedures for foreigners travelling to the EU [17]. One main aspect of the package is to register the entries and exits at the Schengen external borders in the Entry/Exit System (EES) that is planned to simplify life for frequent third country travelers and enhances EU border security. An automated border system supports also EES by saving the necessary data and therefore it is a possible key-tooling for the future.

Motivated by the related security and facilitations challenges at automated border control this paper's vision is to deploy at all types of borders a transparent "One-stop-shop" (OSS) system, which is a highly integrated system allowing a control for border and security checks at one border check point. The "One-stop-shop" system is an interconnected information management system, that integrates several key technologies and displays and stores relevant information according to the specific needs and regulations for the border guards who are responsible for the border management. In the "One-stop-shop" we combine the typical security components which are necessary for security control (e.g. luggage, vehicle), and border control (passport control) with novel technologies. Due to legal requirements (it is not allowed to make border control and security control at one point yet) the proposed OSS system is a vision for future border control that cannot be immediately implemented but shows how the system should work. Additionally infrastructure processes (like airport check in) could be integrated in the OSS process which would facilitate the passenger a lot.

To enable such a solution we present a list of key components to speed-up, facilitate and reinforce border procedures at the external borders of the EU [17]. We focus on components for pedestrians and vehicles in order to support all necessary border crossers and therefore end-users at all types of borders. For the security and border checks we address especially video and other relevant technologies and furthermore we propose how to integrate them into an overall border system. In this paper we do not address biometrical technologies since they are already well described in corresponding papers and passport readers as they would go beyond the scope.

In Sec. II the Requirements for the OSS system are outlined. Afterwards relevant security technologies are reviewed in Sec. III, which can be used in such a system. In Sec. IV one can find a proposal for a configuration of an OSS system. The conclusions are outlined in Sec. V.

II. Requirements

To develop a new OSS system, the knowledge and experience of key stakeholders has to be taken into consideration. Thus, their needs and requirements towards the new OSS system are gathered and analyzed. The main stakeholders are selected from three groups:

1. Border controlling authorities (BA): core processes – existing checkpoint processes and technical requirements (e.g. input / output of the processes, participating actors, roles and organizational units), used technologies, it-systems as well as hardware, interoperability, services, tasks (manual, user, system tasks), information exchange and legal aspects.
2. Travelers (T): human factors and usability, harmonization, flexibility, user acceptance and guidance needs, ABC environments, scalability in all types of borders and speed.
3. Infrastructure stakeholders (IS) such as airport or seaport operators and other security authorities: system development, interoperability, efficiency and harmonization.

The two high-level requirements from the stakeholders are security and speed-up facilitation. All gathered requirements are derived from these two fundamental ones. Each requirement is associated with its stakeholder(s) and classified as either a security (S) or facilitation (F) feature. As previously mentioned we distinguish between a system for pedestrians and another for vehicles, because each system has very different features and constraints. The requirements are divided into functional and non-functional for a better understanding. The latter requirements are displayed in Table 1.

Table 1: Non-functional requirements. (SH – Stakeholder: BA - Border Controlling Authorities, T - Travelers, IS - Infrastructure stakeholders; Type: S – Security, F – Facilitation feature)

Req.	SH	Type	Description
1	BA	S	The system shall be resistant to all sorts of spoofing attacks and tampering.
2	T	S	The system must ensure data protection.
3	BA IS	S F	The system must process the sensor data in real-time or near real-time to immediately alarm border guards.
4	T	F	The OSS system should be self-explanatory.
5	T	F	Citizen should feel comfortable during the border crossing, i.e. the person does not have to touch anything.
6	IS BA	F	Designed OSS system has to show profitability (reasonable costs).

On the other hand functional requirements describe the features identified by stakeholders. These features are essential for an operating OSS system. Thereby, our work concentrates on the most important requirements and leaves out details as well as those, which are for instance dealing with the actual border control process. Moreover, the essential requirement of ensuring a high accuracy person authentication is not considered, since this includes a passport reader and biometrics, which are not taken into account in this work. The other relevant requirements as identified by the main stakeholders are presented in tables Table 2 und Table 3.

