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The emergence of every new technology raises the question of changes in the field of work – from the character of work patterns, changing work relations, employment and unemployment forms to the broader consequences at contemporary societal level. Therefore it is not surprising that social scientists are attracted by work-technology relationship, particularly regarding previous scientific experiences which established possibilities to comprehend that relationship in terms of complex interactional patterns. Moreover, necessity to approach work-technology issues through the interdisciplinary collaborations now seems to be self-evident.

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RADIOFREQUENCY IDENTIFICATION BY USING DRONES IN RAILWAY ACCIDENTS AND DISASTER SITUATIONS

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ABSTRACT

Today, railway operation procedures include the transportation of large amount of hazardous substances. Our research has been motivated by the desire to find concrete and urgent solutions to the safety issues of handling waste generated manly in case of accidents and disaster situations during the transportation of hazardous substances In order to ensure safety in the transportation of dangerous goods, and to facilitate the fast and efficient waste handling of hazardous substances released into the environment during unexpected events, we have elaborated a new method, in which we suggest the radiofrequency identification of dangerous consignments in case of disaster situations by the use of drones.

KEY WORDS

railway accidents, transportation of dangerous goods, waste management, radiofrequency identification, drone

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INTRODUCTION

DEFINING THE SCIENTIFIC PROBLEM

Disasters have always been the part of human life. Their severity, frequency, dimensions and global effects have increased to such extent that protection against them has become a task of highest priority and utmost importance today. The enormous damage caused by such disasters, which have serious economic and social effects, calls for the research into prevention possibilities, the issues and necessity of safe waste treatment [1].

Our research looks into the possibilities to ensure an easier identification of dangerous materials released into the environment during railway-related accidents or disasters, to minimise any consequent damage, and to enable the prompt responding to the effects of the generated hazardous waste. By approaching to waste treatment from the aspect of safety sciences, we focus on the environmental hazards caused by the inappropriate or delayed treatment of the generated waste.

The aim of the present article is to show the possibility of using the method of radiofrequency identification for the treatment of hazardous wastes, in the combined way as suggested by us. By using a drone equipped with an RFID reader, hazardous substances may be identified in a faster way, preventing the serious damage that may be caused by the release of hazardous wastes in the event of a disaster.

The present study consists of the following sections: following the introduction, Section 2 discusses the technical safety technology factors related to the transportation of hazardous substances. Section 3 presents the possible solutions of radiofrequency identification used in the transportation of hazardous substances. In Section 4 we make a suggestion to the specific use of drones in case of accidents and disasters to allow faster response and the prompt treatment of hazardous wastes. Finally, we present the results that have been achieved so far, formulate our statements for debate and our conclusions as well as our objectives of further research.

OBJECTIVES, STATING THE RESEARCH HYPOTHESIS

The European Union has specified the technical requirements of waste management in its policy and directives mutually agreed by its member states. Considering the results formerly achieved in this field, it can be stated that the fundamental technical-safety requirements must be ensured by a legislation which is in harmony with these directives and in accordance with the latest research results. It is very important that the members of the EU must cooperate in sharing information about the safe railway transportation of hazardous and other wastes. The purpose of this endeavour is to develop a safe method of waste identification and treatment in the situation of accidents or disasters by successfully using, as we proposed, the RFID-DRONE combination. Therefore, our objective is to examine the possible introduction of RFID identification in the railway transportation of hazardous substances. In the present article we wish to prove the hypothesis that the combined RFID-DRONE system can help to facilitate the recovery process and the mitigation of the harmful effects of the wastes of hazardous substances in case of a disaster situation.

REVIEW OF REFERENCES – WITH REGARD TO THE IMPROTANCE AND RELEVANCE OF THE TOPIC

Safety technology includes all technical and technological methods and procedures which aim to protect the life of a person/persons or the normal operation of an object/objects [2].

In case of waste management, this can be achieved by applying the results of technical sciences. During application, all elements which hinder the development, maintenance or introduction of technical safety technologies, or the possibilities to create its conditions, can be considered as influencing factors. The most significant element is the human factor, as it can cause serious damage in case of accidents or disasters which occur as a result of negligence [1].

All personnel having duties and responsibilities in the transportation of dangerous goods must receive appropriate training about the requirements on the transport of dangerous goods to the extent required by their duties and responsibilities, also considering the training requirements on public safety standards. Although the provisions of the relevant sections of the RID prescribe basic and special training, the safety issues of hazardous wastes generated in accidents are not covered even by such special training [3].

In our research, we consider it important that any unburned hydrocarbon or other special operational or transported liquid which can cause soil or water pollution in case of a disaster must be adequately treated in the course of the recovery process. The polluted area must be cleaned of all liquids and other substances which, by this time, will have become hazardous waste [4].

PRESENTING AND DEFINING THE TERMS USED IN THE RESEARCH

The knowledge of the following terms is essential for the understanding of the topic discussed in the present article:

Waste is any substance or object which the holder discards or intends to or is required to discard [5]. In other words, waste is any substance, solution, mixture or object which is generally not suitable for direct use, but which is removed for disposal through recycling procedures, storage in deposits, incineration or in any other ways [6].

According to our own definition, from the point of waste management, the substances declared by their holders as waste are those which:

- are returned to the spheres of production and consumption by various physical, chemical or biological procedures,
- are temporarily stored in comforted and safe deposits until the development of adequate recycle technologies, or degraded to their basic elements through physical, chemical or biological procedures.

Hazardous waste is the waste which has at least one of the hazardous properties defined in Appendix 1 of the Act on Waste [5].

ADR the European Agreement concerning the International Carriage of Dangerous Goods by Road.

RID the European Agreements Concerning the International Carriage of Dangerous Goods by Rail, its valid version coordinated with the ADR was released in Act LXXX of 2011.

UN number (UN ID): a four-digit identification number of substances and objects specified by the “UN Model Regulations” [6].

Dangerous goods: substances and materials the transport of which is prohibited by the RID or only allowed with certain restrictions [7].

UIC: Union Internationale des Chemins de Fer, (UIC, 16 rue Jean Rey, F-75015 Paris, France) [8].

Radio Frequency Identification (RFID): the reading of chip information carriers used in railway wagons with the help of radio frequencies from a safe distance, in an extremely high speed range or in the situation of an accident or disaster (author's definition).

Drone: UAV Unmanned Aerial Vehicle.

Mini drone: remotely controlled, small, unmanned, propelled robot plane with features that allow for a very versatile use (author's definition). For example an autonomous (3D movements ability) quad-rotor microcopter [9].

SAFETY-TECHNOLOGY ASPECTS OF THE TRANSPORTATION OF DANGEROURS SUBSTANCES

An increasing global crisis affecting every people in the world, with unstable social and political systems and modern migration processes resulted by the uncertain living circumstances and the effects of globalisation, as well as the various environmental disasters must also be considered at the transportation of hazardous substances. For the above-mentioned reasons, the system of railway infrastructure is exposed to increased risk, while its protection is difficult to ensure because of its geographical extension. Thus, if this critical infrastructure is used for the transportation of such materials which are dangerous in themselves even when they are stored, the transportation of these hazardous substances must be done with extreme care and expertise.

Experts of safety-technology research reveal an increasing number of uncertainties in connection with the storage and transportation of hazardous substances and their release into the environment. At the present time it can be observed that the factors influencing safety have taken different forms. There has been a shift of emphasis in the concept of safety, bringing into the foreground such aspects which used to be of secondary importance, but which are now freely generated creating a series of new problems.

Our age is dominated by the trends of globalisation, where divergences in the prospects of development, territorial integrity, moral libertinage, separatism, nationalism, chauvinism, and many other phenomena can deter or even prevent the continuous development of human societies in the long term, where the requirements of environmental safety should also be considered. Negative entities with decreasing moral inhibitions make certain members of the societies sink to formerly unseen depths causing irreversible damage to the environment. Based on the information that is freely accessible on the internet, now any person can be able to make a bomb or a weapon and order the necessary materials, which means that the security aspects of the transportation of hazardous substances must also be reconsidered [1].

RADIO FREQUENCY IDENTIFICATION USED IN THE TRANSPORTATION OF HAZARDOUS SUBSTANCES

THE RANGE OF GOODS THAT CAN BE IDENTIFIED BY THE SYSTEM USED IN RAILWAY OPERATION

The analysis of the past five years shows that the following types of substances have been involved in railway incidents in Hungary: 27 types of flammable liquid substances, primarily gasoil, petrol, hydrocarbon fuels, 11 types of gas, primarily refrigerated-liquefied carbon-dioxide, gas mixtures, and 15 types of acid, mostly sulphuric acid, hydrochloric acid, caustic soda and nitric acid.

Types of common hazardous substances which are transferred or temporarily stored for marshalling:

- Acids and bases: acryl-nitrile, sodium hydroxide (caustic soda), sulphuric acid, hydrochloric acid, nitric acid, ammonium hydroxide (ammonia)
- Hydrocarbons: petrol, gasoil, diesel, iso-butane
- Refrigerated gas mixtures: propane, butane, carbon dioxide
- Based on the European Agreements Concerning the International Carriage of Dangerous Goods by Rail (RID), Table 1 shows the proportion of hazardous substances in relation to the total transported volume.

Table 1. The distribution of RID classified hazardous substances in railway transport.

Explosive substances or objects	0,15 %
Compressed or liquefied gases, or gases dissolved under pressure or refrigerated gases	30,34 %
Flammable liquids	42,52 %
Flammable solids	0,08 %
Substances liable to spontaneous combustion	0,33 %
Substances which, in contact with water, emit flammable gases	0,00 %
Oxidising substances	1,29 %
Organic peroxides	0,00 %
Toxic substances	3,23 %
Infectious substances	0,00 %
Radioactive substances	2,83 %
Corrosive substances	16,05 %
Other hazardous substances and objects	5,95 %
Total	**100,00 %**

Experience has shown that instead of the examination of hazardous substances occurring in large quantities, it is better to examine the most dangerous and most traded substances, as from the point of safety-technology, they can well demonstrate the main features of the system.

In Hungary, for example, among the most dangerous types of substances, the following data shows the volume of radioactive hazardous goods in the first 10 months of 2014, from the point of wagon flow (SZIR R 629 – report queried from the internet):

- Number of wagons: 4,
- Total wagon mass: 300 ton,
- Total mass of goods: 188 ton.

This is a significant amount of radioactive waste which requires special transporting conditions in order to ensure safe trafficking.

Besides, in the past 20 years there have been numerous cases of hazardous substances being released into the environment, for example:

- a tank wagon filled with vinyl chloride derailed and overturned,
- a large quantity from two wagons of acryl nitrite ran off,
- the safety valves of 6 tank wagons transporting ammonia were damaged,
- a barrel filled with etil-iso-thiocyanate was damaged,
- 30 tons of residual fuel oil ran off,
- 1 ton of gas oil ran off from the locomotive with serial number M 61,
- the valve stub of a wagon filled with etil-amino under pressure cracked,

- 20 tons of nitric acid ran off,
- 30 tons of hydrochloric acid ran off,
- 30 tons of kerosene ran off,
- 150 tons of petroleum ran off,
- an unknown quantity of styrene ran off [10].

According to investigation reports, the main reasons for railway incidents include the following cases:

- Technical reasons: central valve leakage, failure of the unloading switch, dome cover gasket or lock cap gasket, safety valve failure/blowing.
- Goods handling problems: central valve/dome cover is open/loose, lock cap missing/loose, improper loading, overloading, improper cargo securing.
- Other reasons: freight-service problems, loading or theft damage, damage from acts of nature.

Considering the above reasons, the RFID-DRONE identification system surveying and monitoring the transportation of hazardous substances can help in the early detection of the major problems, and facilitate the recovery process after the incident by providing real-time information.

THE USE OF THE AUTOMATIC IDENTIFICATION SYSTEM IN CASE OF AN INCIDENT

Experience shows that unexpected situations are mainly caused by the technical failure of a tank wagon or tank container, therefore it is very important to identify the exact location of the means of transport and the type, the parameters and the condition of the substances transported in them.

For the above reason, in the railway environment the identification of the contents of vehicles transporting hazardous substances should not be based on the UN number and the hazard label alone, but it should also be made possible by using radio frequency identification from a safe reading distance. This way the transported substances could be identified in hardly accessible sites or in high speed ranges even when the hazard label is damaged or lost.

Wagons and tank wagons, which are not always in perfect technical condition, can be easily damaged during excessive use in railway operations, especially when shunting, or due to improper loading and unloading, and handling and closing of wagon lids or doors. Therefore, railway operation regulations must be extended, with regards to waste management, to cover the prevention of emergency situations, the instant remediation of the release of hazardous substances in case of a disaster, and the measures to be taken immediately to reduce the effects of pollution.

One of the methods also followed in Hungary is the use of special Vetter-cushions as rescue devices to prevent the release of large quantities of hazardous substances into the environment. This solution is also practical for the reason that it could be instantly used by the railway personnel on site to prevent the possibility of more serious damage before the arrival of special rescue units [11].

Our suggested solutions in such situations:

- It is important to ensure the safe identification possibilities and appropriate handling of dangerous wastes generated when dangerous goods contact with their environment during normal operations or accidents and disasters, as well as the initial forms of remediation,

neutralisation and disposal on site before the arrival of the special personnel and infrastructure.

- The on-site identification of wagons transporting hazardous substances should not be based on the UN number, the hazard label or the internet query of the SZIR R 629 report only, but also on the method of Radio Frequency Identification (RFID). For example, in the incident shown in figure 1, RFID identification could have provided immediate information about the properties of the transported goods.

Figure 1. In this situation only the RFID technology could provide immediate information about the transported goods [12].

It is common in case of an accident or disaster that the position of the wagon impedes the reading of labels or other written information on its side. The information carrier can be damaged or lost. However, by reading a properly embedded chip with the help of a drone first arriving at the site, the released dangerous goods can be instantly identified. The information gained by radio frequency reading can be then forwarded to the Disaster Management and Railway Chemical Protection bodies and other participants helping in the rescue operation. This way specialist could be informed about the situation before they arrive at the site, and they can prepare with suitable equipment, protective clothing, and appropriate recovery, rescue and neutralization strategy in advance.

Another advantage of this method is that it can be used even if the site is difficult to access or if it is totally inaccessible. It can also be a solution to provide information to rescue specialists, this way saving their lives or physical safety in case of poison, infection or explosion hazard. By ensuring a faster and more professional rescue operation, this system can reduce the quantity of hazardous substances turning into hazardous wastes in the track section and its environment, as time is a significant factor in the spreading of pollution.

Examples of the systems surveying and monitoring the transportation of dangerous goods

The Route project (Dangerous Goods Transportation Routing, Monitoring and Enforcement) was a common European research project to analyse accidents occurring during the transportation of dangerous goods, and to develop a system which can adequately track the vehicles of road transport. The speciality of the project was that it did not only focus on the nature of hazardous substances, but those vehicle parameters which could affect the safety of transportation (such as temperature, humidity, acceleration) were also monitored online. The

hazardous materials transported in the vehicles were identified automatically by using the RFID technology. The system enables the planning of transportation routes based on real time information and cooperative systems, which also allow the replanning of the route in case of a problem [13].

It is difficult to access information about the transportation of dangerous goods, and, in case of an accident, it is necessary to conduct a collective analysis of data stored in different systems in order to be able to carefully assess the situation. Consequently, it would be necessary to ensure the accurate tracking of vehicles transporting dangerous goods in railway transport, too. There is no uniform monitoring and tracking system for railway vehicles in Europe. In Hungary, tracking is restricted to the locomotives of railway companies. Nevertheless, there are international examples for the unique identification of railway wagons. The railway systems of the United States have a strong tradition in this field.

In the United States 1,7 million types of hazardous substances are transported by railway each year. Dow Chemical has already started to use the RFID system, in order to help to identify railway wagons carrying hazardous chemicals. 26 000 railway wagons in North America transports about 650 types of TIH (toxic inhalation hazard) chemicals.

The American system uses the EverSee2 transponder with sensors, two-way satellite communication and modem GPS. With the help of the data forwarding software the company is regularly informed about the position of freight wagons and receives a warning if a failure occurs. Dow Chemical also shares these data with the partners involved [14]. Figure 2 shows the simple visual marks used in Hungary today.

Figure 2. Visual marks on a tank wagon referring to the transported goods.

