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ENSURING AERODROME DEVELOPMENT PROCESSES AND USING SENSORY NETWORKS

Summary. Using new technology to track service movement and logistics equipment, passengers or wild animals in the airport area can significantly reduce runway incursion occurrence. Sensor implementation networks will allow for foreign entity identification in a timely manner and take measures to prevent unauthorized access to the track. Modern technologies, which include sensor networks, multifunctional camera systems and radio frequency identification access chips facilitate the creation of complex safety nets at active points and on access roads. Due to their mobility and possible changes in range and direction, sensory networks are an effective method for achieving the desired level of security. Combining elements of modern technology creates space for automated airport security. Security risk portfolios are now defined for 10 different operating domains and give advice to the decision-making process, which the European Plan for Aviation Safety (EPAS) has supported. The aim of the article is to analyse safety in commercial air transport for the period 2006-2015 in comparison

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with 2016 and propose a method that would reduce the number of incidents through sensor networks and using texture analysis.

Keywords: runway incursion; unauthorized entries; hotspots; sensory systems

1. INTRODUCTION

The primary aim of all actors involved in aviation is to keep all threats and risks at an acceptable level, which is managed by two processes called safety and security. The aim of safety is protecting people and property, including environmental issues, against all possible system failures. The aim of security is protecting people and property against acts of unlawful interference caused by humans (i.e., terrorism or unadjusted passengers).

Measurement of the level of aviation safety is achieved by introducing safety indicators. By collecting, regularly evaluating and implementing knowledge gained through security data analysis, it is possible to find events occurring under normal operating conditions, as well as micro events that may represent the initiation impulse of subsequent events defined in the ADREP/RIT Taxonomy of the International Civil Aviation Organization (ICAO)⁵ and the European Aviation Safety Agency (EASA)⁶.

Assuming that near misses are the trigger mechanisms for events, we can find three base layers of indicators based on the analysis of events measured by evaluating state operational safety plans.

- The first layer presents accident statistics.
- Reactive indicators of the second layer give a more detailed view of the so-called significant seven safety issues.
- Proactive third-layer indicators expand, in detail, the types of events in the second layer to increase the data-generated quality of the event investigation.

2. REACTIVE INDICATORS DEFINITION

Reactive indicators that represent the first layer include events of each type depending on the severity and consequences of the event. The first layer consists of accidents, incidents and deaths as described in ICAO Annex 13, ICAO Annex 19 and Regulation (EU) No 996/2010⁷. The first layer presents accident statistics. As the data obtained from the first layer have no telling value, second-layer indicators, which are predictive indicators, were added.

Reactive indicators in the second layer give a more detailed view of the events of so-called significant seven safety issues and are divided into seven types as follows:

- Mid-air collisions and near misses (MAC)
- Controlled flight into terrain (CFIT)
- Runway incursion (RI)
- Runway excursion (RE)

⁵ International Civil Aviation Organization. 2000. ADREP 2000 Taxonomy.

⁶ EASA. Reduced Interface Taxonomy.

⁷ Heinrich, H. W.: Industrial accident prevention: a scientific approach. McGraw-Hill. Safer Complex Industrial Environments: A Human Factors Approach. CRC Press. ISBN 1-4200-9248-0.

- Loss of control in flight (LOC-I)
- Ground collisions (GCOL)
- ANS system malfunction

Reactive indicators, in view of their detail, allow us to explore interaction with each other to the incidence reduction events between the different types of events and the implemented measures.

Proactive third-layer Indicators extend the second-layer event types in detail to increase the event data quality.

In event investigations, two variants of events can occur when factors of the third layer could have been or were not identified at the peak event occurrence.

The research definition comes out from Regulation (EU) No 376/2014, which divides events into four basic groups:

- Events related to aircraft operation;
- Events relating to technical conditions, maintenance and repair of an aircraft;
- Events relating to air navigation services and equipment;
- Events related to airports and ground services.

The analysis based on compulsory and voluntary reports (IOSR) and reports produced at national level (ECCAIRS) allowed us to find the most recurring collision events between airplanes and other objects involve collisions of planes with objects on the ground (vehicles, handling equipment and other objects). The collision possibility is dependent on the level of an airport's operating environment controls, low-level knowledge of operating rules by airport personnel, or the poor technical state of technical handling equipment.

An important indicator concerns unauthorized track entry, where a runway is used by another airplane or there is unauthorized access to the runway. The use of a runway by another plane relates to low levels of crew/ANS communication, technical problems with airport equipment, lighting and signage, or unclear map data. Unauthorized entry of persons and wild animals relates to the low-level physical security of the aerodrome area or a low level of ground clearance.

Another important area is the failure to give or restrict air traffic management (ATM) services provision.

This indicator tracks events that have failed one of the systems providing communication, navigation, tracking and data processing. The indicator is physical and analyses the fault level of the ATM service provider.

The International Civil Aviation Organization (ICAO) defines unauthorized access to the runway as any occurrence at the aerodrome involving the unauthorized presence of an aircraft, vehicle or person in a protected area of a landing and take-off (runway) surface.

Unauthorized entries on the runway are classified by incident severity from A to E (Table 1). The most important classifications for runway incursion prevention and alerting systems (RIPAS) are Classifications A and B, where time is critical. Classifications C and D should be detected by RIPAS, but do not need immediate intervention.

Table 1

Classification of track entry^{8,9}

Classification of severity	Description
A	Serious incident to prevent collision.
B	An incident where there is a reduction in distance and there is much potential for collision, which can lead to a time-critical corrective/evasive response.
C	Incident characterized by sufficient time and/or distance to avoid collision.
D	Incident that meets the runway intrusion definition, such as the incorrect presence of a single vehicle, person or aircraft in a protected area on the landing and take-off surface, but without immediate safety implications.
E	Insufficient information or unconvincing or contradictory evidence hinders the severity assessment.