Table 2: Functional requirements for OSS systems regarding passengers. (Abbreviations see Table 1)

Req.	SH	Type	Description
7	BA	S	System should detect human trafficking. The system must be physically and logically designed so that only one user is allowed per transaction.
8	BA	S	The system must include CCTV surveillance of the gate and interior areas to allow the border guard to monitor user behavior.
9	BA IS	S	System shall allow for left luggage detection.
10	IS T	F	The system shall allow for queue length detection.
11	BA	S	System shall allow for detection of suspicious behavior (e.g. loitering, excessive sweating).
12	IS	F S	The system shall allow for people counting and tracking.
13	BA IS	S	Detection of weapons and other illegal substances.

Table 3: Functional requirements for OSS systems regarding vehicles. (Abbreviations see Table 1)

Req.	SH	Type	Description
14	BA	S	The system shall detect any person leaving a vehicle/ control area during clearance.
15	BA	S	The system must identify vehicles (e.g. by scanning car plates).
16	IS T	F	System shall count vehicles in advance and direct them to different terminals.
17	BA	S	The system shall count number of travellers in a vehicle.
18	BA	S	The system shall detect illegal passengers hidden in a vehicle.
19	IS T	F	The system should support pre-clearance of travellers and their vehicles before arrival to border crossing point.
20	BA	S	System shall detect vapors/toxins emitted by a vehicle (e.g. CBRN substances located inside the vehicle).
21	T IS	F	System enables border checks to be made while travellers remain seated inside vehicle.
22	BA IS	S	The border guards shall observe the OSS system via video surveillance cameras.

III. Security Technologies

Modern sensors and security technologies will allow border, security and custom officers to monitor border checkpoints remotely, ensuring safety, preventing illegal crossings and other threats. There are, however, many potential challenges for OSS systems: the system needs to optimize the border crossing throughput in order to resolve the increasing travel capacities. On the other hand it must be reliable and multifaceted to detect multiple kinds of security breaches. In order to satisfy the functional and nonfunctional requirements from Sec. II advanced technologies based on different sensors need to be applied. There are four main types of sensors - acoustic, optical, seismic and magnetic sensors – as well as full-body technology used to fulfill the described functions adequately. Especially optical sensor systems are a key technology for monitoring and surveillance. Complex applications such as "detecting suspicious behavior" often require multiple sensors combined in one system to fulfill a certain task.

A. Accustic Sensors

Acoustic wave sensors [19] can be used to detect changes in the environment, and more precisely, in a material that is elastic enough to transmit waves on its surface. But possibly the biggest advantage of wave sensors is their multitude of potential application – as they can be applied in products ranging from garage door opener remote controls to detecting traces of chemicals in the water. For purposes of border control however, the most interesting applications are those of toxic detection and movement detection on the perimeter.

Acoustic sensors are not very "universal", as in each instance the application must be specified in order to tune the sensor appropriately. They work by detecting atypical changes in the wave composition. They come in different types, with many ruggedized equipment on the market as well, which, combined with their rather low price, make them an interesting option [18].

Yet another application of acoustic sensors at border crossing could be intelligent voice analyzers. Such devices are now more and more frequently used not only for law enforcement purposes but also for border/customs processing. The voice analysis software detects abnormal changes in intonation, pitch, volume or rate, which can indicate such states as arousal, uncertainty, indecisiveness or deception attempt [27]. Currently used systems include "Human Access Control" (HAC) [29] - for usage in airports, government facilities, prisons and checkpoints. The HAC system is able identify the different emotional structures by learning to distinguish between the ones that signal real intent to commit a crime or terrorist activity and other conditions such as exhausted travelers or excited vacationers.

B. Optical Sensors

There are many different optical sensors and vision systems available nowadays. Relevant applications with optical sensors may include: person separation, left luggage detection, people counting, queue length detection, trespassing, behavior analysis and automatic number plate recognition. Generally speaking most video surveillance tasks are designed for indoor as well as outdoor activities. The quality, however, may significantly decrease. But this strongly depends on the regarded scene. We have not found any video surveillance tasks, however, explicitly designed for outdoor scenes.

Another aspect of these applications is their target platform. There are server-based and edge-based analytics as well as hybrid architectures, which are a combination of both. Edge-based analytics run the algorithms from edge devices like cameras or video encoders. Server-based analytics are based on a centralized server that can handle video input from multiple cameras.