The US company TransCore developed its automatic identification system in the 1980s in order to track its transporting processes with the help of the RFID technology, which had been known for about 50 years by then [7, 15]. This technology has become widely used in America, but it is also present in many parts of the world, including Europe, for example in France, Germany, Austria, Belgium, Poland, Romania, Spain, Switzerland and the UK [16]. Other sources also mention here the Czech Republic and Finland [7]. This application of the RFID technology has not yet been introduced in Hungary, nor has it been listed among the short and long term plans of railway development.

It is another peculiarity that the company Kapsch, which is also known in Hungary (for its GSM-R projects), also offers a system for wagon monitoring. Besides measuring the

appropriate temperature for the transportation of goods, this system is able to detect the speed and the position of the wagons. It also supports the efficient use of the maintenance cycle. It shows if the wagons are forwarded at a speed greater than allowed or if they are loaded over the limit. Furthermore, it also helps to protect the transported goods against theft [17]. This system is shown in Figure 3.

Another company, the Belgian Ovinto offers a system particularly for the monitoring of tank wagons. The system is able to monitor various parameters of the transported - at times hazardous - substances, such as its level, leakage, pressure, shocks and temperature, besides identifying the position of the wagon [18] (Figure 4.).

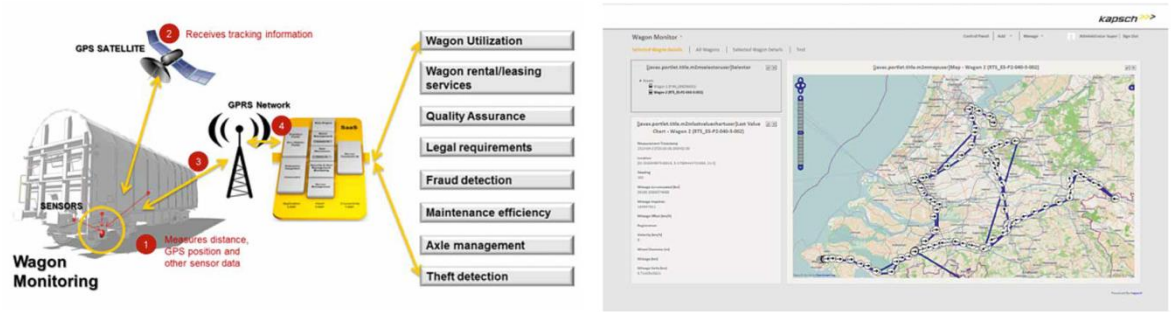

Figure 3. Kapsch wagon monitoring system [17].

Figure 4. Ovinto wagon monitoring system [18].

The modernisation of the transportation of dangerous goods by rail

The number of accidents can be further reduced by using intelligent systems. The vehicles equipped with anti-collision systems can be a very good example for this, as they will become part of our everyday life soon in road transport. Of course, this single application will not make the transport system intelligent, but it can be an important system element.

What measures should be taken to make the transportation of dangerous goods safer in the segment of railway transport? Continuous monitoring of the transported goods, making predictions about the possible obstacles on the transportation route, and maintaining the operability and safety of the means of transport in real time could help to solve this problem.

Presenting radiofrequency identification

Figure 5 shows the Auto-ID systems know today. RFID technology is one form of the Automatic Identification Systems. Its basic idea is that the object for identification is equipped

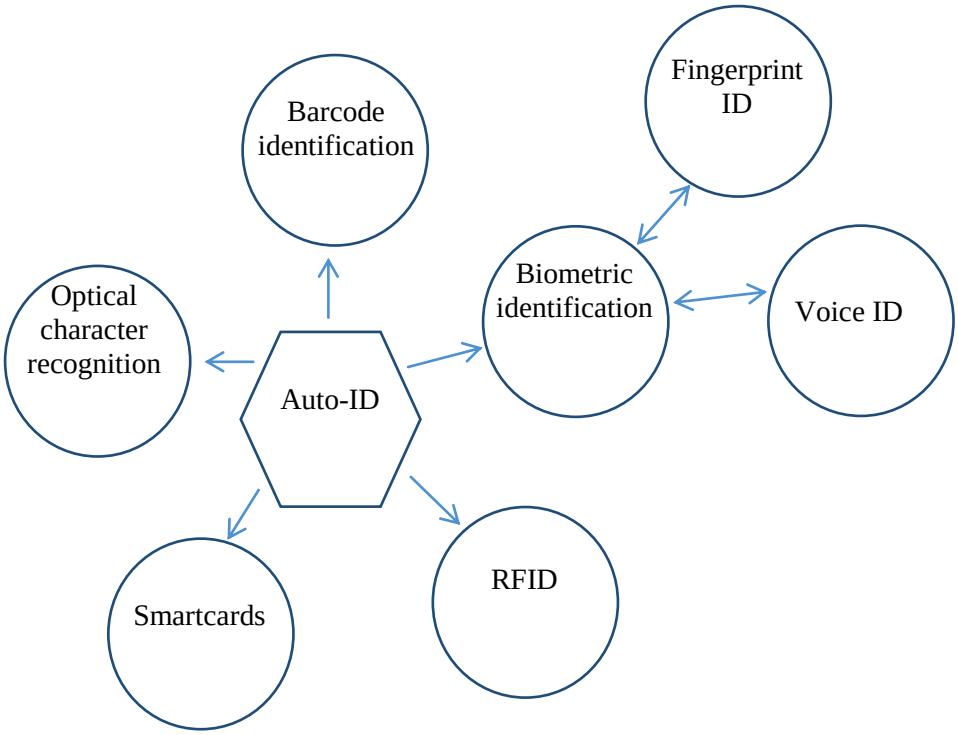

Figure 5. Auto-ID procedures [19].

with an element (transponder or tag) which is capable of data storage [19]. The microcontroller and the antenna together is called RFID "transponder", RFID "tag" or RFID hard tag [20]. The information necessary for identification and other data are stored in the memory of the microcontroller.

There are two ways of retrieving data. One way is when the reader supplies the passive tag with energy (through radio frequency waves) so that it could read the data stored in it. The other way is when the tag has its own energy supply (active system), so that the reader could receive and interpret the radiofrequency signals of the tag (the transmitter). With the latter solution the reading distance can be increased from several metres to a hundred or several hundreds of metres. The reading distance greatly depends on the applied frequency. For large distances and in metallic environment microwave systems (2,45 – 5,8 GHz) should be used.

The safe reading distance of the system used by us was 80 m, based on the first experiments. The operation of the system: the power supply without galvanic connection, data transfer and data exchange is realised by electromagnetic waves and space. This means that information is transferred between the devices through radio waves (Figure 6). This technology is increasingly used in railway environment, too. The Eurobalise S21 system is also based on the radiofrequency technology [19].

One advantage of the RFID system is that it offers machine identification which can be easily automated and used even for special devices. It is also possible to use in high-speed and medium-distance systems by choosing the appropriate technology. For example, a tank wagon transporting a hazardous substance can be uniquely identified by using tags with active and passive memory. The reading security can be improved by using multiple tags on the vehicles. This way there is a greater chance to read some of the tags not only in normal operation but also in case of an accident. The use of multiple tags has a one-off cost, which cannot be compared with the cost of the vehicle.

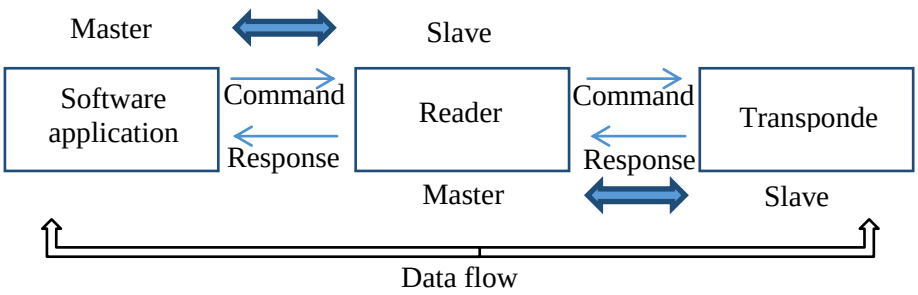

Figure 6. General structure of the RFID system with regards to Master – Slave roles [19].

In order to be able to store the changing data of each rail wagon (about the transported goods) writable memory tags must be used, as, by default, the system prefers the data stored once only. However, there is already a solution for this problem. These tags are capable of storing information for the whole lifecycle of the wagons. To ensure the unique identification of hazardous substances, upon the loading of a wagon the monitoring system reads in the information that can identify the transported goods, for example its physical and chemical parameters, so the parameters of transportation, for example the temperature, can be directly adjusted to them. Equipped with various sensors, the rail wagon can become an intelligent element, and this way the substances which require special storage parameters can be managed real time, and, with the help of the monitoring system the customer can track the current data (position, speed, expected delivery time) of the goods. Such a monitoring system can be upgraded with remote diagnostic solutions.

The disadvantages of the RFID technology could be the electromagnetic interference and its shielding phenomena. This problem could be solved, however, by choosing the appropriate frequency, by placing the transponders carefully and by using multiple transponders or a combination of (active and passive) solutions. In case of active transponders, the devices are able to identify the reader, which also allows the protection of the stored data.

In order to maintain railway safety, it is necessary to use encryption in the RFID system. In his article, Nyikes lists a number of such solutions, out of which the Hash-based access control could be used very well in a railway environment [21]. The system must be also protected against unauthorised interception or data modification [22]. In order to ensure the safe operation of railway systems, it is necessary to examine the effect of the RFID component, as the (modified) signal reflected back by the RFID transponder could cause disturbance in other radio devices [21].

Specific examples of RFID application in railway environment to date

The above-mentioned Eurobalise (ETCS), container identification ISO 10374:1991 (Freight Containers – Automatic Identification), gas cylinders and chemical container identification.

According to Ditmeyer, Senior Lecturer of the University of Michigan, in the United States and in Canada the RFID system based on UHF radio frequency has been used for the identification of railway wagons and locomotives since 1995 [23]. There are several solutions available on the market for Automatic Equipment Identification (AEI). The major component of one of these systems is the tag made by TransCore (see Figure 7), to which the company produces both fixed installation readers and mobile readers (Figure 8).

Figure 7. TransCore tag used in railway transport [24].

Figure 8. TransCore portable RFID reader [25].

THE USE OF DRONES IN THE IDENTIFICATION OF HAZARDOUS WASTES IN RAILWAY ACCIDENTS AND DISASTERS AND DURING RESCUE OPERATION

Drones were first used by Deutsche Bundesbahn, the German State Railway, to increase the safety of railway freight transportation.

PRESENT REGULATIONS OF THE USE OF DRONES

Presently there are approximately one million drones of 2 000 different types in the USA. The estimated number of drones used in the world is around 3 million, and it is exponentially growing. Thousands of drones are flown each year in Hungary, too. The use of these devices, however, is not adequately regulated. Therefore, independent of their purpose, all unmanned vehicles fall under the current regulations of Act XCVII of 1995 on air traffic and Act CLXX of 2015 on the amendment of certain acts related to transport.

Figure 9. The device used in our experiment – there are numerous ways to use drones.

At the moment there is no consistent regulatory framework with regard to unmanned aerial vehicles or drones (see Figure 9), various international bodies are working together in the general regulation of these vehicles. Until the legal act regulating this field comes into force, the Inspection Department of the Aviation Authority of the Hungarian National Transport Authority is responsible for the elaboration of the professional background in the legislative process. During this transitional period, for remunerated activities and other non-hobby activities the Authority applies a permit granting procedure on a case-by-case basis in compliance with the currently effective legal regulations on air traffic. In the current regulatory framework the Authority does not permit the flying of drones above people and the flying of drones at night.

As for the uses for private or hobby purposes: no permit is required for such activities at the moment. On the other hand, the owner of the aerial vehicle shall bear full criminal liability for any accidents or material damage caused during the use of the vehicle and for the infringement of air traffic regulations. In order to avoid such consequences, and in view of the conditions of performing activities which require permission from the Authority, it is strongly recommended to use the device on the owner's property, to avoid use on the property of other natural or legal persons or on public grounds, and to strictly refrain from the flying of the drone above people [26].

The Hungarian National Authority for Data Protection and Freedom of Information issued a recommendation for regulating the privacy and data protection issues of the civil uses of drones, and for the uses of drones in various fields [27].

The recommendation includes the general legal analysis of the issue, on the basis of which the Authority reached to the conclusion that a legal regulation is necessary in this subject. In this context, the recommendation includes suggestions for the legislator suggesting different regulations for the different uses of drones. Moreover, the recommendation contains recommendations for state and commercial use, as well as advice for private users. The recommendation aims to give the best suggestions in this subject for the legislator, for public authorities, market participants and private users in order to ensure that this new exciting technology could be widely used, in compliance with privacy and data protection regulations [28].

Compliance with the regulations of using drones also plays an important part in our research. In any event, until these regulations are fully developed, we pursue the assurance of maximum security during the experiments carried out in our research. The use of these aerial vehicles raises further problems in railway operation areas, for example, when flying above overhead contact lines or in case of an accident causing fire.

CASES OF USING DRONES

Many times it is not possible to determine that out of ten tank wagons piled up in an accident which one is the most dangerous. An appropriately equipped drone can help in its identification. For example, the construction of such a drone requires the use of explosion proof technology.

In 2014, the company ADASA created a drone equipped with an RFID reader to scan the environment of ironmongeries and retail outlets, which is also able to monitor the stock and help the operation of a plant or a shop this way [29]. A device similar to the one shown in Figure 10 could also be suitable for railway applications.

Figure 10. A flying robot by the company ADASA capable of RFID scanning [29].

A possible uses of drones in railway operations

The most important railway applications:

- Identification of dangerous goods
- Monitoring the temperature of tank wagons
- Detecting illegal waste dumping
- En route inspection of the technical conditions of railway vehicles and tracks
- Protection against illegal opening, the theft of dangerous goods
- Checking the safety of level crossings
- Monitoring switches, interlocking systems and signalling lights and their replacement during breakdown
- Monitoring the presence of unauthorized persons (attempting suicide, drunk or deranged) on the railway track, patrol in front of trains, audible warning 13. 01. 2016 –a woman was run over by the train no. 98 036 between the stations of Pinnye and Fertőboz. 15. 01. 2016 – a man was run over by the train no. NIC204 between the stations of Dombóvár alsó and Csoma-Szabadi. 15. 01. 2016 – a man was run over by the train no. 77929-2 at the railway station of Ács. 20. 01. 2016 – a woman was run over by the train no. 6 221 between the stations of Nyírbogdány and Kemecse. 21. 01. 2016 a man was run over by the train no. 8 280 between the stations of Kaposvár and Kaposmérő [30].
- Detecting the shift, fall, leakage or dusting of load
- Surveying the damage or the doors and openings of railway wagons
- Measuring radiation level in case of transporting radioactive waste
- Detecting and lighting the site of an accident or disaster
- Taking rescue packages (medical and chemical) to the site of the disaster.

Other fields of application for drones may be: civil and military reconnaissance, video camera, photographing, environmental protection measurements, parcel delivery, monitoring crops and livestock, thermo sensor, infra camera, monitoring water movements, GPS transmitter, Bluetooth, Wi-Fi transmitter, motion sensor, face recogniser, biometric scanners, following a subject or a vehicle, gun carrier for military purposes, monitoring accidents or disasters, event and place surveillance and many other possibilities.

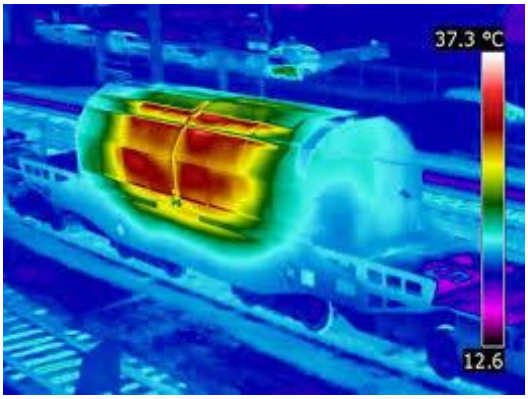

Figure 11. Information about hazardous radioactive consignment that could be provided by a drone equipped with a thermo sensor [31].