Air carriers and large airports are usually equipped with technology for prevention of intrusion onto the runway. The technical and financial constraints of smaller airports are limiting the use of technology to prevent unauthorized access to the runway.

Access to the runway occurs in so-called “hotspots”, i.e., sites that the ICAO defines as “areas to move to an airport with a history or potential risk of an entry (on an airfield where pilots/drivers need increased.” ICAO instructions for preventing runway collisions need to define the distance to the runway, with permission usually transmitted via RTF or others form of signals.

Detection systems for unauthorized entry on the runway need to detect situations within 2 to 6 s. Earlier detection would make it possible to alert a ground vehicle to a runway that has a lower speed and can better respond to the situation at an early stage of the incident

The European Organization for the Safety of Air Navigation (Eurocontrol) has stated that the safety culture of incident reporting is not sufficient. In 2005, the number of reported events amounted to 600 runway raids, with an upward trend of almost 1,000 in 2008^{10,11}. According to the US Federal Aviation Administration, the number of A and B disruptions since 2003 has been decreasing, along with mileage between 2009 and 2010, when a program was introduced to protect against unauthorized entry onto the runway.

The ICAO and Eurocontrol have found that OEs and PDs form the main part of unauthorized inputs on Type A and B runways. However, due to the high level of dangers resulting from a change in safety levels, the technology to prevent unauthorized inputs on the runway should preferably address VPDs and OEs and handling activities.

⁸ Available at: https://www.atmseminar.org/seminarContent/seminar11/papers/366_Stroeve_0121150328-Final-Paper-4-23-15.pdf.

⁹ Available at: https://www.icao.int/Meetings/GRSS-2/Documents/Panel%20P2.2_FAA.pdf.

¹⁰ Eurocontrol. 2010. *Annual Safety Report 2010*.

¹¹ Eurocontrol. 2009. *Annual Safety Report 2009*.

2.1. Issues of so-called “hotspots”

Unauthorized entry onto runways is mostly recorded at airport hotspots, which represent the crossing of airport traffic corridors. Hotspots, as defined by the ICAO, are “areas to move to an airport with a prediction or potential risk of unauthorized entry to the runway requires attention of pilots/drivers”. Ground collisions may occur during push-back and taxi interference or foreign object debris in the manoeuvring area and apron¹².

Many studies have shown that the frequency of unauthorized entry is related to the number of runway crossings and airport layout characteristics. The ICAO classifies unauthorized entries on the runway according to the following types of causes: pilot deviation (PD), operational error/deviation (OE) and vehicle/pedestrian deviation (VPD). Vehicle/pedestrian movement deviations include pedestrians, vehicles or other objects that interfere with operations and movements of aircraft, not approved by air traffic controllers. Under VPDs, unauthorized access to runway service and logistics technology or passengers may occur. Presence on the runway could be the cause of a collision between the entities described on the runway or traffic fluency.

2.2. Track entry statistics

The databases of the ICAO, the EASA and Eurocontrol have shown that the tendency of unauthorized entries onto runways has been increasing in EASA countries due to the increasing number of flight hours. According to annual reports, both the number of passengers and the tonnage of transported cargo has increased. The EASA is the EU agency responsible for the interpretation and enforcement of member states’ rules and is superior to the national aviation authorities.

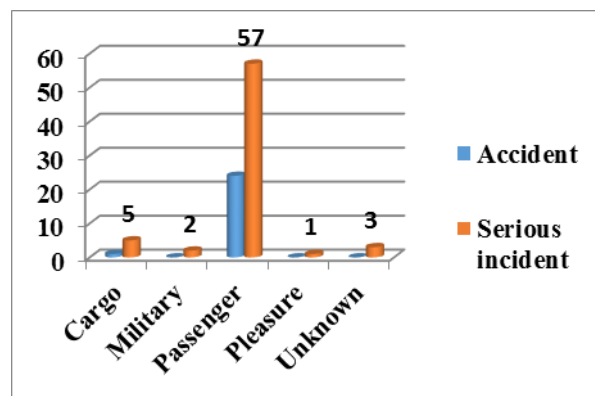


Fig. 1. Commercial air transport accidents and serious accidents in operation¹³

¹² ICAO. 2007. *Doc 9870 - AN/463, Manual on the Prevention of Runway Incursions*.

¹³ EASA Annual Safety Review 2016. Available at:

https://www.easa.europa.eu/sites/default/files/dfu/209735_EASA_ASR_MAIN_REPORT.pdf.

2.3. Commercial air transport aircraft

EASA AOC member states have a lower death rate per million flights than the rest of the world. In 2006, the death rate was much below 0.5. Most accidents and serious incidents still occur during the en route phase¹⁴, followed by take-off, approach and landing. Comparing the 10-year average of different flight phases with real figures for 2015 shows an overall reduction in accident rates for all phases of the flight. The same accident-specific comparison shows an increase in incidents in the en route and take-off phases. The types of accidents in these two phases are related to turbulence and technical problems during take-off¹⁵.

Key statistics of EASA AOC member countries include data on accidents and serious incidents. It could be said that the only fatal accident in the plane of a member state in 2015 was the Germanwings accident. In 2015, a total of 24 fatalities was recorded, exceeding the 10-year average, which accounted for 21.8 fatal accidents. At the same time, serious incidents dropped by 24%, with 58 serious incidents in 2015, while the 10-year average was 75.8. In 2015, there were 150 fatalities, meaning the 10-year average was exceeded. At the same time, in 2015, there was a slight increase in severe injuries, when there were 11 injuries, while the decade average was 9.2 injuries.

Vehicle/pedestrian deviations, which could be defined in terms of the cargo/passenger ratio, were the main cause of accidents or major accidents in 2015.