Optical sensor systems can be divided into three main types – mono vision, stereo vision and network systems (arrays of optical sensors). Another classification, which is also important when choosing adequate optical monitoring technique, is the covered spectrum. The visible spectrum is that particular portion of the electromagnetic spectrum, which can be detected by the human eye. Typical visual sensors such as CCD or CMOS sensors collect this spectrum and process the received signals [1]. Wide dynamic range (WDR) describes an attribute of a system that can record a larger dynamic range than ordinary imaging systems [11]. One way to achieve WDR is to use different exposure times for different pixels, which can be implemented in various ways. One way is simply to combine two or more entire frames obtained with different exposure times. In this way, the dynamic range can be extended up to 120dB. There are also several disadvantages of the described approach. For instance, long exposure times will affect the imaging of moving targets resulting in motion blur. Thermal or infrared images on the other hand, are not dependent on visible light. Instead, an infrared sensor is a device that collects infrared radiation. The camera's sensitivity to infrared radiation, i.e. its capability to distinguish different temperatures in a scene, can be expressed as its noise-equivalent temperature difference. The identification of human subjects is reduced to less than 1km if uncooled detectors are used.

Mono vision is an ordinary camera with a single optical sensor. Many complex vision problems, however, cannot be solved with only processing the image data. Therefore, stereo vision systems are becoming more popular, since these systems are able to deliver dense 3D data in real-time. For instance, stereo vision systems are used for people counting, which is a sophisticated computer vision problem. There are various depth sensing techniques ranging from passive e.g. combining two digital cameras (optical sensors) which are mounted in parallel on a common rigid baseline and a processing unit to active sensors (e.g. MS Kinect from PrimeSense) to determine depth data. Advantages of passive sensors are among others that they can cope with a wide range of ambient light conditions. Disadvantages of this kind of stereo vision are that depth resolution decays with increasing distance and un-textured areas contain no depth information. The PrimeSense has gained a lot of popularity due to its application within the low-cost Microsoft Kinect game controller device. The MS Kinect, however, is limited to indoor usage, because direct sunlight as e.g. outdoors influences the projected pattern. Time-of-Flight sensors emit modulated light onto the whole scene [36]. Special focal plane sensors are able to analyze the run-time of the reflected light on a pixel-basis, in order to deliver range images. Under conditions with bright ambient light, the active illumination units need to consume a lot of energy (up to several 100 Watts), even for moderate distances of 15 meters. Another drawback is the relatively low sensor resolution and possible interferences between different TOF cameras recording the same scene. Lately, especially the scientific community carries out a lot of research to develop arrays of optical sensors working as a network. Cooperation of multiple sensors increases the complexity of the system greatly, but it ensures maximally strong surveillance and minimal false alarm rates. Sensor networks may incorporate different technologies working in unison. For example, a fish-eye camera detects atypical movements and a dome camera starts tracking the targeted person.

C. Seismic Sensors

Third technology useful in border control security provision is the seismic sensors technology. Those devices detect and measure ground motions, both natural, like earthquakes, and man-made, like footsteps or heartbeat [20]. For purposes of border control, obviously person and vehicle detection are the desired functions, and while seismic sensors do have their limitations – mainly range – they can be a useful additional tool to enhance security. They can monitor movements on a selected route or over some length of the perimeter when combined into arrays. Arrays can provide data such as direction of the movement and its speed. Seismic sensors can work both outdoor and indoor and are reliable, rugged and can withstand extreme conditions [20]. An interesting benefit of using them is that they are invisible, so that a trespasser has no idea that his movement is being tracked – no visible, above ground parts are necessary. Usability of said sensors is however limited, as they are not functional when confronted with, for example, groups of people as they cannot distinguish single steps.

Extremely sensitive geophones in combination with signaling software can be used to detect the beat of a human heart [32]. The system is so sensitive that pounding of the human heart can be detected through the chassis of a vehicle, whether empty or laden. Such devices usually go with ground vibration cancellation technologies which improve the quality of scan and allow for deployment in most environments; regardless of weather conditions. Heartbeat detectors pose neither a threat to detected passengers nor operators. Heartbeat detectors are able to detect multiple heartbeats as their frequencies vary. However, to maintain full efficacy and low false alarm rate no passenger shall remain inside the vehicle while scanning [31]. Only then a scan can be reliable.