By adding easily changeable accessories, drones can offer cost-efficient solutions for retail users, while private user will most benefit from the convenience, entertainment and efficiency-enhancing functions of the new technology in the future. Furthermore, there are

considerable advantages of using this technology for the purpose of state responsibilities, most typically in the fields of disaster management, crime prevention, law enforcement, border police, life safety and healthcare services [3].

RESULTS

Recommendations for the introduction of RFID technology in the transportation of dangerous goods:

1. RFID technology can be successfully applied in the railway environment for the unique identification of vehicles transporting hazardous substances.
2. Combined with the RFID system, local transponders (fixed on the vehicles) capable of dynamic data storage can be used to meet the changing needs related to transportation.

Recommendations for the introduction of the combined RFID-drone system:

1. In case of a disaster or accident, it can be used in the affected area to inspect the situation and assess the damage, and to make further predictions, for example, in case of the accidents involving dangerous industrial plants or dangerous consignments.
2. In case of fire in an extended area – involving vehicles transporting hazardous substances or railway operation areas – it can be used to detect the spreading of the fire and to precisely define the affected area.
3. It can also be used to search for survivors with the help of a thermal camera in case of a hardly accessible area.

OUR EXPERIMENT

Our experiment was carried out in a railway environment to examine the operating of the RFID reader near a large mass of metal. On the first occasion, measurements were performed without a drone, holding the reader in hand in different positions.

During the research, the commercially available drones (with GPS navigation [32] and Trajectory Tracking Control [33]) will be equipped with the following elements: a high-resolution camera, a thermal camera, a communication module, an RFID reader and an air composition sensor. We are planning to use the drones during the transportation of hazardous substances for the identification of wastes in case of an accident or disaster. Their use in such an incident can have significant benefits in comparison with the present practice.

Former experiments proved that only high-end drones are capable of carrying a load of 1-2,2 kg by air. Such aerial vehicles of higher capacity (for example: 13 kg) are also available commercially, so these can be used to carry the implemented devices during the experiment [32]. According to our plans, the extra accessories of the drone will not weigh more than 4-5 kg including the batteries which ensure the long flying time. Our measurements show that the drone will be able to perform the identification of hazardous substances from a distance up to 80 m depending on the circumstances found at the site of the accident.

Functionality:

- Communication module: sends the data of the devices and sensors fitted on the drone to the assessment and control centre.
- High-resolution camera: continuously pans the area above which the drone flies providing visual information to the rescue team.
- Thermal camera: can take a thermal image of the site of the accident, which can help to increase the efficiency of intervention and the making of further decisions.
- Air composition sensor: can show the presence of any polluting or poisonous sub-stance in the air at the site of the accident.

- RFID reader: provides instant information about the parameters of the transporting vehicles and the transported substances.

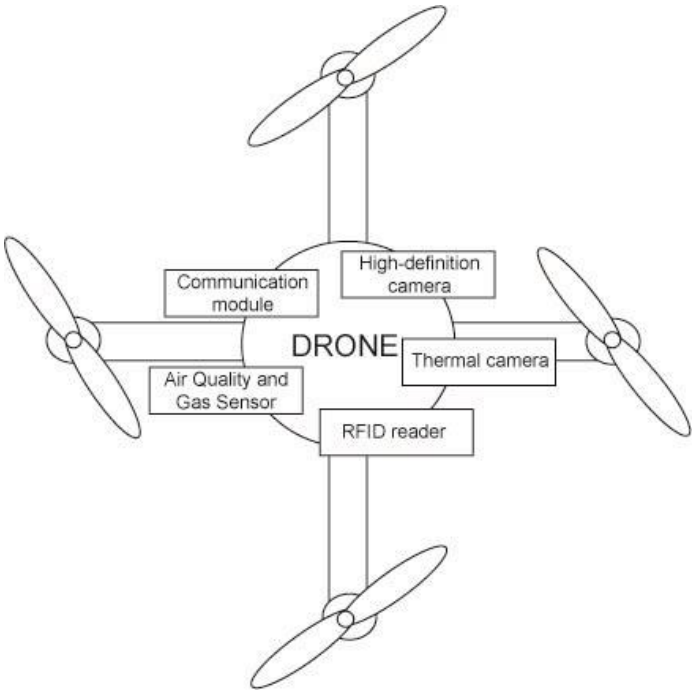

Figure 12. The module systems fitted on the drone (autonomous quadrotor architecture).

Figure 13. Devices of the experiment and the tank wagon with its tag (in red circle).

The combined RFID reader-drone method, as we suggested, is quite new, therefore, our results will be reported after further experiments and research. Our suggestion complies with the concept of the Hungarian National Directorate General for Disaster Management, as this body has the type of drones which could be further developed according to our recommendations to perform the above-listed tasks in a more efficient and safer way.

DISCUSSION

Presently, the RFID technology is used for the identification of railway vehicles in the United States, but it is not used for dynamic data storage related to hazardous substances in the railway environment. Our position is that the RFID technology could be used during incidents in the transportation of hazardous substances as listed above.

Concerning the use of drones, it is important to classify and register them. The categories used in the regulations should be defined by the aspects of usage, not only from the point of take-off weight and kinetic energy, but also from the aspect of private, commercial or safety

technology use, in order to help to initiate and carry out the process of authorisation and identification.

The safety-technology purposes of drones should be distinguished from the use for hobby purposes, as they have unquestionable benefits in such application. Similarly to this topic, drones have already been used in Hungary during a flood event. Their use helped to determine the extension of the flooded area, the situation of possible critical points and the accessibility of escape routes. In case of chemical accidents, a gas detector could be mounted on the drone, which can measure the concentration of the gas escaped into the air, this way ensuring that faster and more precise measures could be taken to protect the inhabitants. There have been examples for such application in disaster management, which means that these devices are able to perform such tasks.

Previously, drones have also been used by various civil rescue organisations to find missing individuals. Small-sized drones are being continuously developed to be able to carry different devices of appropriate weight. A high-resolution, high-sensibility thermal camera is now available in a category of less than 1 kg. We suggest the use of this device, as cheaper cameras with similar features cannot provide the necessary resolution from several tens of meters height. The application of drones equipped with thermal cameras, radiofrequency readers, air composition sensors and communication modules has further potentials in the process of disaster management.

CONCLUSION

Based on the research that we have carried out to date, our conclusion is that the RFID technology can be used to identify the transporting vehicles and the dangerous goods or substances transported or stored in them. This method of identification can be performed in an easier and safer way in case of an accident or disaster situation, even without the direct involvement of human resources, by using a reader mounted on a drone.

The use of drones for civil purposes has preceded the development of legal regulations, and an ever-increasing number of drones are now used for various purposed. In order to examine the problems arising from this situation, and to draw the conclusions at an academic level, it is first necessary to ensure the safe and regulated use of airspace of these vehicles.

Once the necessary legal regulations have been developed, our suggested method of the RFID-DRONE combination could be introduced for the identification and treatment of dangerous goods and wastes in the event of railway accidents or disaster situations.

ACKNOWLEDGEMENTS

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AN IMMUNE SYSTEM INSPIRED THEORY FOR CRIME AND VIOLENCE IN CITIES

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ABSTRACT

Crime is ubiquitous and has been around for millennia. Crime is analogous to a pathogenic infection and police response to it is similar to an immune response. The biological immune system is also engaged in an arms race with pathogens. We propose an immune system inspired theory of crime and violence in human societies, especially in large agglomerations like cities.

In this work we suggest that an immune system inspired theory of crime can provide a new perspective on the dynamics of violence in societies. The competitive dynamics between police and criminals has similarities to how the immune system is involved in an arms race with invading pathogens. Cities have properties similar to biological organisms and in this theory the police and military forces would be the immune system that protects against detrimental internal and external forces.

Our theory has implications for public policy: ranging from how much financial resource to invest in crime fighting, to optimal policing strategies, pre-placement of police, and number of police to be allocated to different cities. Our work can also be applied to other forms of violence in human societies (like terrorism) and violence in other primate societies and eusocial insects.

We hope this will be the first step towards a quantitative theory of violence and conflict in human societies. Ultimately we hope that this will help in designing smart and efficient cities that can scale and be sustainable despite population increase.

KEY WORDS

complex systems, immune system inspired, computational sociology, modelling socio-economic systems, artificial immune systems

CLASSIFICATION

JEL: C51, C65, J18, O21

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INTRODUCTION

Cities are similar to biological organisms [1]. They consume resources and have emergent properties like generation of wealth and violence. Crime is ubiquitous and has been around for millennia. Crime is analogous to a pathogenic infection and police response to it is similar to an immune response. The immune system is engaged in an arms race with pathogens. Similarly law enforcement is engaged in an arms race with criminals.

We propose an immune system inspired theory of crime and violence in human societies, especially in large agglomerations like cities. In this work we suggest that an immune system inspired theory of crime can provide a new perspective on the dynamics of violence in human cities. The competitive dynamics between police and criminals has similarities to how the immune system is involved in an arms race with invading pathogens. Cities have properties similar to biological organisms and in this theory the police and military forces would be the immune system that protects against detrimental internal and external forces.

Such an immune inspired theory or immunological theory of cities has several advantages:

1) There are advantages of looking at complex socio-economic systems like cities from the lens of other complex dynamical systems like the immune system: the observed scaling of a quantity of interest is the result of the complex nonlinear interplay between two different competing systems (pathogen and immune system and criminals and police) [2]. This approach has been also used successfully to derive results for how the immune response against pathogens scales with the size of the complex system (in this case the size of the host organism) [3,4] and how the number of crimes and the response of police against criminals scales with the size of cities [2].
2) Previous work using the immune system as an inspiration has shown the optimal way to locate structures similar to lymph nodes (anatomical structures used by the biological immune system) that facilitate detection of adverse events and response against them in human-engineered distributed systems like mobile networks, peer-to-peer networks and social networks [3-14]. An immune system inspired theory of cities may inform strategies on how to optimally locate police and police stations, and design efficient policing strategies.

The present work lays the foundation for an immune system inspired theory of violence in cities. Such a theory may give insights into how crime, social unrest and civil disorder develops in cities.

Population pressure makes current growth of cities unsustainable. A large percentage of the human population now resides in cities and millions of people migrate to cities each year in search of livelihoods. If cities are to be sustainable and our future growth is to be secured, we must design strategies for smarter and more efficient cities. Ultimately we hope that the present work will be a step towards designing smart and efficient cities that can scale and be sustainable despite population increase. We hope our work will lay the foundation for quantitative theories of conflict in human societies and give insights to help design better and more efficient cities.

IMMUNOLOGICAL PRELIMINARIES

The immune system is involved in an arms race with pathogens that invade the host organism. Cells of the immune system are trained to distinguish self (cells of the host organism) from non-self (foreign particles and organisms considered harmful to the host including viruses and bacteria) [15].

The immune system consists of two arms: the innate immune system and the adaptive immune system. The innate immune system is the first line of defense and consists of cells

like macrophages that clear all particles considered foreign and dendritic cells (described later). The adaptive immune system consists of T-cells and B-cells which constitute tailored and more specific responses to pathogens.

Cells of the immune system called dendritic cells search for non-self in tissue (these cells recognize a broad range of pathogens and in that sense are considered generalists). Once they find something considered harmful, they traffick to nearby lymph nodes (which are specialized anatomical structures that facilitate the interaction between different immune system cells) to present this to other specialized cells of the immune system like B-cells and T-cells.

T-cells are specialized immune system cells that have been trained to recognize non-self. Individual T-cells are specific to particular forms of pathogens or particular patterns of chemicals (called antigens). There are only a few T-cells that are specific to the antigen presented by the dendritic cell and this search takes place in the lymph node. Once the rare T-cell recognizes the pathogen it multiplies itself (in a process called clonal amplification). These T-cells then attack infected cells in an effort to control the infection. In a similar process, cells of the immune system called B-cells also recognize antigens presented by dendritic cells and secrete chemicals called antibodies in order to neutralize pathogens. Antibody binds to viruses which are then removed by immune system cells.

The immune system has specialized cells called memory cells which have recognized past infections. These cells allow the immune system to respond faster if the same pathogen is encountered again.

Immune system tolerance is a process by which the immune system is trained to recognize and not attack organisms which are foreign but benign to the host like gut microbes. Specialized cells called T regulatory cells suppress reactions by other immune system cells so that they do not attack these beneficial organisms [15].

IMMUNE SYSTEM INSPIRED THEORY OF CRIME

The arms race between immune system and pathogens is similar to the competitive dynamics between police and criminals. Cities have properties similar to biological organisms and in this theory the police and military would be the immune system that protects against both internal and external forces. The system is depicted in Fig. 1.

Police are activated by crime just like T-cells and B-cells are activated by dendritic cells. Non-criminals are turned to criminals in the presence of crime. Hence crime is like a virus. This specifically simulates a spread of disorder. The police is analogous to the immune system and criminals are like infected cells. Police also remove criminals similar to how T-cells kill and remove infected cells. The analogies between the immune system and police are summarized in Table 1.

MODELS AND METHODS

The dynamics of the immune system is typically modelled using non-linear dynamical models (using ordinary differential equations and agent-based models) that simulate the spread of disease within an organism [3, 8, 13, 16-18].

Cities can undergo major social upheavals as for example in the London riots of 2011, Arab spring revolutions of 2011 through 2013, and the Stockholm riots of 2013, demonstrating that social disorder can spread very fast in cities. Non-linear dynamical models can capture these dynamics [2, 19].

Table 1. Analogies for an Immunological Theory of Crime.

Human Societies	Immune System
Crime	Virus
Non-Criminals	Susceptible normal cells
Criminals	Infected cells
Police	Immune System
Police first responders	Innate immune system (dendritic cells)
Specialized police forces	Adaptive immune system (T-cells and B-cells)
Police taking out criminals	T-cells killing infected cells
Police removing crime	Clearance of virus by B-cells
Crime database	Immune memory
Police crimes against innocent people	Immune system attacking itself
Police stations	Lymph nodes
Patrolling police	Circulating T-cells

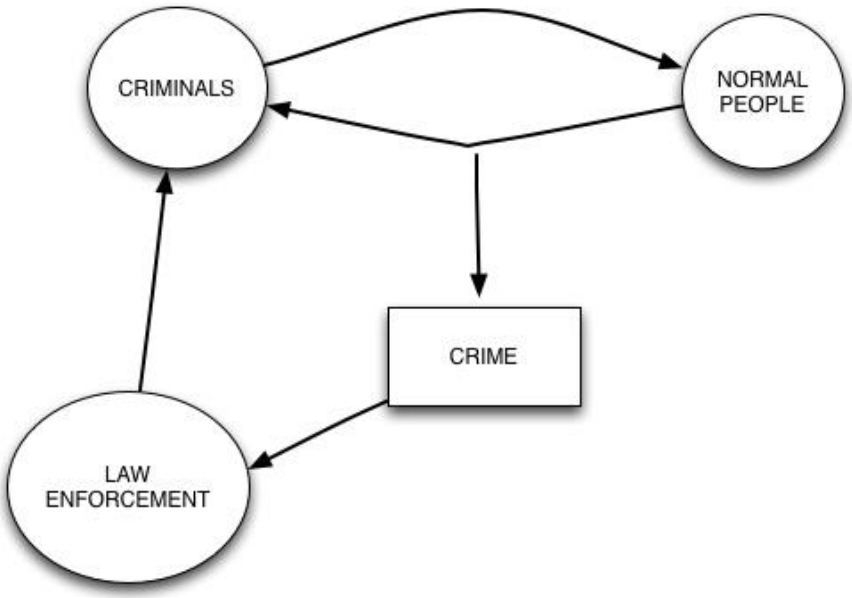

Figure 1. A simplified depiction of the arms race between police and criminals. The interaction between criminals and normal people (non-criminals) causes crime. Crime triggers a police response. Police in turn respond by removing crime and removing criminals (adapted from [2]).

In previous work we used a dynamical model that captures the complex interactions between police and criminals [2].

$$\frac{dC}{dt} = \alpha \cdot D_C \cdot D_{NC} - \beta \cdot C \cdot D_{LE}. \tag{1}$$

We denote the number of criminals per unit city area as D_C (density of criminals). Similarly, the number of ordinary (non-criminals) people per unit area is denoted by D_{NC} (density of non-criminals). Finally, the number of law enforcement officials per unit area is denoted by D_{LE} (density of law enforcement officers). Let us denote the density of crimes as C. We assume that crimes are generated by the interaction of criminals and non-criminals, on which criminals perform a criminal action, with rate constant α. Crimes are prevented by law enforcement at a rate proportional to the density of crimes and the density of law enforcement with rate constant β. The model is diagrammatically represented in Fig. 1.