Table 2

Number of accidents and serious incidents
on average during the flight phase: 2005-2014 vs. 2015

Standing	Acc. avg. 2005-2014	4	Serious acc. avg. 2005-2014	3
	Acc. 2015	3	Serious acc. 2015	2
Taxi	Acc. avg. 2005-2014	4	Serious acc. avg. 2005-2014	3
	Acc. 2015	7	Serious acc. 2015	5
Take-off	Acc. avg. 2005-2014	2	Serious acc. avg. 2005 - 2014	6
	Acc. 2015	17	Serious acc. 2015	11
En route	Acc. avg. 2005-2014	3	Serious acc. avg. 2005 - 2014	7
	Acc. 2015	30	Serious acc. 2015	23
Approach	Acc. avg. 2005-2014	2	Serious acc. avg. 2005 - 2014	1
	Acc. 2015	15	Serious acc. 2015	11
Landing	Acc. avg. 2005-2014	7	Serious acc. avg. 2005 - 2014	5
	Acc. 2015	9	Serious acc. 2015	3

¹⁴ That part of the flight from the end of the take-off and initial climb phase to the commencement of the approach and landing phase (ICAO official definition: Annex 6/III Operation of Aircraft - International Operations - Helicopters 2010. Available at: https://ext.eurocontrol.int/lexicon/index.php/En-route_phase).

¹⁵ Available at: https://www.easa.europa.eu/sites/default/files/dfu/209735_EASA_ASR_MAIN_REPORT.pdf.

2.4. Ground collisions and ground handling

Hazardous areas concern plane collisions with other planes, obstacles or vehicles. It is necessary to take into account that a plane moves on the ground by its own propulsion or by being towed. The risk area also includes all activities related to ground handling (aircraft loading, refuelling etc.). It could be said that 27% of fatal accidents will be caused by land collisions and other related ground events in the decade to come. Given that this is a growing trend, it is important to take action after a thorough analysis to improve the current situation.

An analysis of vehicle/pedestrian deviations (on runways) shows that the causes of unauthorized entry onto the runway are roughly the same as if a ground vehicle driver entered the runway area without authorization from the ATL department (usually ground or tower) and in cases where the driver of the landing gear does not see a sufficient distance in the holding area of the relevant runway. An overview of the factors contributing to unauthorized access to the runway is given in Figure 2.

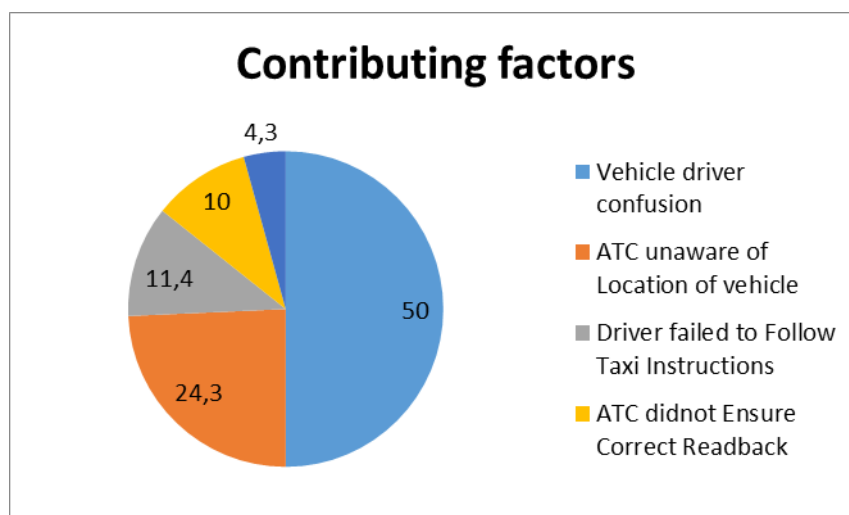


Fig. 2. Factors contributing to unauthorized access to the runway by land-based drivers or by persons moving over the airport's operating areas

Another area under consideration is the possibility to prevent or cut instances of unauthorized entry onto the runway area, as summarized in Figure 4 below.

The International Air Transport Association (IATA) has defined ground handling as follows: "It covers the complex series of processes required to separate the plane from its load (passengers, baggage, cargo and mail) on arrival and combine it with its load before departure."

Finding a solution to cut aircraft collisions on a track with land-based vehicles or persons could be based on the responsibility definition for finding measures. Responsibility for the safety of ground operations lies with the member state.

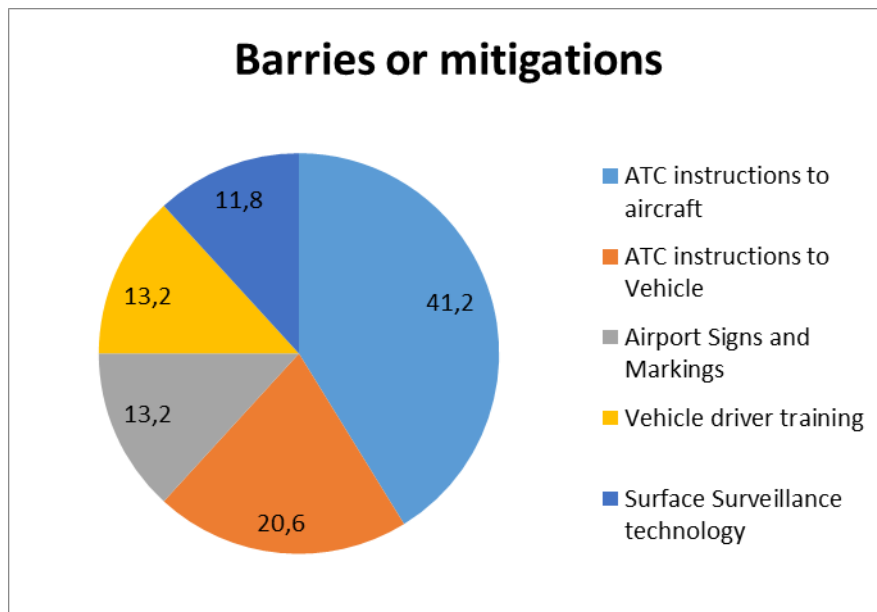


Fig. 3. Possibilities to prevent or cut instances of unauthorized entry onto the runway

3. THEORY OF INTRUSION PREVENTION SYSTEMS

Existing risk identification in ground handling operations is based on detailed mapping of subjects, the action interface and the daily routine of activities, including a time map. The data obtained could be further used for later analysis.