D. Magnetic Sensors

Magnetic sensors can be used for security reasons to detect concealed metal objects, such as knives and guns. Commonly used metal detectors are in fact magnetic field sensors [22] – ranging from vehicle detection devices, through metal detecting gates, to handheld metal detectors. Magnetic sensors are able to detect any changes in the magnetic field around them [23]. The most common technology for metal sensing are very low frequency (VLF) detectors. These consist of transmitter and receiver coils. The former one sends electricity along the wire and the latter one receives frequencies that come from the target object. Once the magnetic field is pushed down the ground it pulse back immediately. Whenever a magnetic field finds a conductive object on its way it makes this object to generate its own magnetic fields and thus magnetic field anomalies can be observed and measured. VLF metal detectors have also the capacity of distinguishing between different materials.

For toxic (e.g. chemical, biological) weapons detection magnetic-resonance techniques (e.g. nuclear magnetic resonance or nuclear quadrupole resonance) are frequently used at border crossings. Nuclear quadrupole resonance is also used to detect solid explosives and narcotics. Moreover, those techniques are also used to detect explosives concealed in a luggage, since the detection system is able to detect radio frequencies emitted by the explosive components of the object [26].

E. Full body scanners

A part of electromagnetic spectrum comprises X-rays that lay between ultraviolet and gamma radiation. It is frequently used in full body scanners for border security purposes to scan travelers and their luggage for illegal objects [28]. Two most typical X-ray imaging technologies that are of main interest for OSS systems, due to their desired features, are backscatter X-ray and millimeter wave scanner (passive or active). The first one uses ionizing electromagnetic radiation, which generally is carcinogenic. In contrast, the second technology uses non-ionizing electromagnetic radiation. Both technologies are able to detect any kind of materials (e.g. concealed weapons or other illegal objects) with the use of electromagnetic radiation. One of the greatest advantages of full body scanners is that they do not require travelers taking their clothes off to perform a scan – clothing and other materials are translucent to those devices.

IV. Proposal for a Technology Based Border System

In this section a best matching between the presented requirements in Sec. II and the best technologies available (Sec. III) is carried out. First of all, some common remarks to some non-functional requirements are provided.

Generally speaking video and other surveillance applications are usually carried out in real-time or at least near real-time, so that they are suitable in an OSS system, too (req. 3). Anti-tampering, which prevents the manipulation of any sensor (e.g. a camera), is a very important task since this module automatically informs the operator when a sensor is manipulated in any way such as redirection, blocking or defocusing of cameras or other sensors. Without this module, it can take a long time before any sabotage is actually noticed. Anti-tampering is usually already integrated into (video) surveillance products such as CCTV cameras. The same accounts for other sensors related to security applications. Hence, req. 1 is very often satisfied. Moreover, carefully considered human machine interfaces help to increase the acceptance of the OSS system because users feel comfortable with the system (req. 4, 5). The overall efficiency of the system increases, too.

As surveillance and security applications appear in more places, so do the concerns about the invasion of privacy (req. 2). Privacy advocates worry whether the potential abuses of video surveillance and other kinds of sensors outweigh their benefits. A fundamental challenge is to design monitoring systems which serve the security needs while protecting the privacy of the individual at the same time. Edge-based systems can be one solution, if the system only transmits events (e.g. object in field) instead of a video. In general, the complete technical system, however, needs to be analyzed in order to solve privacy issues.

The acceptance of one-stop-shops by the airport or sea operators also strongly depends on acquisition costs (req. 6). Hence, we would like to provide some general remarks about this issue: Hardware is a major part of the costs, if large quantities of these gates are installed at border crossings. For instance, a simple CMOS sensor is much cheaper than an infrared imaging module. Obviously the same accounts for mono and stereo vision systems. The latter need two optical sensors and more computational resources to process the data. Especially novel technologies e.g. full body scanners are obviously very expensive. In this work, however, we focus on technologies and not prices. Eventually the latter aspect needs to be anticipated in the selection of the technological solutions to actually create a product.

In order to satisfy the requirements from Sec. II a great number of tasks need to be specified. Requirements are assigned to tasks and technological solutions resulting in novel OSS systems specified for pedestrians and vehicles. This matching, which has not been carried out before, enables the further development of OSS systems. Results are presented in Table 4 and Table 5, respectively. The selected solutions are either products, which are well-known in the market, or promising emerging technologies. Afterwards each solution is briefly discussed and limitations and constraints analyzed.