This model can be simplified under conditions of steady state (holds during normal peaceful time periods and not during times of violence) to yield an equation for crime [2]:

$$C_{SS} = \frac{\alpha \cdot D_C \cdot D_{NC}}{\beta \cdot D_{LE}} \tag{2}$$

where $Crime_{ss}$ is the number of crimes in cities at steady state, $N_{criminals}$ is the number of criminals, $N_{non\text{-}criminals}$ are the number of non-criminal people, N_{police} denotes the number of police in cities and α, β refer to constants of proportionality in the relationship. Equation (2) is a general equation which unites crime in different contexts: from crime in cities to crime in universities [2].

Mathematical models can also be used to simulate the spread of disorder in cities. The following model simulates an increase in police numbers in response to a sudden increase in the number of criminals as is expected to occur in cities during times of social unrest. This has been empirically observed in the London riots of 2011 [19]. This model implements a phenomenon of spreading of disorder whereby non-criminals undertake criminal activities when they observe a lot of crime in their vicinity [20].

$$\frac{dD_C}{dt} = \alpha\big(C(t)\big) - \beta D_C D_{LE} \tag{3}$$

$$\frac{dD_{NC}}{dt} = -\alpha\big(C(t)\big) \tag{4}$$

$$\frac{dD_{LE}}{dt} = \eta\big(C(t)\big) \tag{5}$$

$$\frac{dC(t)}{dt} = \delta D_C D_{NC} - \gamma C(t) D_{LE} \tag{6}$$

$$\alpha(C(t)) = \frac{a_1}{1+e^{-a_2 * C(t)}} \tag{7}$$

$$\eta(C(t)) = \frac{a_3}{1+e^{-a_4 * C(t)}} \tag{8}$$

Non-criminals are turned to criminals in the presence of crime. Hence in this model crime is similar to a virus. This specifically simulates a spread of disorder. The police is analogous to the immune system and criminals are similar to infected cells.

Criminals are generated from the ordinary population at a rate α, which is a function of total crime in cities: this implements a spreading of disorder [20]. Law enforcement fighting crime actively are increased at a rate η dependent upon crime to simulate an increase in police numbers in response to crime in specific areas. Criminals are also removed (e.g. by imprisonment) at a rate proportional to the density of law enforcement and the density of criminals, with rate constant β. Finally crimes are generated by the interaction between criminals and non-criminals with rate constant δ. Crimes are prevented by law enforcement at a rate proportional to the density of crimes and density of law enforcement, mediated by a rate constant γ. The precise forms of the functions α(C) and η(C) would depend on the available data. Here we choose a sigmoidal function to simulate an increase in police (and criminals) till some constraint is met (saturation in police numbers or criminals). A representative model simulation is shown in Fig. 2.

It is also possible to build more complex models where police action produces more crime. Such models can be used to simulate revolts against administrations and civil unrest like in the Arab Spring revolts. We envisage considerable difficulties in estimating parameters for such models. However these models can be used for what-if analysis to guide public policy makers and government bodies in making judicious decisions about how many police to deploy, where to deploy them and how to control adverse effects like police brutality.

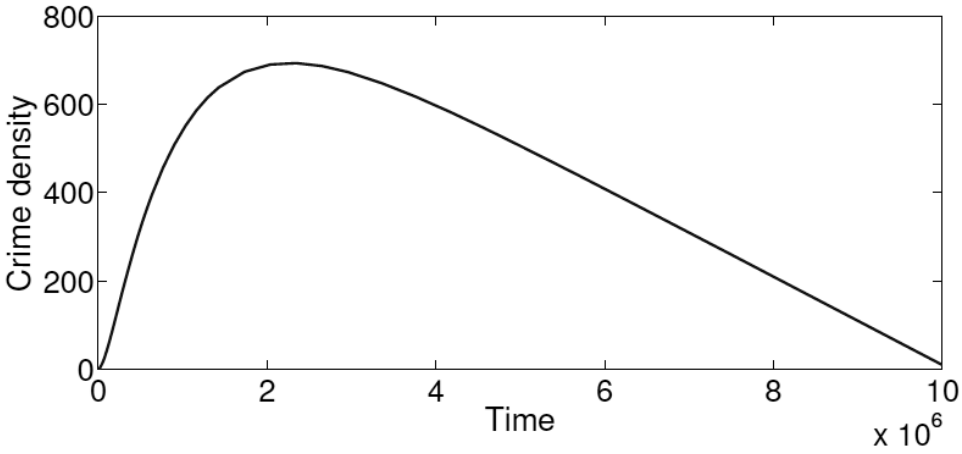

Figure 2. A sample plot of density of crimes (crimes per unit area) over time (in seconds) as predicted by a non-linear dynamical model (see preceding discussion).

DISCUSSION

Crime has been synonymous with cities ever since their inception. The competitive dynamics between police and criminals has similarities to how the immune system is involved in an arms race with invading pathogens. In this work we suggest that an immune system inspired theory of crime can provide a new perspective on the dynamics of violence in human cities.

QUANTITATIVE THEORY OF VIOLENCE AND CONFLICT

We view Equation (2) as a single equation which unites crime in different contexts: from crime in cities to crime in universities [2]. It gives us hope that there may be a more general quantitative model for crime and violence in human societies.

We see that this work as a first step towards a deterministic theory of human behavior and violence in societies. Isaac Asimov had written imaginatively about a field of predictive human behavior which he called psychohistory [23]. Although this remains an extremely ambitious goal, in the era of big data we may be able to predict behaviors of large ensembles of people [21] without being able predict actions of individuals.

PRIVILEGED ROLE OF THE IMMUNE SYSTEM

Our work also raises a question about why immune system cells are apparently able to behave unselfishly. For example why does the immune system not attack the host organism all the time? Equivalently why do police not attack innocent people all the time?

There may be strong incentives at play that prevent such aberrant behavior. Cells of the immune system have privileged metabolism [22], i.e. they have access to more metabolic energy than other cells adjusted for body size. Similarly soldiers and police get a lot of social prestige and status from serving and get additional privileges not available to civilians. This may also explain why soldiers and police are willing to give their lives for their countries and fellow citizens. This is not to say that there is no damage to normal cells. Normal cells are damaged and killed during vigorous immune responses. The cost of such “bystander effects” may be considered acceptable in the immune system compared to the risk of not killing possibly pathogen-laden infected cells.

Nevertheless these incentives are never always enough and sometimes we do observe breakdowns in militaries and police leading to civil war and mutiny. Quantitative models of the kind introduced in this work may inform policies on how to design incentive strategies for police in order to reduce crime as also reduce police corruption and judicial violence against innocent people.

The search for pathogens by the immune system is harder in larger organisms since the search has to be conducted over a larger physical space. However the time taken by the immune system to detect a pathogen and neutralize it does not scale with the size of the organism (scale-invariant detection and response) [3-7]. Organisms also allocate energy to the immune system linearly proportional to their body size. This linear allocation of metabolic energy to the immune system is one reason (among other factors) that helps the immune system achieve scale-invariance [3-12]. This is possibly due to natural selection and the importance of the immune system to the survival of organisms.

This raises the intriguing possibility that if cities allocated more (linearly) financial resources towards police (and hence number of police scaled linearly with city size), then crime would scale linearly with the size of the city; hence the density of crime would be scale-invariant (from Equation 2). However in reality larger cities allocate fewer resources per capita towards crime prevention than smaller cities (sub-linear scaling [2]). Strategies like these can inform policies on how much financial resource to allocate to crime fighting in cities and can also help quantify the economic cost of violence. Ultimately we hope that this will help in designing smart and efficient cities that can scale and be sustainable despite population increase.

APPLICATIONS

Our theory and models can inform strategies on how to pre-position police. If criminals and police are constantly increasing and competing (for example during riots), such models can suggest an optimal number and placement of police. Since police also need to ramp up quickly and police need to be trafficked to a particular place rapidly, there are parallels to how the immune system prepositions cells in lymph nodes. Other specialized anatomical structures like iBALTs (inducible bronchus-associated lymphoid tissue) are also created dynamically by the immune system close to previous sites of infection so as to reduce response times during future attacks (which may likely take place close to previous sites of attack) [24]. In previous work we have shown how the immune system optimally trafficks T-cells to infected sites to minimize the time taken to eliminate pathogens [8, 13]. Our work may be able to suggest immune system inspired “algorithms” to optimally route police to locations of crime.

Specifically the search for pathogens becomes harder in larger animals because the search is now through a larger physical space. As a result the immune system has evolved to have larger lymph nodes in larger animals in order to be able to send out more T-cells to infected regions [3]. Similarly it may be more difficult to track criminals in larger cities. Our work can be extended to determine an optimal size of police stations (number of police per police station) and how that should scale with the size of the city. In an immunological theory of cities, these lymph nodes would be police stations and patrolling police would be analogous to circulating T-cells [8, 13]. Our theory can be extended to make theoretical predictions of optimal placement and size of police stations for a particular city size.

Our models (see Section Models and Methods) can also be used to predict how much crime can be reduced by an increase in numbers of police. The actual predictions will depend on the precise model formulation, policing strategies and model assumptions. Our models can be extended to incorporate geographical spreading of crime, and can be used to recommend ways to optimise police allocation to minimise this spread. Our models advocate for optimal and timely allocation of law enforcement in order to check the geographical spread of crime.

The response of the police need not be centralized as it usually is. There have been proposals for a decentralized response where people respond all together instead of just police (which is similar to how the immune system responds to infections without any centralized control). Some have suggested that a distributed detection and response strategy may be more efficient compared to a centralized policing scheme [25].

More diversity in the workforce is thought to lead to more productivity [26]. However immigrants are also the subject of attacks in various cities around the world. How should modern cities design public policies that balance protection against foreign invaders with the immense productivity that comes from foreigners in a global workforce? It has been suggested that more contact between diverse factions and groups can reduce prejudice and possibly inter-group violence, subject to a number of conditions [35-37]. This is similar to how the immune system learns to tolerate non-self by repeated encounters with certain pathogens (see Section Immunological Preliminaries). This can inform public policy on immigration in cities and lead to practical outcomes like how to reduce attacks on immigrants. Such strategies may also yield insights into how successful cities are able to defend themselves against intruders while incorporating new people with diverse skills.

We also outline models (see Models and Methods) which simulate scenarios where police action elicits a more violent reaction from the ordinary population. These models can be used for what-if analysis to guide public policy makers and government bodies in making judicious decisions about how many police to deploy, where to deploy them and how to control adverse effects like police brutality. Although difficult at present, it may be possible in the future to predict with some uncertainty the effect of specific police actions or policies.

In the immune system adverse effects like T-cells attacking normal cells are controlled by another specialized set of immune system cells called T-regulatory cells which suppress aberrant behaviour. This suggests that another institution (like a government body with oversight or a specialized police force) can be brought in to control errant police behaviour.

The immune system does sometimes cause harm to uninfected normal cells while killing infected cells (called bystander effect). However it is within some bound since unconstrained harm to self would outweigh the benefits of destroying pathogens. Governments and policy makers would do well to keep this in mind and minimize harm to civilians while targeting criminals. Unfettered violence against civilians may ripen conditions for civil wars.

Finally, cities are also engines of wealth creation and vital to national economies. A quantitative model that couples the non-linear interaction between the generation of wealth in cities and violence may help in quantifying the economic cost of violence.

CONCLUSION

Our models are inspired by the biological immune system and we have previously used them to show how the immune system optimally allocates immune system cells (similar to police) to fight off pathogens (analogous to criminals) in a timely and efficient manner [2]. The immune system is engaged in an arms race with pathogens. Similarly law enforcement and militaries are engaged in an arms race with criminals. We propose an immune system inspired theory of crime and violence in human societies.

We believe there are implications for urban planning and policy with regards to how police stations can be placed optimally and how many and how big police stations need to be in order to control crime; there are also implications for urban planning and housing and how to prevent the spread of crime itself.

Our work can also be applied to models of terrorism and secessionism where two or more factions are involved in a co-evolutionary arms race [27]. In future work, we will look at how co-evolutionary arms races between police and criminals may select for more extreme and violent traits in criminals.

We speculate that our model could also be applied to violence in other primate societies [28] and colonies of eusocial insects [29]. For example ants from different colonies have been known to attack each other. Ants also have specialized castes (similar to police) that are dedicated to protecting the colony against invaders and internal strife.

In summary, our work can inform strategies on designing smart and efficient cities that can scale and be sustainable despite population increase. Our work also suggests the power and generality of dynamical systems in being able to simulate complex systems as diverse as immune systems, intra-cellular regulatory networks, violence in human societies and scientific collaboration networks [2-15, 31, 32]. We hope that this work will lay the foundation for a general and ultimately predictive theory of violence and conflict in human society.

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Interdisciplinary Description of Complex Systems 15(2), 144-148, 2017

CONCEPTUAL APPROACH TO UTILISATION OF THE UNMANNED AERIAL VEHICLES IN DIVERSE ACTIVITIES

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ABSTRACT

This paper considers current situation and development of software for group of mobile agents applicable on group of unmanned aerial vehicles. Generally, unmanned aerial vehicles are used for transfer of information, mass and energy and their group work enhances their success rate in comparison with the success rate of the use of a single unmanned aerial vehicle. Despite the constant daily use, their potential is realized only in a small portion. It is argued that software development is the natural further step in achieving considerably larger portion of realizations of their potential of groups of unmanned aerial vehicles. Starting requirements that such software must fulfill are rudimentariness of the code, openness regarding number of group members and closeness regarding information exchange. Prospective directions of development of that software are analyzed.

KEY WORDS

software, mobile agents, unmanned aerial vehicle, autonomous group, redundancy

CLASSIFICATION

JEL: L62, L93

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INTRODUCTION

The use of systems of autonomous agents cover numerous applications in a number of activities. While operating, agents in such systems constantly measure certain parameters related to their states or to the state of their environment. A general accompanying characteristic of these measurements is that they are processed with statistical limitations in real time. If the ability of such a system is to be determined empirically, it is necessary to conduct multiple tests with time involved and energy consumed. Ability to assess capabilities of the system would enable the implementation of the system of autonomous agents on a larger number of qualitative various systems. Ability to assess capabilities of the system is defined as the ratio of required and implemented characteristic of system. The system is deemed competent if the ratio is large enough. Therefore, the lack of the method for assessing abilities severely suppresses the possibility of efficient and proper use of a system of autonomous agents.

Examples of the use of autonomous agents are transport of loads and people between multiple locations, non-destructive and irreversible searches of the area, monitoring of natural phenomena, underwater research, traffic control, implementation of communication networks in adverse environments and others. The most commonly used autonomous agents for such tasks are stationary or mobile robots, underwater vehicles, aircraft, agents in a virtual environment, and other types of agents that perform a smaller number of simpler operations, including collecting and processing directly or indirectly measured data on the environment.

GROUP OF MOBILE AGENTS

The concept of controlled group motion was applied onto autonomous group of mobile robots. They prevalently operate in known and unknown interior spaces and have been thoroughly tested in such conditions. Main task for mobile robots is allocating free space and defining mathematical model of movement in observed physical space filled with barriers. Methods that have been widely applied include methods such as are C-space method, equidistant path method, potential field method and fuzzy logic methods [1]. In recent times the majority of use belongs to applications of the cognitive method [2]. That approach is based on collaborative work of independent robots, or in general agents [3, 4].