An analysis of available literature is the result of Table 3, which provides a comprehensive overview of the subjects involved in the ground clearance process.

Table 3

Phase and ground movement activity

Phase	Define activity content
Taxiing after landing	The phase starts when you leave the runway after the landing and ends when you arrive at the check-in area. The plane is powered by its own drive.
Standing on apron	The phase begins when the plane arrives at the ramp and stops at the assigned stand. The plane is in motion at this stage.
Exploding the plane from the stand	The airplane is pushed from the stall to a defined area (and direction) by a tractor to the ramp, from where it moves on its own.
Taxiing to start	The phase begins when the plane begins to move by its own drive from the ground and ends at the arrival point of the runway.

The total number of ground handling incidents in the analysed period reached 2,841 for 14 million flights. It could be said that this equates to one incident per 5,000 flights.

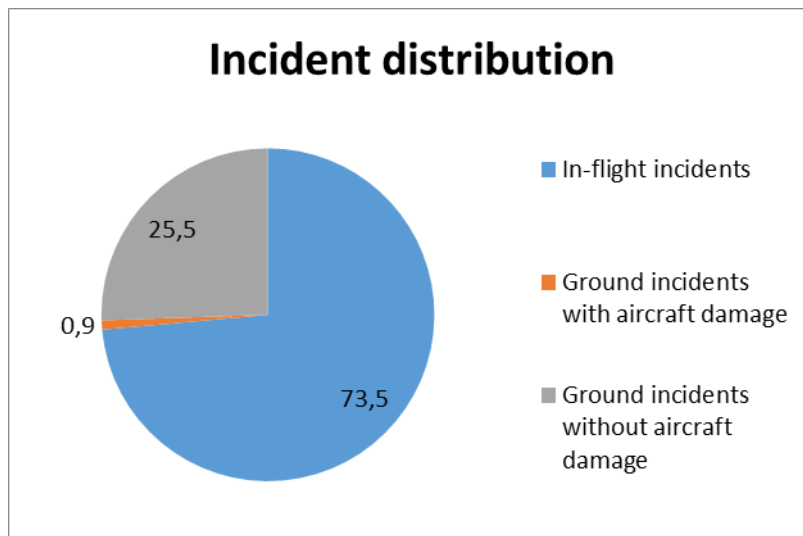


Fig. 4. Breakdown of incidents

26.4% of incidents are associated with ground events, with 0.9% resulting in damage to the plane. Figure 5 shows that most (84%) ground accidents occur when the plane is in motion.

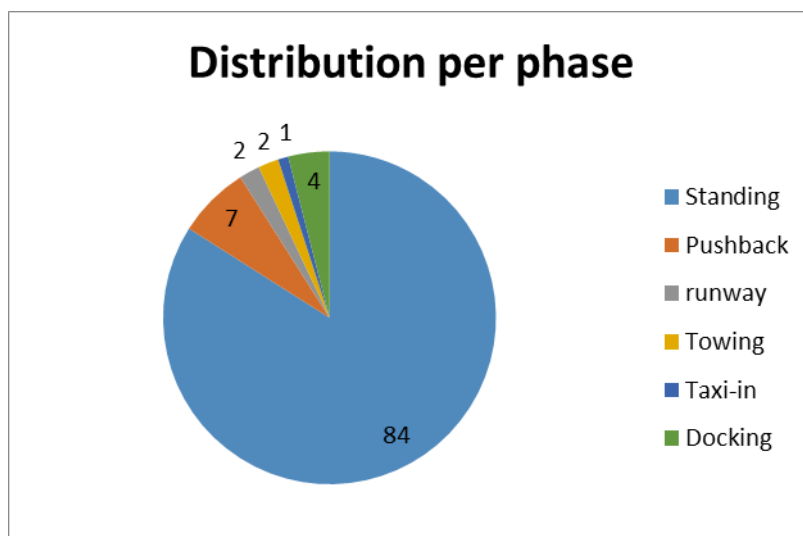


Fig. 5. Incident breakdown by phases

Most incidents occur at the standing stage; the authors only analysed those who enter this phase. The bodies that cause ground incidents are described in Figure 6, which also expresses the number of incidents caused by ground entities.

Figure 6 provides information on which entities are most involved in ground incidents. The most significant actors involved in ground incidents in relation to the total number of incidents are listed in Table 4.