A. Pedestrians

The main usage of the OSS systems for pedestrians is at airports (and harbors). Hence, this system is usually located indoors, which simplifies to apply technologies. The proposed tasks and technical solutions for an OSS system are presented in Table 4.

Table 4: Proposal of sensor selection for passenger OSS systems.

Req.	Task	Solutions (Technologies)
7	Person separation (Prevent tailgating and piggybacking)	* Newton – T-DAR (passive stereo vision system) [4] * iEE – TDflex (TOF stereo vision system) [3] * Top-view stereo vision system by AIT [2]
8	Observation of the interior OSS system	* CCTV cameras
9	Left luggage detection (Detection of small and large objects)	* IPS Intelligent Video Analytics [6] * BOSCH IVA 5.5 [5] * Top-view stereo vision camera by AIT [2]
10	Queue length detection	* Blue Eye Video – B-Queue; * Stereo vision camera by AIT (no top-view) [7]
11	Behavior analysis (Suspicious behavior)	*Bosch – IVA 5.5 [5] *Infrared sensors, stereo vision sensors, WDR sensors; *Remote Tester & Analyzer (RTA) based multi-sensor surveillance system [8]; * voice analysis [27], [29]
12	People counting	* CMOS, WDR, infrared sensors; * Hella – Precision Stereo Camera [25];
13	Detection of illegal substances, weapons, etc.	*Audio and Magnetic sensors [19][26] *Full Body Scanners [35] Passive millimeter wave scanners: *SPO-7R™ – Concealed-threat stand-off people screening security system [33]

Person separation ensures that not more than one passenger is present within a secure area (e.g. an ABC gate [7]). This task should not be mingled with “People Counting” since person separation focuses to detect tailgating and piggybacking to prevent frauds. Currently two commercial products for person separation (req. 7) are available [3][4]. Integrators of border installations, however, are not satisfied with the existing commercial solutions yet. Hence, a novel approach has been developed by AIT [2] and evaluated by 600 trials during a preliminary investigation. The accuracy of the new technical solution was about 97%, which is very promising. This means an improvement of more than 10%. For the practical usage, however, more extensive evaluations need to be carried out.

The observation of the interior of the OSS system (req. 8) can be carried out by CCTV cameras with ordinary CMOS sensors. That is because the illumination (environment) can be controlled since these systems are located inside buildings. If optical sensors are used for e.g. person separation, a real-time video stream of the interior is already available and no additional cameras need to be installed.

Left luggage detection (req. 9), which is also denoted as "idle object" or "object left detector", verifies that passengers do not leave any item inside the OSS systems. This task is very challenging because it needs to be able to detect very different kinds of remaining objects (e.g. passport versus suit-case). Many providers of video analytic algorithms [5][6] sell this task among others. So far this task only process 2D images and depth information is not considered by commercial products. Stereo vision systems, however, achieve better detection rates than mono vision systems [2]. It seems plausible that the additional depth information, which stereo vision systems provide, help to better detect arbitrary objects. Hence, stereo vision systems are applied if a very high level of security and highly efficient operation is desired.

A specific task of people counting is "queue length detection" (req. 10), which shall reduce the amount of waiting time in front of OSS systems. The information about the current queue length can be used to equally distribute the new passengers in real-time between the open OSS systems. This kind of detection is challenging because usually the queue length detection has to reliably work in crowded scenes in which many objects are partly occluded. On the other hand an accuracy of 85% to 90% is usually sufficient for this application. So far commercially available products are based on a top-down perspective. A disadvantage of this perspective is the missing typical head-shoulder patterns of humans, which can be of great value to reliably detect humans. Moreover, the size of the area monitored by a camera strongly depends on the ceiling height in the top-down perspective. Hence, new optical systems [7] may be independent of the physical structure and be directly integrated into the OSS system.