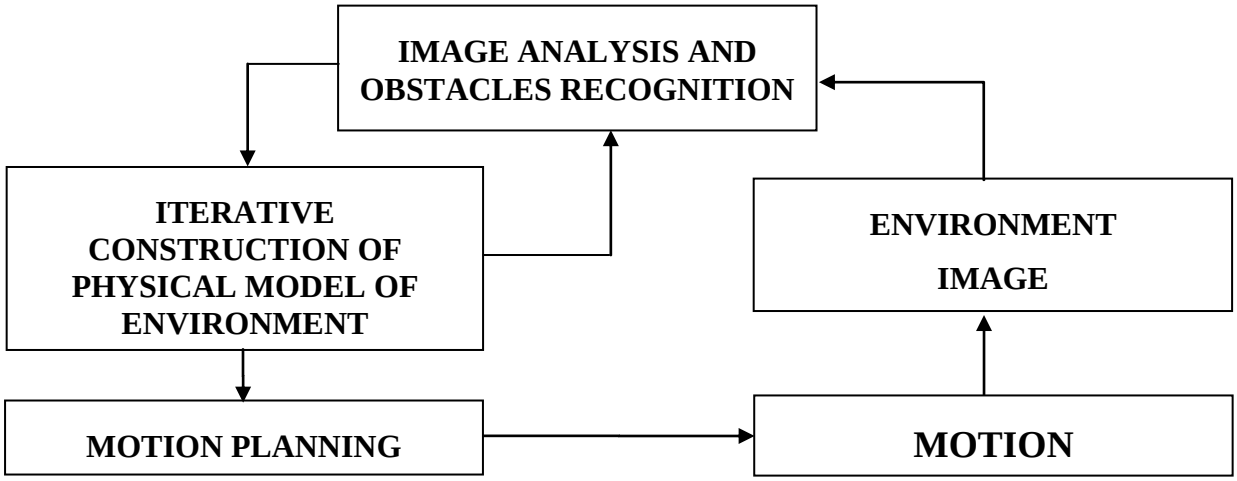

Figure 1. Decision procedure during a typical mobile robot's task performance [6].

An agent is an independent process, which performs a specific task either in collaboration with other agents or individually. All agents work in the same time period. Every agent has

initial state, time duration, input and output. Input of one agent can be output from another agent and outputs are the characteristics and events. They can be hierarchically structured and have different priorities, but appears the problem of excessive communication and coordination between them. From the perspective of agents their function can be defined as visual, audio, time, store and memory [5]. In case of movement agent must record the environment, analyze it and in an iterative procedure decide which path is optimal [6]. Figure 1 illustrates a typical mobile robot's decision procedure during task performance.

UAV IMPLEMENTATION

Generally, UAVs are used for transfer of informations, mass and energy. Priority of UAV research must be oriented on software development. That development makes possible realization of most of the capabilities attributed to them by their construction.

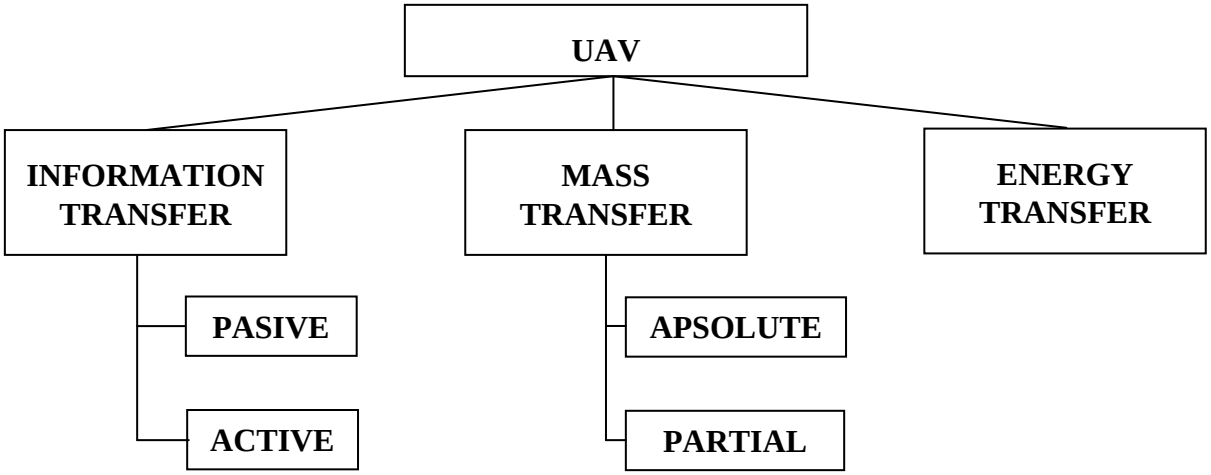

Figure 2. UAV classification.

Let us describe in more details the classification presented in Fig. 2. Information transfer can be passive and active. Passive transfer refers to information collected from the environment during the flight and analyzed after UAVs landing. In the case of active transfer, information is sent from the UAV to station referent for further analysis, usually real time processing. Mass transfer can be absolute and partial. Absolute transfer refers to the weight of the UAV which represents constant load during the flight. Partial transfer refers to the weight of the cargo that UAV lets off during its flight.

Regarding the number of UAVs exploited for a given objective two different classes are introduced (Fig. 3):

- Single unit mission.
- Group of UAVs mission.

These two classes are related to substantially different approaches, regarding relevant criteria for success determination.

In the first class, a single UAV must be equipped with all necessary equipment and instruments, thus as a rule their mass is rather large. Such an UAV is easier for maintenance and control during the flight than the second class UAVs. Major disadvantage is the risk in performing the task because if that UAV crashes or is in other mission fails.

In the second class, a task is subdivided between UAV group members. In that way a redundancy is achieved so failures in one or several UAVs do not bring about automatically failure of the complete mission.

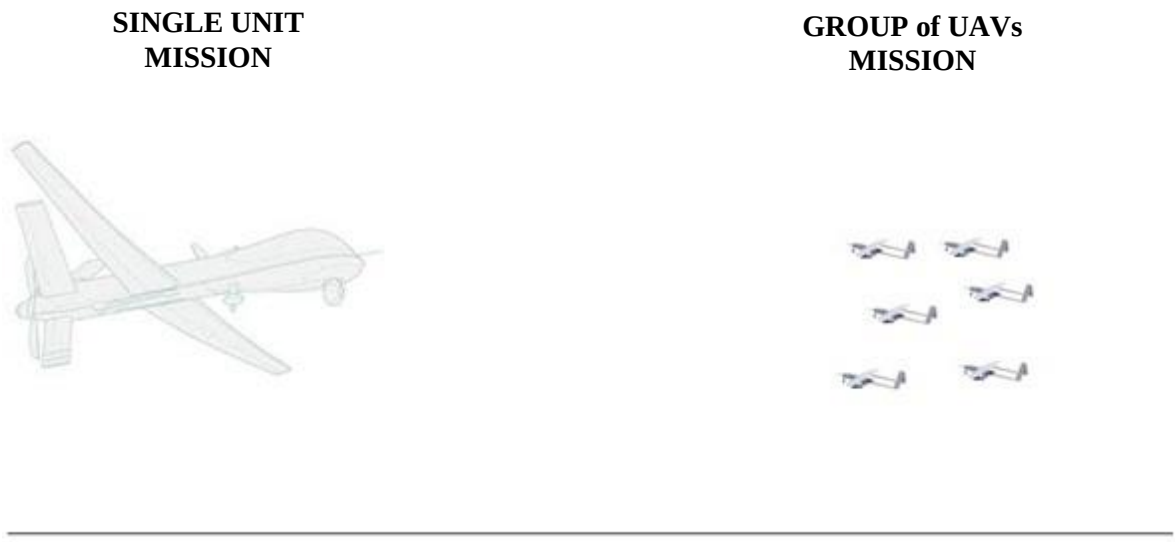

Figure 3. Defined classes regarding the number of UAVs exploited for a mission.

That is major advantage of this approach. Each member of the group collects data from environment and exchanges it with other members. Small part of internal memory is used for exchange of data and the rest is used for flight control. An additional consequence is that each member is in principle cheaper, in a limiting case so cheap that there is no need for but the simplest maintenance, as otherwise UAVs are replaced by new ones. Crucial problem, regarding the second approach, is absence of the software which controls such a group which enables the group to conduct predicted mission in a rather efficient way. Alternatively, if human operator controls UAV group performance, still the nonexistence of described software limits the group efficiency.

SOFTWARE DEVELOPMENT FOR GROUP OF MOBILE AGENTS

Software for autonomous action of a group of mobile agents is not full developed because there is no sufficient level of understand the essence of collective performance which can be effectively formalized and operationalized.

However, the following characteristics are universally present in the basis of their underlying software:

- Rudimentariness,
- openness regarding number of group elements and
- closeness regarding information exchange.

Regarding the code rudimentariness, the software must have as few as possible commands of simpler character and overall as short as possible code. Regarding openness, the software must enable the group to preserve functionality even if one or more elements are missing. On the other hand, openness of the software to the number of elements allows adding new elements which ultimately increases probability of successful task realization and that extends the duration of the group action if requested. The closeness regarding information exchange, puts demand on the software in the sense that if the element in a given time interval does not receive data from other elements of the system he can continue to conduct its subtasks. That characteristic of software resembles the standard software systems of transport aircrafts.

These determinants have several consequences; one of them is a redundancy. More specifically, the possibility of variable total number of agents and variable number of communication links is fail-operational. Fail-operational means that a fault in a system must be detected, localized and the system must be dynamically reconfigured.
Whereas progress in development of the software has a significant and measurable impact on the effectiveness of distributed systems and in general of embedded systems, significant efforts are involved in development of software and related algorithms.

CONCLUSION

A contemporary level of technics makes possible construction of fully operational autonomous groups of UAVs, yet such groups do not exist in practice. The cause for that is insufficient level of developed and embedded software. Consequently, it is opportune to put a priority of UAVs research onto software development. That development makes possible realization of most of the capabilities attributed to by their construction. The basis of such software, like rudimentariness, openness regarding number of group agents and closeness regarding information exchange, must be fulfilled. Progress in development of the software has a significant and measurable impact on the effectiveness of distributed systems and in general embedded systems. Significant efforts are involved for development of the software which would make possible full development of the potential of group of UAVs.

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THE PROCESS OF HANDLING AN EXCESS OF COMPLEX AND INTERDISCIPLINARY INFORMATION IN A DECISION SUPPORT RESEARCH SITUATION

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ABSTRACT

Researchers are sometimes expected to investigate a complex and interdisciplinary subject-matter in order to provide scientific support for large-scale decisions. This may prove challenging: typically, a lack of cohesion between the pieces of information investigated in the starting phase may cause confusion. This article suggests one possible road from this problem, which may lead to holistic understanding and next to communication and implementation of this understanding. The process is presented as a diagram, and selected aspects of it are analysed. The process involves moving to a higher level of generalisation in order to gain a better overview and potentially invent new concepts, and next moving back to a more detailed level in order to communicate and implement these insights. Potential challenges and roadblocks are identified. The possible conflict between normal science and decision support is briefly investigated; it is pointed out that "post-normal science" may be a more appropriate description of such processes than simply "science".

KEY WORDS

interdisciplinary research, generalisation, environmental valuation, theory of science, prudence

CLASSIFICATION

APA: 2340, 2380, 2630, 4010, 4050, 4070, 4120
JEL: C91, D81, Q50, Q51

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INTRODUCTION

CHALLENGES IN SCIENTIFIC DECISION SUPPORT

A research project is sometimes expected to recommend a decision or to reach a conclusion that can have bearings for policy, and consequentially for society and nature. During such a process, the researcher may find that this will involve sensitive conflicts and dilemmas, and he may have to trade off and interpolate between different goods, evils and consequences in order to reach a conclusion. As science is ideally objective and value-neutral, these dilemmas may be challenging to deal with in a scientific or science-like context.

Valuation of nature is an example: it is a key field of study within environmental economics which may enhance our understanding of the importance of different enviromental consequences. A related field is thus the research area of environmental impact assessments. In some such quantitative assessment methodologies, numerical weights can be assigned to different environmental impacts (e.g. climte change, acidification or eutrophication) according to their importance or (negative) value. In life cycle assessment studies, the optional and explicitly value-based part of this kind of valuation is called weighting [1]. When valuation/weighting is used in a numerical environmental assessment study, a resultant numerical score can be used to support a decision of whether or not the intervention being assessed is “good” or not. As both the environment and the possible sphere of normative concerns are vast and complex, the scope of valuation/weighting is similarly vast, and any inquiry that moves to the core of these topics will consequently typically be both complex and interdisciplinary.

EXCESSIVE COMPLEXITY MAY CAUSE CONFUSION

In complex and interdisciplinary decision support contexts, one will sometimes observe that the scope of existing paradigms may become too narrow, and an insistence on the “normal science” described by Kuhn [2] may prove to become too rigid. Inter-paradigmatic research sometimes required by the broad scope of e.g. environmental valuation was called “post-normal science” by Funtowicz and Ravetz [3].

One typical threat to a decision support research process in a complex, inter-disciplinary and therefore inter-paradigmatic context is that the amount of relevant information, literature and data becomes vast, thus threatening to stall the researcher by means of “information overload”. In the experience of the author, in such situations it will sometimes be difficult to foresee or understand how to get to the next step in the research process; a lack of full understanding can lead to, or perhaps simply is, metacognitive difficulty. Any attempt to write or otherwise communicate something intelligible about the subject-matter at hand in this “confused” stage will typically lack direction and, importantly, coherence. This article will try to sketch one possible approach or system for avoiding that complex decision support projects are hindered or even terminated due to confusion and incoherent information.

META-ANALYSIS: CHALLENGING, BUT NECESSARY?

META-ANALYSIS OF NUMERICAL RESULTS

One possible strategy is to aim for a meta-analysis of quantitative results (or estimates) in literature. For instance, Elvik [4; Ch.9] outlines a procedural approach to such meta-analysis, and applies it to valuation of human life based on questionaire-like methodologies. He points out, however, that valuation estimates show an unacceptably wide dispersion, and questions whether such meta-analysis is a viable approach. Apparently, simply averaging such

estimates is problematic, as results of different studies fluctuate substantially. Perhaps the problem of divergence in such results can be attributed to the phenomenon that valuation, whether contemplated by a researcher or by others during the completion of a questionnaire, is inter-disciplinary and inter-paradigmatic in nature. In the following, therefore, meta-analysis of ideas rather than of numerical results will be the main consideration.

NO META-ANALYSIS: POSSIBLE ANALYTIC MYOPIA AND FAIRNESS CONCERNS

Another possible approach would, however, be to claim that there is no need for meta-reflection: the researcher simply chooses to continuously keep a narrow scope, and thus assesses a single aspect, e.g. one where he already possesses in-depth expert knowledge.

From the discipline of law, however, a fairness argument against this is that it introduces the researcher's own bias to the decision support's methodology and conclusions. For instance, an expert in reptile biology may choose to develop an environmental valuation method which predominantly considers reptiles, and which turns out to exclude most other possible environmental aspects such as non-reptile species, human health and resource depletion. It would perhaps not take sufficiently into account that environmental impacts are very diverse and multi-faceted, viz. e.g. [5].

In scientific decision support, there are two obvious elements: science and decision support. A scientist's intra-paradigmatic expert reasoning, where it is normally seen as important to have a focused, narrowed-down scope, can for instance be contrasted against judical decision-making. These two paradigms are not necessarily completely different or contrary to one another, but may to some extent emphasise different features, qualities and virtues.

In large-scale and complex decision contexts, and particularly where there will be winners and losers, impartial judgment is normally seen as important. In most countries, public servants and judges who can be thought to be one-sided or prejudiced in a particular decision situation are in fact excluded from the decision in question, in order to increase impartiality and objectivity. In the English language this is called recluse or judical disqualification. The philosopher John Rawls calls a somewhat similar fairness principle for use in policy and distributitive justice contexts the "veil of ignorance" [6]. The philosopher Thomas Nagel calls a similar idea the "view from nowhere" [7]. Rawls' basic idea is to adequately consider all relevant vantage points, whereas the idea of Nagel is to retreat to one neutral vantage point. These two ideas are not necessarily in conflict; perhaps Nagel's vantage point can only be seen as one notch more general. From this neutral point of view, all relevant aspects can purportedly be considered in due amount, so that the amount of omissions (potential lies of omission) can be reduced in the final judgment. Unfortunately, a scientist or engineer getting lost in scrutiny and technicalities may experience a loss of the big picture and potentially fall short of the impartiality and fairness ideals.

The difference between the "detailed/absorbed" (technicality-focused) and "neutral/distant" (contemplation-focused) modes appears to be somewhat counter-intuitive and peculiar, and perhaps the two can be called different paradigms in their own right. There is an active scientific field of research within social psychology called construal level theory, which investigates the relation between and the properties of these two different levels of understanding [8]. Observations within this scientific paradigm can be useful for an in-depth circumspection and understanding of levels of abstraction.