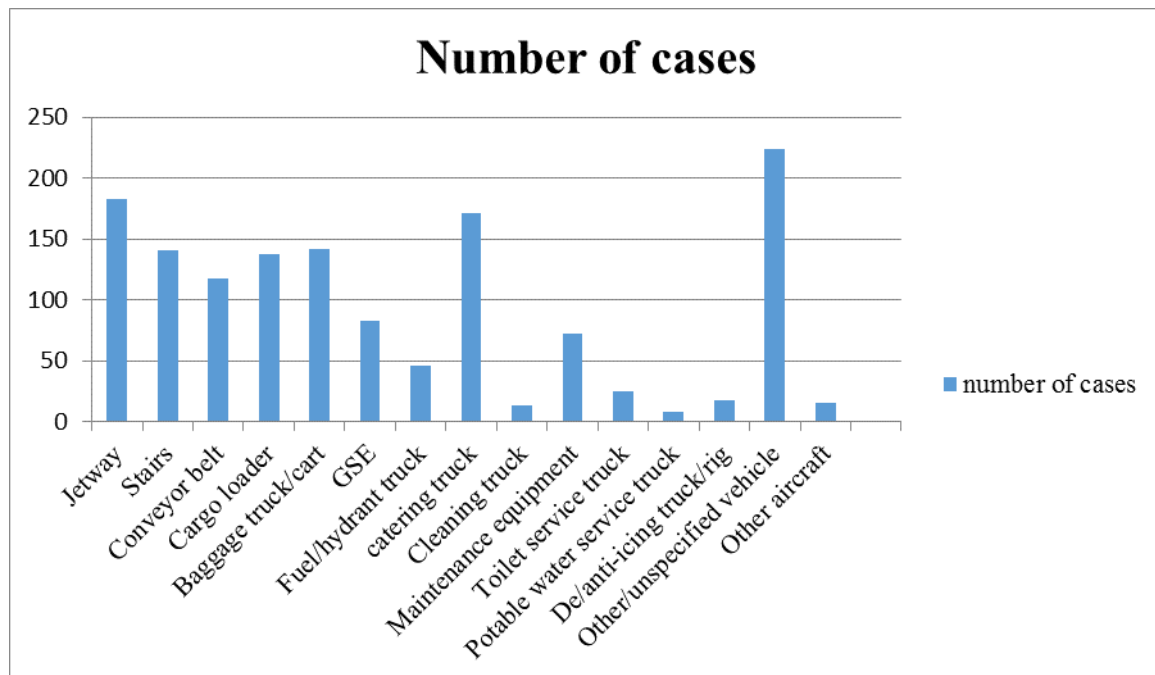


Fig. 6. Breakdown of incidents by subjects

Table 4

The ranking of subjects by land-based incidence

Subject	Incidence rate (%)
Other/unspecified vehicle	16.3
Jetway	13.1
Catering truck	11.8
Ground service equipment	10.1
Stairs	8.9

4. SENSORY SYSTEMS

Sensor systems allow for capturing phenomena in many ways and the identification processes based at the airport for ground operations. Modern technology allows us to track multiple identified phenomena at the same time. The system suitability for the selected airport is determined by the security need. At present, SMR and ASDE surveillance radars are used at the airport, but they could be exchanged with a camera system.

The aerodrome subjects' connectivity could be achieved through technological means by the implementation of digitizing systems. Key elements include a tele-information network, a sensor network, a satellite telecommunication network, digital communication systems and radio frequencies, unmanned vehicles and nanotechnology¹⁶.

¹⁶ T. Dukiewicz. 2016. "Systém ISTAR jako determinanta vojenského informačního prostředí". In *International Military Technical Conference Tactics 2016*. Brno. [From Czech: "ISTAR as a Determinant of the Military Information environment".] ISBN 978-80-7231-398-3.

Combining different types of video capture with a camera system, which has enough motion detection accuracy, could be an alternative to radar.

Combining cameras (classic security and infrared) will increase the accuracy of motion detection with the place of determination for the object in the order of metres, especially for larger objects. The surveillance camera system at small airports could be used primarily to check traffic in operating areas.

4.1. MicroTrack - detection of perimeter disruption

A system of ground coaxial cables allows for the detection of perimeter disruption through an electromagnetic field. Deviation in electromagnetic field values prompts the launch of airport security activities.

The system creates fields with specified characteristics, and the change in characteristics gives information about a non-standard object in the electromagnetic field. Diverse levels of electromagnetic field disturbance make it possible to find the size of the object and the resulting potential hazard. The system uses two basic configurations:

1. Measurement of electromagnetic field distribution change
2. Amplitude and frequency change

The perimeter secured by the pairs of cable systems has a 150-200-m zone dimension and generates a magnetic field that is about 3 m wide and 1 m high over its entire length.

The size of the magnetic field depends on the factors as follows:

1. Measurement of electromagnetic field distribution change
2. Subsoil
3. Material
4. Other surrounding lines
5. Spacing from surrounding objects and metallic structures

Measurement deviation is several metres long and the security system could be complemented by closed-circuit television (CCTV). Each scanned zone could be set separately, due to different environments.

4.2. Analysis of crowd movement in real time

The system is the superstructure of motion video abnormal motion detection. Rather than an individual object, the movement of a whole group of people is analysed using motion vectors in the “mask of space”. The mask of space is defined by the characteristic features of the environment, which may be typical directions of movement in the given areas of the mask.

Identifying environmental characters will allow us to define so-called hot and cold places, characterized by different levels of occupancy of group movements. Defining the mask will allow the analysis of group movement. The system based on the normal direction of movement and behaviour in the crowd is a common phenomenon of much concern. The algorithm of normal motion and behaviour can later find an abnormal phenomenon, which is a basic condition for further activities¹⁷.

¹⁷ Real-time crowd motion analysis.