Behavior analysis [12] (req. 11) plays an especially important role in video surveillance applications, too. The goal of this kind of analysis is to automatically detect abnormal behaviors and hostile intents in the deployed application e.g. "loitering" or "fighting". The challenge of these types of tasks is the semantic behavior learning and understanding from observing the activities of humans. There is still a lot of research ongoing, because many problems are not satisfactorily solved yet. Hence, there are only products available for simple scenarios such as loitering [5]. Määttä et al. present an approach for detecting abnormal activities from multi-sensor surveillance systems [8]. A multi-sensor surveillance system is meant for monitoring office buildings and homes. In case of a security incident, e.g. fire or break-in, the system will report an alarm to a security officer. So far this approach is not commercialized; maybe because of the complex system configuration which may otherwise cause false detections. Another approach is the voice analysis of the passenger as offered by [27]. Prior to granting travelers access to various facilities the system asks them a couple of questions. The traveler's answers will be analyzed and their emotional state such as arousal or uncertainty can be assessed in order to determine their real intentions for crossing borders. The analysis is completed in less than one minute. This information can be fused with optical sensors as additional security measures.

The task "People counting" (req. 12) can be used in different applications. On the one hand it can assure that only a certain number of persons are within a defined field. This may even account for the number of passengers within one vehicle. In this way this task can increase the security. On the other hand people counters are also used to analyze customer (passenger) traffic in order to improve the overall efficiency and increase the service quality. There are already many products with different optical sensors available in the video surveillance as well as retail market. For instance, the Hella camera [25] does not only depend on analyzing 2D images but also considers the depth information of the scene. In this way this product should achieve a better performance than other products only relying on 2D data.

The detection of metal objects and other potentially dangerous goods (req. 13) have been solved by different types of sensors such as magnetic and audio sensors [26] [19]. However, to effectively detect all potentially dangerous objects those sensors need to be used together and specially calibrated. The whole process is time consuming as well as ineffective for some materials. For that reason, full body scanners prove to be more effective as they are able of basically detecting all kinds of objects with various materials [33] [35]. So far current full body-scanners are definitely still too slow (significantly decrease the process) to integrate them into the OSS. On the other hand a lot of research is carried out to overcome this obstacle and speed-up the control [35].

B. *Vehicles*

The border and security check of vehicles is more challenging than for pedestrians, since a vehicle blocks off the view of border guards towards the driver and passengers. Therefore immigrants can hide inside the vehicle in order to illegally cross the border. The valuable tasks and technical solutions for a new OSS system dealing with these issues are presented in Table 5.

Table 5: Proposal of sensor selection for vehicle OSS systems.

Req.	Task	Solutions (Technologies)
14	Detection of trespassing (leaving the car / control area)	*Tripwire, object in field realized via optical sensors * BOSCH IVA 5.5 [5] * IPS Intelligent Video Analytics [6] *seismic sensors e.g. geophone [21]
15, 16, 19	Automatic Number plate Recognition - ANPR	*Several commercial products are available, e.g. *Siemens – Sicore ANPR camera system [10] * ELSAG North America [9]
17	Counting passengers inside vehicle.	Passengers need to leave vehicle. Then people counting is carried out [25].
18	Detection of illegal passengers hidden in vehicle.	Heartbeat detector: *MicroSearch® G3 [30] *AVIAN [31] *Intelsec - Heartbeat - Human Detection System [32] Backscatter X-ray: *Z Portal® For Passenger Vehicles [34]

20	Detection of illegal/ toxic objects	* Magnetic / acoustic sensors [24], [34]
22	Observation of the OSS system.	* Infrared sensors, WDR sensors; * Dome CCTV camera.

Detection of trespassing (req. 14) is one of the fundamental tasks in (video) surveillance to prevent illegal intrusions. For instance, high sensitive areas within a building such as cargo space where no humans should normally be need to be protected from trespassing. For this, the tasks “tripwire”, “object in field” or “entering field” – all comprised by “trespassing”- are available, which allow the user to define a field with specified conditions. Only if these conditions are satisfied, alerts are generated in order to inform the operator. This generic approach provides the opportunity to also detect persons leaving the car or the control area. Next to optical sensors this can be also achieved with the use of seismic sensors [21]. These are highly sensitive sensors which can be calibrated to detect human footsteps. Anytime a person leaves the vehicle or enters a restricted area an alarm is triggered.

For traffic management and control applications at border checkpoints optical sensor systems can be applied, which carry out an automatic recognition of the vehicle registration plate. This process is actually called automatic number plate recognition (ANPR), which is also known as automatic license plate recognition (ALPR). There are two main applications for ANPR. On the one hand recognized registration plates can be used to count the number of cars passing by (req. 16). In this way the queue lengths of vehicles in front of checkpoints can be determined and new cars approaching the checkpoint can be directed to the access points with the lowest amount of waiting time. On the other hand, the registration plate can also be used for automatic identification of the owner (req. 15, 19). There are many products [9] [10] based on ANPR, which are operated throughout the world. Current application areas comprise parking automation and security, access control, motorway road tolling, journey time measurement as well as law enforcement.