Although meta-analysis was shown in the above to be challenging, some sort of broader assessment seems to be mandated in order to avoid too narrow and, at some level or another, biased policy advice. The next chapter will outline a framework that was identified post-hoc in the process to reach a more impartial, or high-quality, valuation methodology, cf. [1] (and

forthcoming articles). In the following, the need for fairness and the need for a more holistic overview in order to escape confusion are assumed to be convergent considerations.

OUTLINE OF SUGGESTED FRAMEWORK

Figure 1 shows the process diagram for research suggested and further discussed in this article. It can be understood as a road map out of an "information overload" situation and towards an archetypical understanding and implementation, or a model, of the acquired information.

The diagram shows how a project can take six stages, each of which is connected to a different virtue. The vertical axis describes a suggested level of generalisation for each stage; the horizontal axis denotes time: earlier stages to the left and later stages to the right.

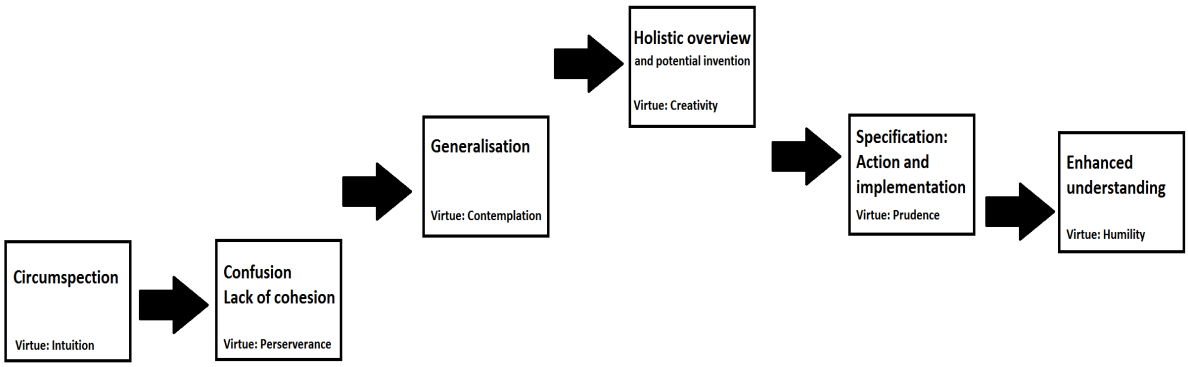

Figure 1. An outline of the process framework described in this article.

EARLY STAGES: INTUITIVE CIRCUMSPECTION

For the case of a very complex and interdisciplinary topic, one will sometimes experience that the more one reads and learns, the more incompatibility between what is learnt can be discerned. This may lead to confusion and a need to see the acquired information in a broader perspective. Investigating the topic in a circumspective manner until one reaches a state of confusion may, however, be necessary in order to understand at an early stage that interdisciplinarity with potential contradictions and severe complexity are involved.

Confusion can be understood as a strong lack of, and at the same time a strong desire for, cohesive knowledge surrounding the subject-matter at hand. At this early stage, however, one's knowledge may often resemble a patchwork of more or less equally important information. One way to ease an increase in cohesion is to decrease the level of detail in the information, or, to increase generalisation.

A HIGHER LEVEL OF GENERALISATION: ADVANTAGES AND DISADVANTAGES

When considering a wider scope of information, and particularly when transgressing Kuhn's paradigmatic boundaries, the information one finds to be all-encompassing in relation to the subject-matter will typically become gradually less specific: by increasing the generalisation level (and thus the abstraction level), one will often be able to get a better overview of more information. The drawback is that this information will be more generic and stereotyped.

For instance, the reptile biologist may try to consider all species and not only reptile species in his valuation methodology. The advantage is a broader scope and a more neutral point of view, but a drawback is that information will be more generic, e.g. available data will likely be of a more averaged and less accurate nature. Debatable, sweeping assumptions will likely

have to be made to e.g. find the value of reptiles compared to the value of other species. If the scope is widened further, e.g. to comparing the value of these species to the value of human health and social well-being, the assumptions that have to be made will be even more superficial and riddled with even more dilemmas. Again, the researcher's analysis will cover more holistic ground when the scope is widened, but the analysis will have to become quite abstract and generic. Jan Smuts, in his book Holism and Evolution describes the process of increased generalisation thus [9]:

> "The abstract thus becomes the real, the concrete is relegated to a secondary position. This inversion of reality is very much the same procedure as was followed by the scholastic and other philosophers who attributed reality to universals instead of to concrete particulars."

At this higher level of abstraction, it is possible to develop concepts, terms, analyses, etc., that may come in handy in order to classify and understand more specific-level information. Often, these more stereotyped concepts and analyses will prove helpful in illuminating the more detailed level, as they may be able to provide cohesion between and thus bridge gaps of knowledge. To a smaller or larger degree, however, a general analysis will always serve to obfuscate the complexity and the individual character of a particular situation. Smuts called this particular kind of reductionism the "error of generalisation".

HOLISTIC CONTEMPLATION AND POTENTIAL INVENTION

When contemplating the more overarching spheres of abstract-level understanding, one may feel that one has a quite good holistic understanding of the subject-matter in question. Sometimes, conceptual inventions that bridge many of the blanks and unknowns can emerge and make the researcher attain not only a higher level of knowledge, but also a higher level of understanding. The exact nature of such inventions are perhaps not anticipated in advance during the project, and the nature and limitations of such inventions are difficult to precisely describe and discuss here.

It is obvious, however, that a good invention will make what previously looked impossible seem simpler, and that it will solve some of, but not all, problems that had previously been identified. On further scrutiny, what seem like ingenious inventions may, of course, turn out to be of less practical value than imagined. One particular practical obstacle is to communicate and implement a very general novel idea or concept.

THE PAIN OF REVISITING THE SPECIFIC LEVEL: WRITER'S BLOCK

It may be riddled with difficulty to get out of the aforementioned general mode and e.g. start writing an article on the topic or about the concepts, terminology or invention one has discovered. The sentences one tries to write may come out as incoherent or somewhat haughty, or one may experience "writer's block".

From the author's experiences, there can be several reasons for this, some of which can be related to the above-mentioned generalisation:

- One needs more time to contemplate the issue (i.e. there is not really a writer's block),
- At an emotional level, one does not want to leave the satisfactory sense of understanding that higher-level understanding can provide. Or, if the process of increasing the level of generalisation was experienced to enhance cohesion and as providing an illuminating overview of the subject-matter, doing the exact opposite by decreasing the level of generalisation may seem counter-intuitive and disruptive,
- Potentially, forgetting details that did not fit into the higher-level generalisations may spawn excessive confidence in one's own understanding,

- Consequently, one can easily become unwilling to revisit or discover details that demonstrate that this understanding was at least somewhat superficial, flawed or, worse, misguided. In other words, one may experience excessive aversion to what Smuts called the "error of analysis", i.e. to the perceived loss of holistic overview experienced when moving to a more narrow, in-depth analysis: the opposite of Smuts' aforementioned "error of generalisation" [9],
- The researcher may also fear a discovery that little *practical* progress was made at the more abstract level, which would be incompatible with e.g. research deadlines, etc.

Certain strategies can be used to overcome the negligence of writer's block and similar phenomena. For instance, one can try to aim at six principles of prudence (cf. Figure 1) described by philosophers Macrobius and Plotinus according to [10]:

- *Circumspection*: The researcher (re)investigates several lower-level, detailed aspects of the issue, even if this *from the more general level* may both be unpleasant and seem somewhat random or irrelevant to the task at hand,
- *Docility*: The researcher, perhaps contrary to intuition, convinces himself that he has more to learn about the issue and accepts that he may not have understood everything correctly,
- *Foresight*: The researcher evaluates and plans future tasks to be done,
- *Caution*: The researcher accepts to proceed with small, prudent steps rather than with large, creative leaps,
- *Reasoning*: The researcher rejects slogan-like lack of reasoning and embraces open-ended, logical reasoning based on cautious circumspective investigation,
- *Intuition/understanding*: The researcher seeks out tasks and attitudes that enhance intution and understanding, and avoids those that reduce intuition and understanding.

Somewhat curiously, it can be conjectured that these partial virtues of prudent rational thought are perhaps not too far away from being opposites of what is required to get from the specific to the general level.

A disadvantage of this descent back into the details is that the researcher will likely not manage to conveive new, inventive ideas during or after this stage. An advantage is that this stage may allow implementation and communication of what has already been learnt.

END RESULT: HYPERPRESICION

Funtowicz and Ravetz describe how numerical results from very complex, post-normal science projects within e.g. valuation of nature will end up as "hyper-precise" [3]. Uncertainty estimates will typically not be able to describe what they describe as quality, plurality and intellectual and social mission; the largest uncertainty will on the contrary be how these issues are dealt with by the researcher. Hyper-precision may come as a surprise to those who never tried to visit a holistic, generalised understanding of the subject-matter, and it may be an ample source of discussion points for those who did reach such understanding (whether somewhat illusory or not) and later painstakingly narrowed it down to one or a few particular concepts or inventions.

Funtowicz and Ravetz can be understood to emphasise that the term "scientific" in scientific decision support should not be interpreted as Kuhn's "normal science", but as their invention "post-normal science". The current article may also indicate that scientific decision support in an inter-paradigmatic context is somewhat of an oxymoron if "scientific" is interpreted as normal science. Science is not policy-making, and policy-making is not science – but the two can nevertheless be combined, as long as it is clear that results are not exact and definitive, but open to interpretation and further elaboration. Discussion should therefore be given strong prevalence in presentations of scientific decision support.

DISCUSSION AND CONCLUDING REMARKS

From a practical point of view, it is paramount to avoid too long idle or semi-idle periods of information collection, contemplation and invention (not to mention writer's block) both at a lower and higher level of generalisation within the sketched process. The model process outlined in this article can hopefully reduce difficulty and frustration and improve metacognition by providing an improved understanding of the challenging movement between phases of a complex interdisciplinary project. While the outline could be useful as a road map in wide-ranging decision support projects, it should be noted that it is merely a humble suggestion by this author based on general experience, and that it has not been experimentally verified that it will enhance or speed up a project. Perhaps future innovations within the aforementioned field of construal level theory may come up with suggestions for how to efficiently use different cognitive modes of contemplation and action in research projects.

There may also be other viable roads than the one suggested in this article. Perhaps it will prove time-saving if the confused and desperate researcher with "information overload" insists on avoiding an movement into haughty generalisations, by instead carving out a down-to-Earth way forward – or perhaps it will just be futile. And on the contrary, perhaps the arrogant "world champion" of his subject-matter should join a convent instead of tainting his precious illumination by revisiting and communicating its details and thus being forced to re-join the brute realities of the real world. Or perhaps it is rather a sign of ignorance to ridicule some of those whom we perceive to be arrogant?

Of course, it is conceivable that it is too structured and too simple to talk about one generalisation phase and one specification phase; these stages will probably – in practice – happen at different times dispersed throughout the process.

Trying to prematurely force one's way out of an information maze and decision freeze does not always work. Perhaps the legends of the Minotaur and Faust can be considered for further understanding of this peculiar topic.

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AUGMENTED REALITY IN TOURISM – RESEARCH AND APPLICATIONS OVERVIEW

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ABSTRACT

Augmented reality is a complex interdisciplinary field utilizing IT technologies in diverse areas such as medicine, education, architecture, industry, tourism and others, augmenting the real-time, real-world view with additional superimposed information in chosen format(s). The aim of this paper is to present an overview of both research and application aspects of using augmented reality technologies in tourism domain. While most research, and especially applications, are dealing with and developing visual-based augmented reality systems, there is a relevant amount of research discussing the utilization of other human senses such as tactioception and audioception, both being discussed within this work. A comprehensive literature analysis within this paper resulted with the identification, compilation and categorization of the key factors having the most relevant impact on the success of utilization of augmented technology in tourism domain.

KEY WORDS

augmented reality, tourism, AR applications

CLASSIFICATION

JEL: L83, Z32

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INTRODUCTION

In the augmented reality environment user is presented with a real-world view in real-time, but artificially augmented with information that is generated and superimposed by a specific computer system including but not limited to digital images, videos, texts, sounds, GPS location data, tactile vibrations, and similar. The information about the world may become interactive and possible to manipulate with. The augmented reality applications include numerous fields, such as medicine [1-4], architecture [5, 6], education [7-9], industry and robotics [10,11], entertainment, military, and others.

A more recent study exploring the versatility of applications of augmented reality is presented by Billinghurst et al. in [12], but also a less recent, but equally valuable contribution is made by Yu et. al [13], including application, limitation and future direction review of augmented reality.

At this point, it is important to explicitly distinguish the augmented reality from a concept of virtual reality. While virtual reality uses exclusively virtual surroundings (computer-generated graphics, animations and other information), augmented reality uses real-world surroundings, augmented with virtual objects [2] in real time.

Physical environment can be augmented via any human sense [14], including sight, touch, hearing, taste and smell, although the most commonly used augmentations up to date are visual and auditory, with visual displays having a “pivotal role in supporting the spatial on-trip activities of tourists” [15]. This paper will present both systems based on visual information, and systems based on other sensory input researched and/or developed in the tourism domain.

AUGMENTED REALITY IN TOURISM

Augmented reality has the potential to improve the tourist experience and help tourists to access relevant information, thus improving their knowledge regarding their touristic destination, while increasing levels of user’s entertainment throughout the process [16]. The information provided to users via augmented technology may be context-aware and personalized to user’s characteristics and needs.

Yovcheva et al. [17] define the augmented tourism experience as a “complex construct which involves the emotions, feelings, knowledge and skills resulting from the perception, processing and interaction with virtual information that is merged with the real physical world surrounding the tourist.”, arguing that the topic of experiences (expected and actual) from using the augmented reality technology in the context of tourism is still not sufficiently researched.

Utilization of augmented reality in tourism context proved to be a promising path in several existing papers such as [14, 18], was being a target application context in earlier research efforts [19-21], but also in more recent work on augmented reality context, such as [22, 23].

Garcia-Crespo et al. argue that the tourism industry is currently in need of highly dynamic, interactive and entertaining technology-based integrated value-added services [24]. The same authors present the developed SPETA system, which provides recommender services based on the knowledge of user’s preferences and current and past locations.

Kounavis et. al discuss the use of augmented reality applications in the tourism context, addressing the technical aspects of mobile augmented reality application development, but also examining the state of the art of such developments and propose an archetypal

framework for the development of mobile AR applications [25]. Their research is limited exclusively to augmented reality mobile application development, but they argue that several examples have shown that augmented reality "can aid tourist organizations and professionals towards reaching a wider audience by serving as the delivery technology of appealing multimedia content and mobile applications, fine-tuned to various knowledge levels."

The main issues with the mobile AR technology authors recognize in mobile hardware requirements (fast enough CPU, large enough RAM capacity, camera, continuous WiFi and/or 3G connectivity, etc.), and, more importantly, in interoperability issues emerging across mobile platforms, and although there "are many frameworks and toolkits for developing mobile applications based on AR technology", the developed applications cannot be used in all the relevant mobile operating systems.

Table 1. Availability of frameworks through mobile operating systems [25].

	iOS	Android	Symbian	BlackBerry
DroidAR		X		
DWARF				
Layar	X	X	X	X
IN2AR				
FLARManager				
PanicAR	X			
SudaRA				
FLARToolKit				

The Archeoguide project has delivered a personalized electronic guide and tour assistant to cultural site visitors, providing a walking experience through a cultural environment in order to have the possibility of observing the real world, with visualizing 3D reconstructions of monuments and thus acquiring additional information during the visit [20, 26].

Fritz et. al describe the development of an AR interactive visualization system based on the concept of tourist binoculars and with integrated AR scene enhancements within the tourist application [16]. The focus idea is for the user to retrieve personalized multimedia information by means of user-friendly interface, thus aiming to increase the overall touristic experience.

Authors list several other examples of using the augmented reality technology in tourism, namely, augmented walks, where tourists are placed within the real environment, but with the possibility to view additional artificial information in the form of 3D reconstructions of monuments, either via digital screens, or head-mounted displays. Within the "Ename 974" project, the system superimposes the real-world scenes with virtual 3D reconstructions of archaeological monuments; the results are displayed on a visualization device [27].