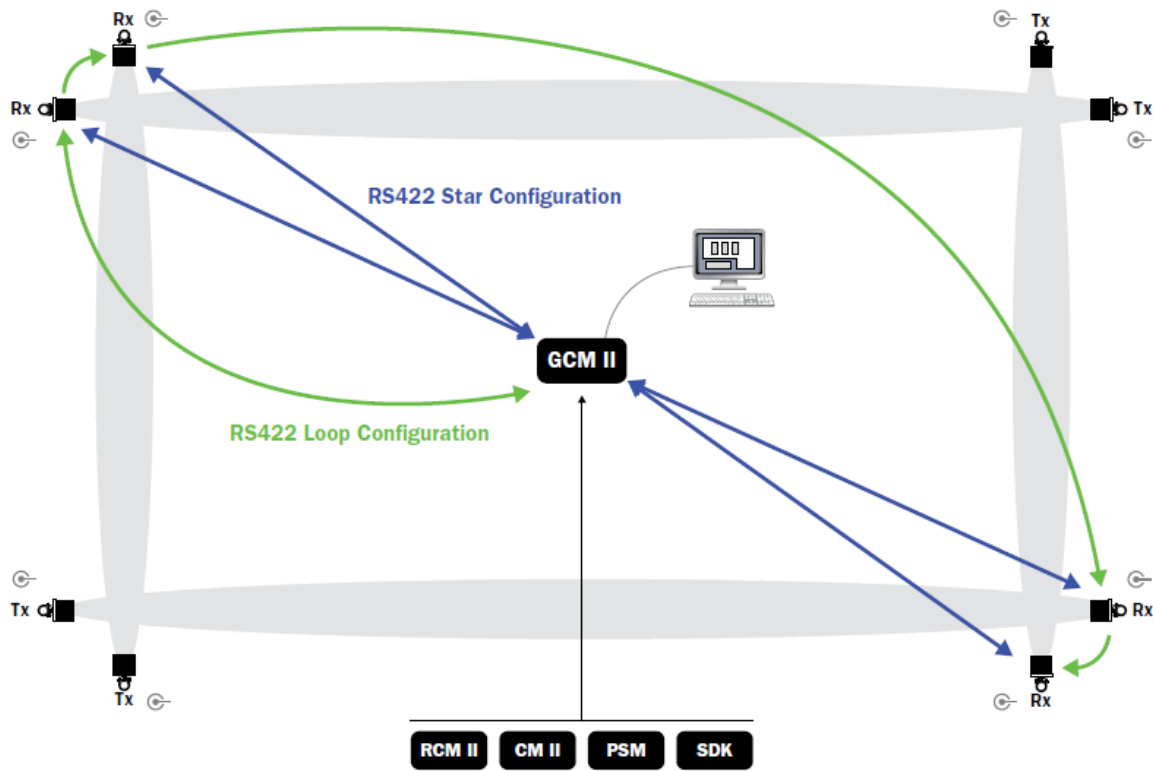


Fig. 7. MicroTrack detection¹⁸

Passenger movement in airport areas is a complex architecture, which is based on a specific national behavioural culture, the architecture of the inner and outer infrastructure of the terminal and the airport, and the conditions for the visual supervision realization. The main processes are:

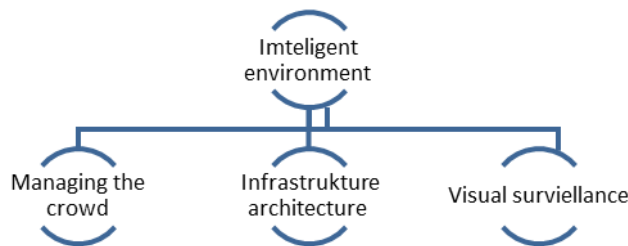


Fig. 8. Management of crowd movement control in the terminal

An analysis of crowd movement at the time windows will serve to propose a change in the environment with respect to the disconnection point's elimination of and the narrow throat to increase the flow of passengers' continuity.

¹⁸ Available at: <http://www.southwestmicrowave.com/pdfs/MicroWave-330-Data-Sheet-EN.pdf>.

4.3. Tracking crowd movement in crowded space

Finding connections to passengers' movement in the terminal's internal spaces is an important factor enabling the same person identified in a time sequence within defined spaces. The architecture of the airport clearly determines the trajectory of people's movement, and identifies the main flows of the crowd and the deviations in personal behaviour. This process serves to find abnormal behaviour. It is clear that theories of chaos can apply here, where the diverging crowd could be deviated from the supposed movement of the crowd. The task of airport security structures is to find serious violations of motion algorithms, and to find risk behaviour based on general knowledge of the interior. Complications with risk identification increase with traffic density.

A proper behaviour algorithm set-up also requires an appropriate taxonomy of approaches. Identifying suspicious behaviour in the crowd requires analysing the number of people, while monitoring individual people or groups. The goal of the activities is to find participants in the crowd, regardless of their place and timing.

Track-to-person activities require the exact location of each person in the internal or external areas of the airport while identifying the time sequences of movement and the static positions of persons or groups. It is possible to accept the idea that some approaches, which are used to count people in objects, could be applied to define people-tracking algorithms. Appropriate motion algorithm settings could be used to count people in the crowd as well as track them.

Processes associated with counting people in the crowd also allow for tracking of traces of movement in the target mask. A person's movement in a "bottleneck" is likely to reflect the patterns of behaviour of people in the crowd. Empirical experience shows that people group themselves into "group songs", which move to each track at constant speeds. By analysing group tracks, the inclusive behaviour of people or groups could therefore be identified more quickly if crowd density is at an acceptable level^{19,20}.

Structured scenarios for a person's movement in a conceived crowd structure require video sequences divided into cells, which move in a defined space with different architectural solutions that must move everyone in a crowd continuously while completely avoiding obstacles and barriers²¹. The automatic movement of people in a crowd later allows us to find different behaviours of persons or groups.

Group behaviour research, which has been carried out for many years, has simulated the behaviour of the crowd in different modelled situations. The aim here has been to check the general view of group behaviour, with the results used to improve the level of crowd analysis.

Created algorithms for computer vision, which are used to analyse the crowd, could be applied to improve the use of life information and to aid in the realistic display of crowd synthesis algorithms^{22,23}. The spatial distribution of the crowd in real space could be used to

¹⁹ J. Rittsche, P.H. Tu, N. Krahnstoeve. 2005. "Simultaneous Estimation of Segmentation and Shape". In *Proceedings of Computer Vision and Pattern Recognition* Vol. 2: 486-493. Washington, DC.

²⁰ F. Solera, S. Calderara, R. Cucchiara. 2016. "Socially Constrained Structural Learning for Groups Detection in Crowd". *IEEE Transactions on Pattern Analysis and Machine Intelligence* Vol. 38(5): 995-1008.