Unfortunately, at this point the reqs. 17, 18 and 21 cannot be reliably solved altogether with the existing technologies. Hence, we propose a solution, which does not satisfy req. 21, but resolves the other two requirements. In this way an OSS system can be designed which can be actually operated at land and sea borders. For our solution we propose the following procedure: 1. Vehicle approaches scanner/control area. 2. Passengers leave the car. 3. Passport is checked while vehicle is screened for hidden passengers and illegal objects. 4. Passengers reenter the car and leave the area.

The detection of illegal passengers (req. 18) can be achieved with heart beat detectors [30][31][32]. This technology uses vibrations caused by human heartbeat to detect hidden human beings hiding in vehicles and cargo. The technology is more reliable and cost-effective than other sensor approaches and safer and faster than manual searches. The magnetic vehicle sensors, when placed on a vehicle or a container, determine whether a human is inside without the time-consuming and expensive task of unloading and inspecting the entire vehicle or container and all of the contents.

While scanning for hidden passengers the system can search for illegal and toxic objects (req. 20). The evaluated solutions, which can also help to detect humans, include: Backscatter x-ray imaging [34] – used mainly at airports for passenger scanning, can also be used to inspect cargo and vehicles. Backscatter scanners use only radiation reflected from the objects, and do not emit potentially dangerous ionizing radiation, limiting health concerns yet staying as effective as traditional x-ray scanners. Backscatter imaging can show hidden objects, explosives, liquids and different contraband, and usually scans the vehicles from both sides and from the top for added accuracy and photo interpretation. Vehicles move through a special gate slowly and output is generated immediately. Passive millimeter wave scanners are another technology for screening. It works best for trucks that have non-metallic sides, which comprise almost 90% of all trucks travelling through Europe [24]. The screening of a truck is made as the vehicle passes (no stop is required) with the use of 35 GHz linescan imaging system and the image is generated. The whole process is smooth and typical flow patterns are preserved. Already installed systems prove to be effective detecting hundreds of stowaways hidden in the trucks [24].

A 24/7 observation (req. 22) of the OSS system requires special CCTV equipment dealing with the very different illumination and weather conditions. Hence, robust surveillance cameras with either WDR or infrared sensors seem favorable. The dynamic range of a WDR camera extends up to 120dB [13]. Moreover, the sensor achieves a high image resolution as well as a high frame rate. By contrast a WDR sensor is more expensive and different artifacts such as motion blur or visible pulsing may occur. In comparison to CMOS do infrared sensors work without any illumination, so that infrared cameras can be used in total darkness. Disadvantages are the low image resolution, expensive hardware, false color images and that objects with a similar temperature range cannot be differentiated.

As previously mentioned req. 21 cannot be satisfied at the moment. This results in a more time-consuming border control for the proposed solution, since passengers need to leave and reenter the vehicle. We believe, however, that there will be technologies in the future, which can cope with req. 17, 18 and 21 altogether. Then an even more efficient OSS system can be designed.

V. CONCLUSIONS

In our work we assembled the key security technology components for novel OSS systems anticipating the requirements demanded by the main stakeholders. This resulted into two systems – one designed for pedestrians and the other one for vehicles, which can be operated at air, land as well as sea borders. Moreover, the constraints and limitations of these technological solutions with respect to this particular application were discussed.

The requirements for an OSS system for pedestrians can be satisfied; partially with the latest ongoing technological developments such as the novel “person separation algorithm” combining image and 3D depth data. Furthermore, full body scanners may be soon an essential part of the system to improve the security level. On the other hand one of the main challenges of OSS systems designed for vehicles is to prevent illegal border crossings of hidden persons. We presented a solution which is based on sophisticated heartbeat detectors to search for hidden passengers. Note, that this OSS system is still not entirely satisfying, because req. 21 –passengers shall remain seated – cannot be fulfilled yet. We are confined, however, that this problem will be resolved and that the proposed OSS systems with the different technology elements will achieve a significant impact on future border control procedures.

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