According to [16], several national parks in the US have also "added augmented reality stations to view archaeological sites on far distant cliffs and other inaccessible locations". The devices enabling the augmented reality experience are telescope-like and are superimposing animations on the real-world scenes, providing virtual recreations and information on real fossil remains.

Smartphones represent the first medium with the potential to introduce augmented reality to the mass market, which has a significant impact for augmented reality tourism applications [28-29].

This potential rises from the facts that smartphones combine all the necessary technologies for enabling augmented reality applications, in one pocket device, unlike head-mounted displays or full-sized computers or laptops.

Yovcheva et al. claim that, in the context of mobile augmented reality applications, the effective and usable design is still "at its infancy", and cover the overview and evaluation of 22 smartphone applications in their work, outlining "tourism-related domain-specific design challenges" [30]. The selected criteria for comparative overview and evaluation of smartphone augmented reality applications is presented in Table 2.

Table 2. A selected criteria for comparative overview and evaluation of smartphone augmented reality applications for tourism [30].

Functionality	Description
1. **Search and Browse**	Search and browsing (categorical search) mechanism provides access to relevant information (Rasinger et al., 2009).
3. **Context-aware push**	The tourist may miss out on important/interesting information, especially in information-rich urban settings (Raisnger et al., 2009).
4. **m-Commerce**	The possibility for booking/reservation and payment (Rasinger et al., 2009).
5. **Feedback**	A mechanism to provide and/or receive feedback from/to other tourists or tourism authorities (Rasinger et al., 2009).
6. **Routing and navigation**	The possibility to obtain directions and navigation to a POI, once it is visualized in AR view and selected (Umlauft et al., 2003).
7. **Tour generation**	Adding POIs to a (pre-generated) itinerary allows tourists to plan better and manage their leisure experience (Umlauft et al., 2003).
8. **Map services**	Helps tourists to obtain an overview of a larger territory (Suh et al., 2010).
9. **Communication**	Option to realize direct contact with accommodation providers, exhibition owners and others involved in service provision (Rasinger et al., 2009).
10. **Exploration of visible surroundings**	Apart from looking up for information about a particular item, place, object and category, tourists may wish to "explore" available information about their surroundings without pre-defined criteria (Ajanki et al., 2010).
11. **Interactive AR view**	A "clickable" AR view could serve as an interface to additional, more detailed information about a point of interest (Wither et al., 2009).
12. **Filtering of AR content**	The option to filter and change interactively the visualized content in AR view. This is an important feature, keeping in mind that urban environments are rich in potential targets for annotation (Tokusho and Feiner, 2009)

Authors conclude the applications' review with notes that current smartphone augmented reality applications provide tourists with location-specific information regarding the user's current surroundings, enable updated access to variable content, enable flexibility when delivering text and/or multimedia information and provide interactive annotations on top of map-based services. However, authors further argue that some relevant functionalities are still missing, such as context-aware push of information, feedback, routing, m-commerce, context awareness, and similar.

Further research into the mobile augmented reality application is presented by Han et al., who are investigating tourists' requirements for the development of a mobile AR tourism application in urban heritage, in the Dublin context [31]. The investigation was performed by in-depth interviews with 26 international and domestic tourists visiting Dublin city. Authors note that the "technology is just on the verge of being implemented in a meaningful way in the tourism industry", passing the initial hype stage. One of the main concerns is the non-interactive aspect of pushing the information to users.

The same authors argue that the end-user point of view has been neglected when developing augmented reality applications for tourism context, and therefore their research aims "to

identify and analyse tourist requirements to implement Augmented Reality technology in Urban Heritage". The results of their study showed several relevant aspects which could lead to better understanding and development of augmented reality applications for users; first, users (tourists) require a source of local and updated information which resides within the context and timeframe of their visit; the social networking functionality including reviews and suggestions from other users are widely used and could facilitate repetitive use; simple navigation and the design of user interface proved to be key factors for continuous use of augmented reality application.

In order to enhance visitor experience, museums are also preserving media such as radio, movie clips, photography, and one of the illustrative examples is the use of a guidebook in a historic home [32].

Augmented reality also tackles outdoor navigation where [33] demonstrate the use of augmented reality for collaborative navigation and information browsing tasks in an urban environment, having a direct impact on tourism domain. The information is presented to users via a head-mounted display, overlaying the real-world with a combination of text, graphical objects, 3D objects and images. Both navigation and information browsing functions support collaboration.

Some research on augmented reality in tourism context is focused on usability aspects and cognitive issues [34], but there is also research targeted towards expected user experiences from using augmented reality technology [35] and actual experiences [36]. Olsson et al. [37] documented captivation, motivation, engagement and novelty as some of the more relevant characteristics of expected user experiences with using augmented reality technologies.

Yovcheva et al. [17] have also worked on conceptualization of augmented tourism experiences, describing the main characteristics of augmented tourism experiences and outlining the framework consisting of "most significant determinants of augmented tourism experiences". The aim of the paper, according to authors, is to set directions for further research of augmented reality in the tourism context, but also to provide concrete help for designers and developers in engineering augmented tourism experiences.

The same authors have listed characteristics of augmented tourism experiences, their potential use within the tourism domain and examples of already developed AR systems. These characteristics include awareness, efficiency, empowerment, engagement, fun, liveliness, meaningfulness, motivation, novelty, playfulness and entertainment, safety, surprise, tangibility. Fig. 1. illustrates authors' developed framework for engineering augmented tourist experiences.

Authors conclude that the value that augmented reality systems facilitate in the overall tourist experience is determined by the fit between context and content, referring to the spatial, temporal, personal, and technical context where the AR system is being used.

Non-visual aspects of the augmented reality utilization within tourism context are discussed within several following papers.

Wei et al. [38] discussed haptic display and audio display, with their combination evaluated in representing tourism information to users with a mobile phone. The results of the study showed that information represented in the combined haptic-audio display yielded highest identification rate (86,7 %), while "no significant effect was found for rhythm or amplitude alone".

PocketNavigator [39] is a pedestrian navigation application with implemented tactile compass, which is using vibration patterns for navigating users to destinations.

Giachritsis et al. presented a method for developing tactile navigation patterns in context of basic directions, landmarks and actions [40]. Authors found that simple directions were simpler to identify in comparison to actions or landmarks.

Tactile displays for pedestrian navigation were also researched by Srikulwong and O'Neill [41]. The results of their study showed that, when using wearable tactile displays for pedestrian navigation, users' navigation accuracy was equivalent to that with a visual-based system, and that the route's completion time was significantly faster.

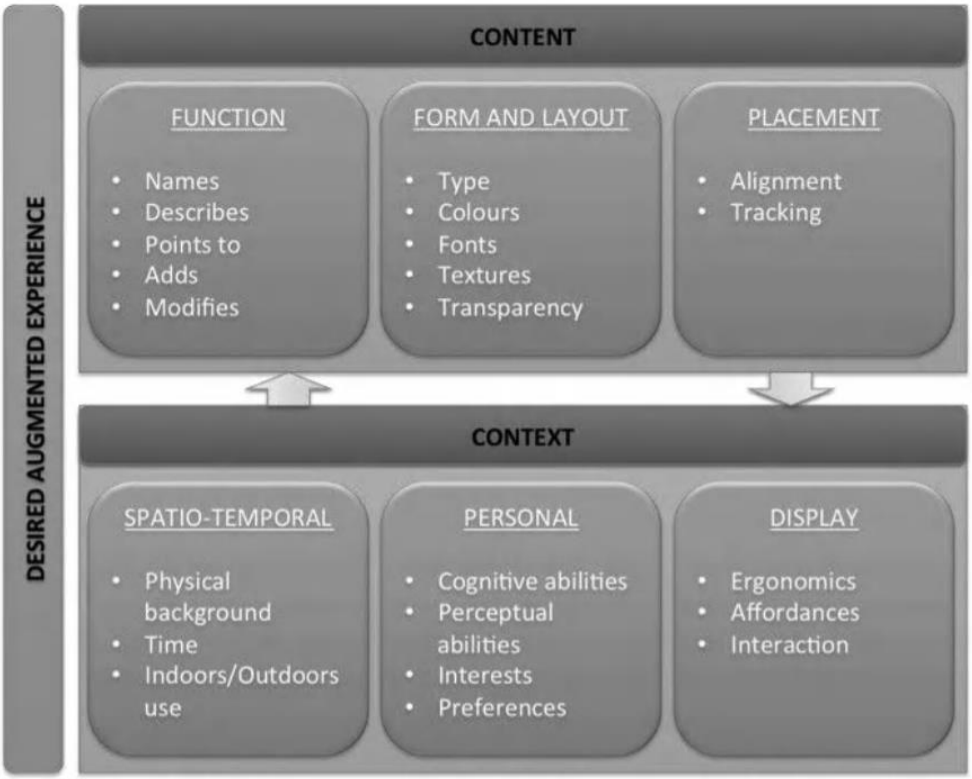

Figure 1. Framework for engineering augmented tourist experiences [17].

OVERVIEW OF RELEVANT FACTORS

Several identified dimensions and factors having a direct impact on the success of utilizing augmented reality technologies in tourism domain have been identified and extrapolated by the relevant literature analysis presented in the previous section. The factors were categorized within several dimensions: general requirements, functionalities, issues, overlay types and technologies, as presented in Table 3.

The key requirements for the augmented reality applications include dynamics, interactivity (push-only content proved to be inadequate in this context), entertainability, strong connection between user context and delivered content (delivered content should be up-to-date, real-time, local, and context-sensible in general), intuitive and adequate user interface avoiding cognitive overload, simple navigation within the application for effective application utilization. Functionalities are mostly extrapolated from [30] and supplemented with additional ones which were identified in the analysis process. Browser and search functions enable navigating through relevant content and finding the one which is relevant to the user. Map services include map browsing, routing and navigation, and are closely related to automatic tour generation for the user exploring the area of interest. Map services can also be associated with social networks, which might include feedbacks and various users'

discussions on related content. Communication enables direct channels to service providers, agents, and/or other users, etc.

Overlay types include identified sensory inputs which are currently in relevant use. Those include text, graphics, videos, sounds, and tactile input (vibration patterns for example).

Table 3. Identified dimensions of using the augmented technology within tourism context with related factors.

General Requirements	Functionalities	Issues	Overlay Types	Technologies
● Interactivity ● Dynamics ● Entertainability ● Context-content correlation ● Intuitive user interface ● Simple navigation ● Captivating, motivating and engaging content [37] ● Awareness, efficiency, empowerment, engagement, liveliness, meaningfulness, motivation, novelty, safety, surprise, tangibility [17]	● Browse, search ● Map, routing, navigation ● Communication ● Context-aware push ● Mobile commerce ● Social networks ● Collaboration ● Tour generation ● Recommender services	● Hardware requirements ● Device-specific challenges ● Interoperability ● Portability ● Ease of use ● User comfort ● Accessibility ● Push-only ● Safety	● Text ● Graphic ● Video ● Audio ● Tactile	● Handheld integrated ● Head-mounted ● On-site static peripherals ● Site-related mobile

Technologies are categorized on several types, such as handheld devices with integrated technologies such as display, GPS, gyroscope, compass, accelerometer which include smartphones, tablets and similar; head-mounted devices such as HUDs, lenses and similar; on-site static devices such as monitors, projectors, speakers, binoculars, and similar; on-site mobile devices where the AR environment is for example embedded within the tour vehicle; etc. Issues can be identified in hardware requirements (RAM, CPU, display resolution, sensors, etc.), hardware-specific challenges (for example, using mobile phone as an AR device requires constant holding of the device in front of the user, affecting the comfort and safety requirements; distorting effect of the phone's camera is changing the real-world view as seen through the eye; etc.), interoperability of the applications through the number of platforms (incompatible hardware platforms or operating systems for example), portability of devices, comfort and safety in using the devices, questions of accessibility for persons with damaged and/or non-functional senses, and non-interactive nature of push-only content. To address all these issues in an augmented reality environment might prove to be a challenging task, but ultimately would lead to a more successful utilization of the AR technology in tourism domain.

CONCLUSION

This article presents an overview of past and present research and applications in utilizing the augmented reality technologies in tourism context, while identifying and categorizing key factors having the most significant impact on the successful utilization of such applications. Identified factors are listed within several appropriate categories: general requirements, functionalities, issues, overlay types, technologies, and present a clear starting point for the future overviews, research and developments within the area.

While most of the research and applications are oriented towards augmented visual overlays, a certain amount of papers is dealing with non-visual inputs such as audio and haptic, which might be comparably effective in certain use-case scenarios (routing for example), but with the potential to have considerably less distracting elements in comparison with the visual overlays, thus positively affecting, for example, the safety requirement. Such technologies are currently in need of further development and research in order to reach the availability and utilization level of visual-based applications and devices, but certainly have the potential in the field domain.

The Introduction section of the paper overviews the augmented reality technology in general, clarifies the distinction between the augmented reality and virtual reality, and gives an overview of related work.

The Augmented Reality in Tourism section provides a comprehensive literature overview of research, technology and application developments in the context of utilizing the augmented technology in tourism domain.

The Overview of Key Factors section identifies and elaborates those key factors having a critical influence on utilizing the augmented technology in tourism domain, and categorizes them in several appropriate groups, namely, general requirements, functionalities, issues, overlay types and technologies.

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RANKING OF CROATIAN RESEARCHERS FROM SEVERAL DISCIPLINES USING GOOGLE SCHOLAR DATABASE

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ABSTRACT

Using the h-index and the total number of citations in (natural) sciences, techniques and humanities in this article the best 10 Croatian researchers is ranked. The list may be formed based on the h-index and the total number of citations, given in Web of Science, Scopus, Publish or Perish Program and Google Scholar. Data for the first 10 researchers are presented. Google Scholar is the most complete. Therefore, to define a single indicator, h-index calculated by Google Scholar may be a good and simple one. The author chooses the Google Scholar database as it is the broadest one.

KEY WORDS

ranking, Croatian researchers, Google Scholar, h-index, total number of citations

CLASSIFICATION

ACM: D.1.1.
JEL: O31
PACS: 89.70.Hj

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INTRODUCTION

Due to the requests in a variety of activities (for example, who will be proposed as a project leader) ranking researchers in different disciplines of science become very important in last decade. Ranking is possible on different criteria: number of published papers, number of citations, etc.

One of these measures is h-index which includes both the productivity and citation impact of the publications of a scientist. The index was suggested in 2005 by Jorge E. Hirsch [1]. h-index can be determined according to the different sources:

- Google Scholar,
- WOS (Web of Science),
- Scopus,
- Publish or Perish Program.

In this article the list of the 10 best researchers of Croatian researches is presented. List covers researchers from natural sciences, techniques and human sciences.

As a primary source Google Scholar [2] has been used [3-12]. The author chooses the Google Scholar database as it is the widest (see Table 1). Introduced by Google in 2004, Google Scholar has become a very popular alternative data source. Google Scholar is the most complete [13-16].

Therefore, to define a single indicator, h-index calculated by Google Scholar may be a good and simple one.

Ranking is possible to be based on h-index (primary) and total number of citations.

Table 1. Rate of citations in Scopus and Web of Science according to Google Scholar ones.

Discipline	Scopus citations as % of Google Scholar citations	Web of Science citations as % of Google Scholar citations
Humanities	11,5	7,0
Social Sciences	30	22,7
Engineering	57,6	45,7
Sciences	64,2	65,6
Life Sciences	70,5	66,8

The article is organized as follows:

- In Section 1, the Introduction is given,
- In Section 2, the Ranking list of researchers in Croatia is considered,
- Conclusions are given in Section 3.

RANKING LIST OF CROATIAN RESEARCHERS

In the following text detail information about researchers on the list based on Google Scholar are presented,

List of 10 best Croatian researchers can be constructed based on different sources. The primary condition for ranking is the h-index and the total citation number of the publications.

Table 2. h-index and number of citations for Croatian researchers from extracted disciplines, from Google Scholar.

No.	Researchers	h-index	Citations
1.	Ivica Puljak	114	70 062
2.	Nikola Godinovic	107	65 283
3.	Darko Mekterovic	90	49 004
4.	Mile Dželalija	82	44 648
5.	Nikola Poljak	80	19 176
6.	Sven Gotovac	62	18 271
7.	Linda Vickovic	62	15 387
8.	Eugen Mudnic	61	17 959
9.	Ozren Polašek	57	17 514
10.	Stipan Jonjic	52	8 523

Researchers, from Google Scholar data, were ranked according h-index in decreasing order as a first criteria and then by the total number of citations (Table 2).