²¹ J. Rittsche, P.H. Tu, N. Krahnstoeve. 2005. "Simultaneous Estimation of Segmentation and Shape". In *Proceedings of Computer Vision and Pattern Recognition* Vol. 2: 486-493. Washington, DC.

²² S.R. Musse, M. Paravisi, R. Rodrigues, J.C.S. Jacques, Jr., C.R. Jung. 2007. "Using Synthetic Ground Truth Data to Evaluate Computer Vision Techniques". In *Proceeding of the IEEE International Workshop on Performance Evaluation of Tracking and Surveillance*: 25-32.

²³ G. Taylor, A. Chosak, P. Brewer. 2007. "OVVV: Using Virtual Worlds to Design and Evaluate Surveillance Systems". In *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*: 1-8.

create a crowd behaviour simulator^{24,25,26}, while the observed main directions of crowd movement could be used for simulation^{27,28,29}.

5. SURVEILLANCE BASED ON MULTI-PICTURE CAPTURING

The airport security overview uses surveillance radars known as surface movement radar and aerodrome surface detection equipment.

5.1. Ground surveillance radar

Primary surveillance radars are the most widely used means of detecting motion at large airports. They allow air traffic control and airport traffic to cut collisions and trajectory disturbances. Survey radars also cover areas between traffic areas to give a complete overview of the airport's perimeter situation.

The sensitivity requirement could be interpreted as follows:

1. Detection of all objects in the aerodrome, where the least reflective area of the target is 1-3 m².
2. Scanning space within the range of 0-100 m.
3. The refresh rate is at least 60 frames/min.
4. Radar ability to detect all targets with a speed of 0-450 km/h.
5. Reliable detection in all-weather conditions up to 100 mm/h.
6. Differentiating two nearby objects.
7. Deviation of target location detection in metres.
8. Responding to false reflections on large reflective surfaces.

5.2. Multimedial sensor system in foreign object damage on runway detection

In the current state, the occurrence of foreign object damage (FOD) on the runway is continually controlled by ground handling at the airport, with deteriorating weather or night-time conditions significantly reducing control efficiency. New technologies make use of the ability to automatically detect FOD on the desktop and invoke subsequent activities to ensure security.

System sensors positioned along the track can continuously capture the track surface and detect objects under all climatic conditions. The sensors are equipped with an infrared camera, as well as an optical two- and three-dimensional camera, and connected to the radar sensors.

²⁴ E.L. Andrade, R.B. Fisher, "Simulation of Crowd Problems for Computer Vision". In *Proceedings of the First International Workshop on Crowd Simulation*: 71-80.

²⁵ E.L. Andrade, S. Blunsden, R.B. Fisher. 2006. "Modelling Crowd Scenes for Event Detection". In *Proceedings on the International Conference on Pattern Recognition*: 175-178. Washington, DC.

²⁶ J.C.S. Jacques, Jr., A. Braun, J. Soldera, S.R. Musse, C.R. Jung. 2007. "Understanding People Motion in Video Sequences Using Voronoi Diagrams". *Pattern Analysis and Applications* Vol. 10, No. 4: 321-332.

²⁷ N. Courty, T. Corpetti. 2007. "Crowd Motion Capture". *Computer Animation and Virtual Worlds* Vol. 18, No. 4-5: 361-370.

²⁸ S.R. Musse, C.R. Jung, J.C.S. Jacques, Jr., A. Braun. 2007. "Using Computer Vision to Simulate the Motion of Virtual Agents". *Computer Animation and Virtual Worlds* Vol. 18, No. 2: 83-93.

²⁹ M. Paravisi, A. Werhli, J.C.S. Jacques, Jr., R. Rodrigues, A. Bicho, C. Jung, S.R. Musse. 2008. "Continuum Crowds with Local Control". In *Proceedings of Computer Graphics International (CGI'08)*: 108-115. Istanbul, Turkey.

Linking with the optical system allows us to find the object on the desktop. Sharing information will allow the transfer of the operator who performs the removal of the object from the track. The person sensor has a 700-m radius. False signals caused by animals, birds or small objects moved by wind are eliminated by the need for an object to stay static for a defined minimum duration³⁰.

5.3. Detection of FOD and PID³¹ microwave radar

Tarsier systems and SMART have been developed to detect FOD based on microwave radar³². In order to cover an adequate part of the perimeter, the radar placed at a minimum height of 10 m above ground level, with a specific placement, also needs to allow FOD, PID and tracking movements at the airport.

Microwave radars run on wavelength ranges between 94.5 and 95 GHz and a beam width between 0.28 and 0.3° allow for the detection of small objects according to their type, up to a distance of 1-2 km with an accuracy of about 2.5 m³³.

The systems are supplemented with optical sensors for precise focus and object evaluation. The disadvantage is that they only detect only small metal and dielectric objects. Technological development is still beyond the limits of use of these systems. Technological advances in systems are increasing accuracy in terms of focus and resilience, which contributes to improved security.

6. RECOMMENDATION

The authors recommend the use of the texture analysis method, which represents complex visual patterns of subjects or masks of spaces with characteristic brightness, colour and size. An important fact is that local spaces involve different uniformities of space, densities of the crowd, regularities of movement, linearities of behaviour and frequencies of movement³⁴. Four basic problems of texture analysis were defined³⁵.

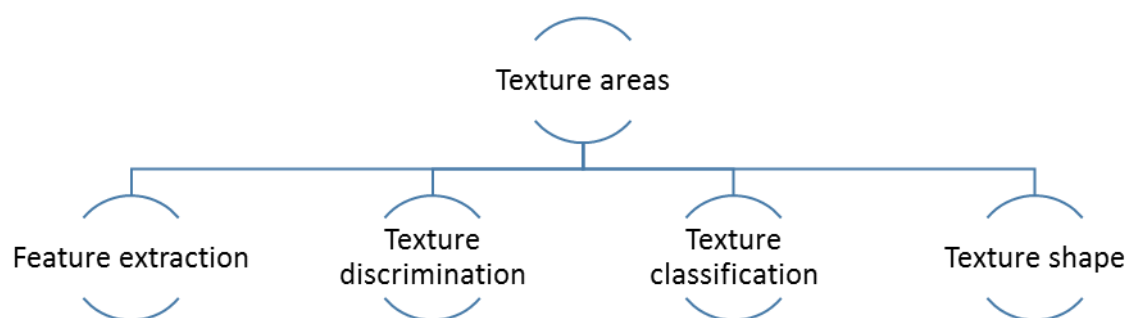


Fig. 9. Texture problematic areas

³⁰ Photo/radar sensors detect debris on airport runways.

³¹ Perimeter intruder detection.

³² Tarsier/spl R/is a millimetre wave radar for airport runway debris detection.

³³ Millimetre wave radar applications for airport surface movement control and foreign object detection.

³⁴ M. Levine. 1985. *Vision in Man and Machine*. New York, NY: McGraw-Hill.

³⁵ P. Brodatz. 1966. *Textures - A Photographic Album for Artists and Designers*. Mineola, NY: Dover.

Feature extraction is the first stage where the security manager will use structural, statistical, modelling and transformation methods.

Structural approaches for resolving the texture represent a suitably defined microtexture with a clearly formed macrotexture spatial arrangement hierarchy^{36,37,38}.

To describe the texture, it is necessary to define the basic rules of the warp movement of the crowd and the rules of placement in the space. The choice of base fibres is based on the characteristics of the set and the crowd moving opportunity along the selected base fibres. The approach assumes that the occupants will occupy certain places or the surrounding area, allowing for a sufficient description of reality used for synthesis and analysis.

Abstraction of the texture description could be affected by the insufficient definition of texture threads due to the variability of microprocesses and macrostructures. The problem may also be concerned with the lack of clarity between microtextures and macrotextures. The use of mathematical morphology is a proper tool for structural analysis^{39,40}.

We can use the autoregressive model expressed by the formula:

$$f_s = \sum_{r \in N_s} Q_r f_r + e_s$$

where f_s is the in situ image intensity, which indicates an independent variable and the equally distributed noise, N_s is the adjacent element s , and θ is the model parameter vector.

Another useful model is Markov's random field, which represents the chance of the process of interacting with all local elements. The model is based on the assumption that cell similarity is quite likely in a given state among adjacent cells^{41,42}. As a result, direct interaction occurs only between the immediate neighbours. However, Markov's random field may change as a result of promotion within a globalized world⁴³.

$$p \propto \exp\left(-\frac{E}{T}\right)$$

Another useful model for crowd movement is the fractal model, which represents fractal observations and shows a strong correlation with human judgement, based on crowd movement intensity, and predictable narrowing. The correct distribution of the crowd movement fibres, including the linear motion logarithm spectrum, is suitable for texture creation and thus suitable for modelling⁴⁴.

³⁶ R. Haralick R. 1979. "Statistical and Structural Approaches to Texture". *Proceedings of the IEEE*, 67, 5: 786-804.

³⁷ M. Levine. 1985. *Vision in Man and Machine*. New York, NY: McGraw-Hill.

³⁸ T.A. Pham. 2010. *Optimization of Texture Feature Extraction Algorithm*. Available at: <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.827.8904&rep=rep1&type=pdf>.

³⁹ J. Serra. 1982. *Image Analysis and Mathematical Morphology*. Cambridge, MA: Academic Press.

⁴⁰ Y. Chen, E. Dougherty. 1994. "Grey-scale Morphological Granulometric Texture Classification". *Optical Engineering*, 33, 8: 2713-2722.

⁴¹ A. Blake, A. Zisserman. 1987. *Visual Reconstruction*. Cambridge, MA: The MIT Press.

⁴² K.P. Murphy. N.d. "Undirected Graphical Models (Markov Random Fields)". Available at: <https://www.cs.ubc.ca/~murphyk/MLbook/pml-print3-ch19.pdf>.

⁴³ N.D.F. Campbell, K. Subr, J. Kautz. N.d. "Fully-connected CRFs with Non-parametric Pairwise Potentials". Available at: <http://homepages.inf.ed.ac.uk/ksubr/Files/Papers/PrwPotPaper.pdf>.

⁴⁴ Fraktál lze nejjednodušeji definovat jako *nekonečně členitý útvar*. Available at: <http://www.ksr.tul.cz/fraktaly/definice.html>.

7. CONCLUSION

The use of sensor networks is based on the correct identification of ground handling and movement processes for persons, wild animals and logistics vehicles in the internal and external aerodrome areas. By using sensor systems combined with CCTV, the level of safety and incident reductions in unauthorized entrances on the runway will increase, as well as reducing the number of airport staff needed. Based on the assumption that the human factor is the greatest risk to security controls, it could be assumed that the massive use of technology will cut error rates while allowing staff to prepare themselves to cut incidents through direct intervention.

Ground-based air traffic safety services are activities associated with runways, handling ground operations and the maintenance of working areas. A solution to increasing safety is the use of sensor network capabilities and optical camera systems to analyse abnormalities. It is necessary for future surveillance systems to allow the airport's security components to determine the movement-related abnormality with the security vehicles' movement and the person's movement in defined masks, and enable the readiness of these components to limit the abnormal effects.

The combination of modern surveillance technology for crowd and service vehicles and MicroTrack, in order to guard the perimeter, will allow us to control defined zones and track people in all areas of the airport. The use of sensors in camera systems will enable a high level of air traffic safety. Different airport characteristics will need different approaches to the sensor network's configuration. The determinants of networking are influenced by the level of the building infrastructure, the transport network, people movement prediction and the crowd in the defined motion masks.

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