Based on the data of Google Scholar the list of the 10 best Croatian researchers is given in Figures 1-10. The primary condition for ranking is the h-index followed by the total citation number of the publications.

1.

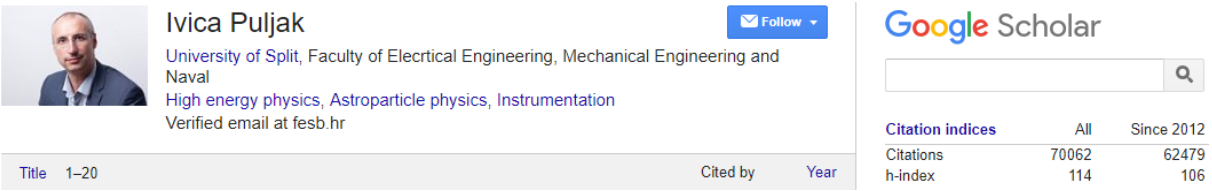

Figure 1. Ivica Puljak, h-index = 114, citations: 70 062 [17].

2.

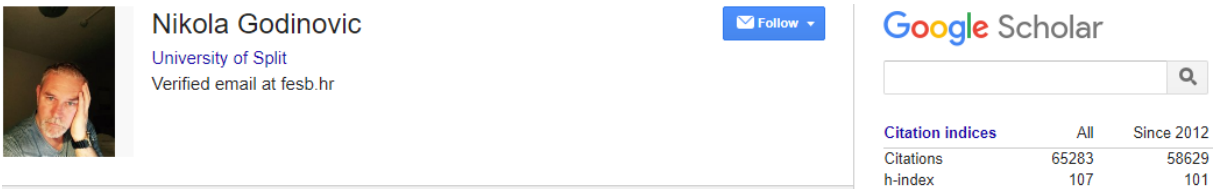

Figure 2. Nikola Godinovic, h-index = 107, citations: 65 283 [18].

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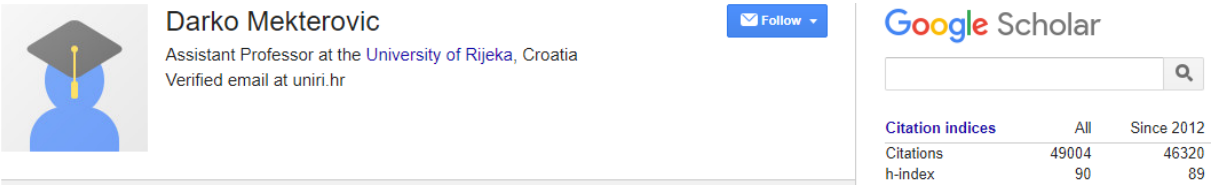

Figure 3. Darko Mekterovic, h-index = 90, citations: 49 004 [19].

4.

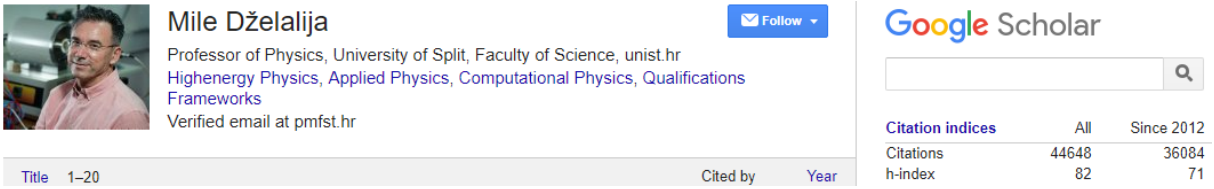

Figure 4. Mile Dželalija, h-index = 82, citations: 44 648 [20].

5

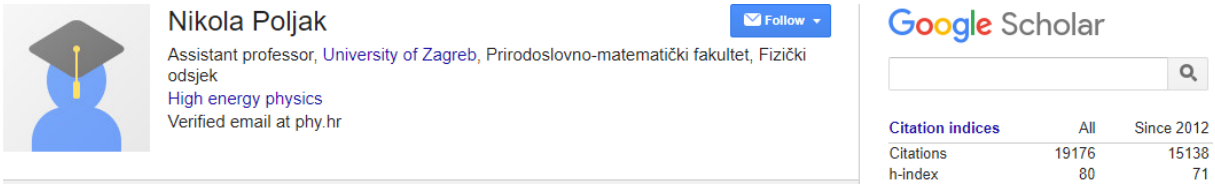

Figure 5. Nikola Poljak, h-index = 80, citations: 19 176 [21].

6.

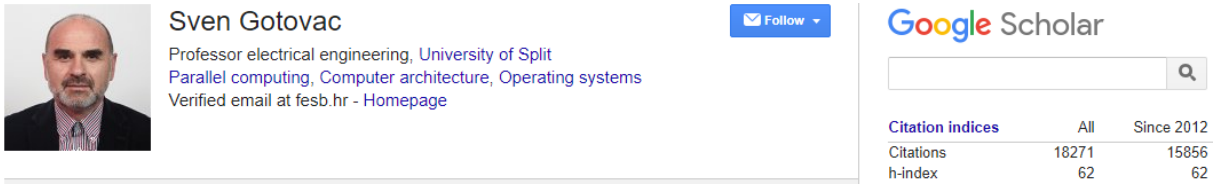

Figure 6. Sven Gotovac, h-index = 62, citations: 18 271 [22].

7.

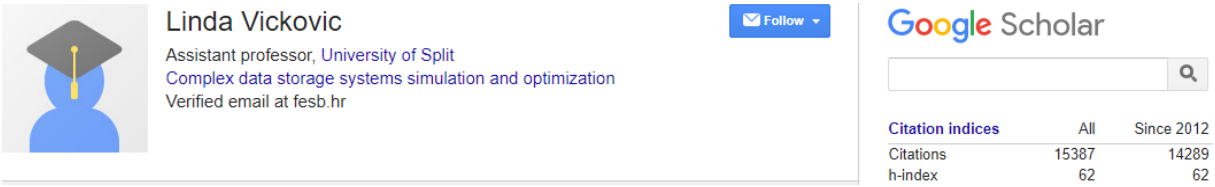

Figure 7. Linda Vickovic, h-index = 62, citations: 15 387 [23].

8.

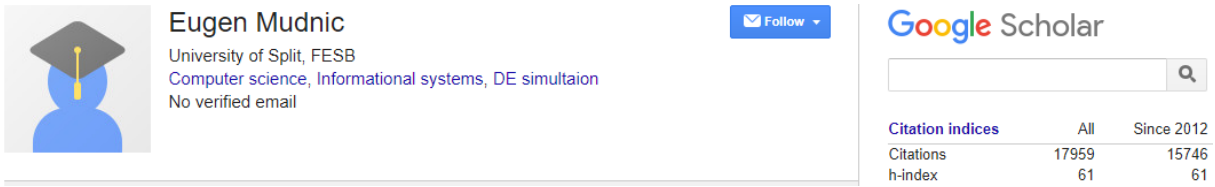

Figure 8. Eugen Mudnic, h-index = 61, citations: 17 959 [24].

9.

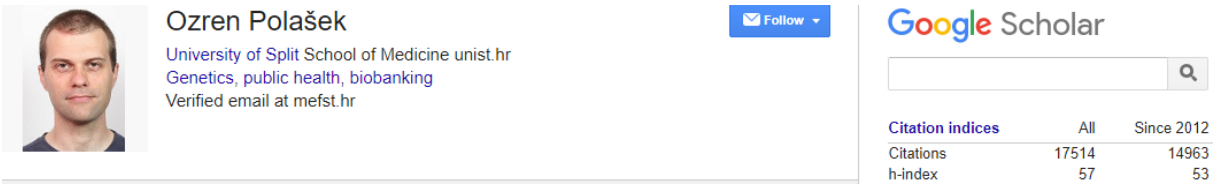

Figure 9. Ozren Polašek, h-index = 57, citations: 17 514 [25].

10.

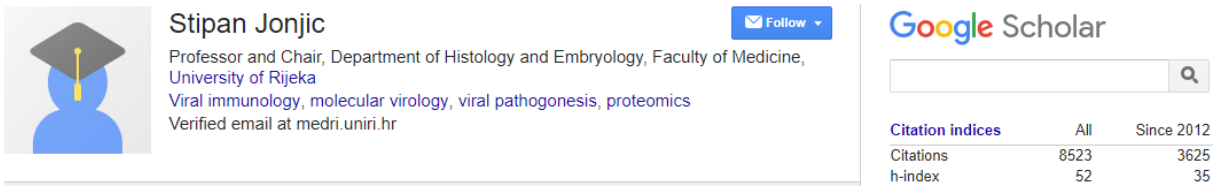

Figure 10. Stipan Jonjic, h-index = 52, citations: 8 523 [26].

CONCLUSIONS

List of best 10 reseachers in natural sciences, techniques and humanities, of Croatia is presented, The ranking is made based primary on h-index and total citation number based on the database in Google Scholar, Researches ranked first by h-index in decreasing order and then by the total number of citations,

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RADIOFREKVENCIJSKA IDENTIFIKACIJA POMOĆU BESPILOTNIH LETJELICA PRILIKOM ŽELJEZNIČKIH NESREĆA I KATASTROFA

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SAŽETAK

U današnje vrijeme, upute za rad na željeznici bave se i prijevozom opasnih tvari. Naše istraživanje motivirano je nastojanjem brzog iznalaženja specifičnih rješenja sigurnosne problematike baratanja otpadom, nastalim prvenstveno prilikom nesreća i katastrofa vezanih uz prijevoz opasnih tvari. Kako bi se zajamčio siguran prijevoz opasnih tvari i kako bi se postiglo brzo i učinkovito baratanje otpadnim opasnim tvarima ispuštenim u okolinu tijekom izvanredniih situacija, razmotrili smo novu metodu, radiofrekvencijsku identifikaciju opasnih sadržaja pomoću bespilotnih letjelica.

KLJUČNE RIJEČI

željezničke nesreće, transport opasnih tvari, upravljanje otpadom, radiofrekvencijska identifikacija, bespilotna letjelica

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OPIS ZLOČINA I NASILJA U GRADOVIMA TEMELJEN NA IMUNOLOŠKOM SUSTAVU

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SAŽETAK

Zločin je prisutan oko nas tisućljećima. Zločin je sličan patogenoj infekciji dok je policijski odgovor na njega sličan odgovoru imunološkog sustava. Biološki imunološki sustav ukljuen je u svojevrsnu utrku s patogenima. U radu se predlaže teorija zločina i nasilja u ljudskim društvima a posebno u velikim aglomeracijama poput gradova, temeljena na imunološkom sustavu.

Rad zastupa stav kako opis zločina temeljen na imunološkom sustavu može dati novu perspektivu dinamike nasilja u društvima. Kompeticija između policijskih snaga i kriminalaca slična je načinu na koji imunološki sustav djeluje prema invazivnim patogenima. Gradovi imaju svojstva slična biološkim organizmima i u ovom opisu policijske i vojne snage odgovaraju imunološkom sustavu koji štiti organizam od štetnih unutarnjih i vanjskih djelovanja.

Zastupani opis ima posljedice na javne politike: koliko financijskih sredstava treba uložiti u borbu protiv zločina, koje su optimalne policijske strategije i brojnost policijskih snaga poastavljenih u različite gradove. Ovaj pristup može biti primijenjen na druge vrste nasilja u gradovima (poput terorizma) kao i na nasilje u drugim zajednicama primata i društvenih kukaca.

Rad je prvi korak prema kvantitativnoj teoriji nasilja i sukoba u ljudskim društvima. Naposljetku, nadam se kako će ovo pomoći u dizajniranju pametnih i učinkovitih gradova koji mogu biti održivi pri stalnom porastu populacije.

KLJUČNE RIJEČI

kompleksni sustavi, inspirirano imunološkim sustavom, računalna sociologija, modeliranje društveno-ekonomskih sustava, umjetni imunološki sustav

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KONCEPTUALNI PRISTUP UPORABI BESPILOTNIH LETJELICA U RAZLIČITIM DJELATNOSTIMA

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SAŽETAK

Rad razmatra trenutnu situaciju razvoja softvera za grupu mobilnih agenata u slučaju primjene na bespilotne letjelice. Generalno gledano, bespilotne letjelice su primjenjene za prijenos informacija, mase i energije i njihov rad u grupi povećava učinkovitost obavljanja zadataka u odnosu na primjenu pojedinačne bespilotne letjelice. Unatoč svakodnevnoj uporabi, njihov potencijal ostvaren je u vrlo maloj mjeri. Sljedeći korak u povećanju iskorišeneosti potencijala grupe bespilotnih letjelica je razvoj softvera za njihovo upravljanje. Početni uvjeti koje takav softver mora ispunjavati su jednostavnost kôda, otvorenost obzirom na broj članova grupe a zatvorenost obzirom na razmjenu informacija među članovima. Rad analizira potencijalne smjerove razvoja tog softvera.

KLJUČNE RIJEČI

softver, mobilni agenti, bespilotna letjelica, autonomna grupa, zalihost

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BARATANJE BROJNIM KOMPLEKSNIM I INTERDISCIPLINARNIM INFORMACIJAMA U ODLUČIVANJU PRILIKOM ISTRAŽIVANJA

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SAŽETAK

Od istraživača se ponekad očekuje istraživanje kompleksnih i interdisciplinarnih područja, kako bi dali znanstveni doprinos odlučivanju na velikim rasponima. Ovo može biti izazov jer, uobičajeno, početni nedostatak poveznica između istraživanih informacija može izazvati konfuziju. Rad predlaže jedan mogući put k rješenju tog problema, koje može dovesti do holističkog razumijevanja, a zatim i do njegove primjene. Proces je prikazan dijagramatski. Njegovi izdvojeni aspekti su analizirani. Proces uključuje prijelaz na višu razinu poopćavanja kako bi se postigao bolji pregled i formulrali mogući novi koncepti, a zatim povratak na početnu detaljniju razinu kako bi iskomunicirali i primijenili dobiveni uvidi. Identificirani su potencijalni izazovi i etape. Ukratko je razmotren potencijalni sukob između uobičajene znanosti i podrške odlučivanju te je istaknuto kako *post-uobičajena znanost* može biti bolji opis naznačenih procesa nego samo *znanost*.

KLJUČNE RIJEČI

interdisciplinarno istraživanje, poopćavanje, procjenjivanje, teorija znanosti, razboritost

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PROŠIRENA STVARNOST U TURIZMU – PREGLED ISTRAŽIVANJA I PRIMJENA

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SAŽETAK

Proširena stvarnost kompleksno je inderdisciplinarno područje koje koristi informacijske tehnologije u raznim područjima poput medicine, edukacije, arhitekture, industrije, turizma i ostalih, proširujući pogled na stvarni svijet u stvarnom vremenu sa dodatnim preklopnim slojem informacija u odabranom formatu ili formatima. Cilj ovog rada je pregled korištenja tehnologija proširene stvarnosti unutar domene turizma sa istraživačkog aspekta, ali i aspekta primjene. Dok se brojni radovi i primjene dotiču isključivo razvojem vizualnih sustava proširene stvarnosti, postoji i relevantan broj radova koji se bave razvojem sustava temeljenih i na ostalim ljudskim osjetilima, poput osjetila dodira i zvuka, koji su oboje obuhvaćeni unutar ovog pregleda. Opsežni pregled literature unutar ovog rada rezultirao je identifikacijom, kompilacijom i kategorizacijom ključnih faktora koji imaju relevantan utjecaj na uspjeh primjene tehnologije proširene stvarnosti u domeni turizma.

KLJUČNE RIJEČI

proširena stvarnost, turizam, primjena proširene stvarnosti

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RANGIRANJE HRVATSKIH ZNANSTVENIKA IZ NEKOLIKO DISCIPLINA POMOĆU BAZE GOOGLE ZNALAC

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SAŽETAK

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KLJUČNE RIJEČI

rangiranje, hrvatski znanstvenici, Google Znalac, h-indeks, ukupan broj citata

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