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Drones in Smart Cities

Rapid development of information and communication technologies (ICT) in Hungary provides great opportunities for the emergence of smart cities in the years to come. A similar or even a larger-scale development is experienced in the market of unmanned aerial vehicles (UAV). Over the past years, the unmanned aerial vehicles (UAVs) – commonly known as drones – have been demonstrating a rapid expansion not only in the area of government and industry use but in the public sector, as well. A selection of more than 1,700 types of drones is available in almost any of the online stores. The great variety of offered types implies the diversity and possibility of a multi-purpose use, from the agricultural sector through security technology to market/civil services. Wandering a little bit from the point of device dimension and moving into the systems dimension, the integration of devices fulfilling various functions allows to implement cost-effective and sustainable complex system, providing a high level of comfort. By weaving two innovative areas for development into each other, one can significantly expand the possibilities of using drones in the everyday life. This article focuses on the description (non-exhaustive) of potential application areas resulting from the integration of drones and smart city technologies, putting particular emphasis on security-related roles and new tasks arising from the operation of smart cities.

Keywords: *UAV, ICT, smart city, UAM, cities of tomorrow, AAV*

1. Introduction

The creation of smart cities was initiated by the boost in the ICT development [1] back in 2008–2009, as the emergence of two extremely important areas – a large-scale development of wireless networks and appearance of so called IoT tools (Internet of Things) – goes back to that time [2]. In addition to urbanisation processes, economic development and social maturity, technical development is considered one of the most important drivers for the emergence of smart cities. Application of new technologies has enormous potential in the development of cities, which requires the determination of innovation directions and elaboration of a unified system of definitions and concepts, so I am going to start my article with the definition and explanation of the smart city concept. Needless to say, that I am not going to create a new definition and prefer to use as a basis those already existing concepts that best fit in with the systematisation of new directions for development arising from the merge of drone and smart city technologies.

2. Dimensions and functions of a smart city

Smart City is not the term that exactly defines the underlying content, but rather a designation that can be used as a generic concept. When dealing with this topic, we can also come across such terms as "digital city" and "intelligent city", which can also be linked to sustainable, economically efficient urban development, as well as to the functions and services opening up new dimensions and arising from the application of ICT technologies. In terms of the international professional literature, in my point of view, the most communicative wording is the definition offered by the British Standards Institution (BSI) [3] since it seems to be sufficiently general, comprehensive and fits into the topic touched upon by the publication. The above-mentioned definition specifies smart city as one where there is "effective integration of physical, digital and human systems in the built environment to deliver a sustainable, prosperous and inclusive future for its citizens". Needless to say, that many other approaches exist in addition to the above-described one, due to the fact that this concept is widely used and, correspondingly, those using the concept put their own viewpoint in its centre. Some other definitions to mention:

- Digital city. Digital city is understood as a wired, digitalised city that uses ICT for both data processing and information sharing, but also supports communication and Web 2.0 democracy [4] [5].
- Sustainable city. It is understood as a city using technology to reduce CO_2 emissions, to produce energy in an efficient way and to improve energy efficiency of buildings: it will be a green city [6].
- Technological city. It is understood as a city using technology to improve its infrastructure and services, efficiency and effectiveness: its smart projects focus on urban space quality, mobility, public transport and logistics [7].
- In Hungary, Government Decree 314/2012 (XI.8.) provides the definition of a smart city in two parts, as follows: "a settlement that elaborates and implements its integrated urban development strategy based on the smart city methodology. Smart city methodology: urban development methodology of settlements or a group of settlements that develops their natural and built environment, digital infrastructure, as well as the quality and economic efficiency of municipal services using cutting edge and innovative information technologies, in a sustainable way and with increased public involvement".

The wording formulated in the above Hungarian legal act, as well as definitions provided in the publication of the British Standards Institution (BSI) describe the way leading to the achievement of the desired state, i.e. its methodology, rather than the achievable state itself. Typically, studies carried out by key players of the industrial sector break-down the areas determining the directions for development into sub-systems covering, as a rule, 6–8 sub-areas (security, people, energy, economy, communication, government, environment, mobility, services, water) [8]. Based on the above, the general goal is to make the city – in addition to economy and sustainability – more liveable, more secure, more lovable and more attractive. In order to achieve this goal, one should determine development directions that would assure that the residents feel better and also offer a solution to the problems of the settlement [9]. Nowadays, these goals can be easily achieved with the help of ICT, the effectiveness of which can be further enhanced by the use of UAV devices. New, important functions appear at the intersection of ICT and UAV technologies, and the efficiency of existing ones can be further increased. During the past few years, rapid development – among others – of the aerospace, computer, instrumentation and control technologies has opened the possibility for a wide-range expansion of such devices that previously were available only to a small, specific user community. Nowadays, the most dynamically developing type seems to be the unmanned aerial vehicles. Not a day goes by without reading in mass media about UAV-related innovations, developments and new areas of application [10]. While analysing the market of potential application of UAV devices, three major areas can be identified according to the classification based on certain sectors using the technology:

- Recreational (hobby) use, civil application
- Industrial and commercial use
- Public service area

At the present moment, the highest market potential of UAVs within industrial and commercial area of application is connected with the infrastructure industry (36%), which means a considerable area for development in case of smart cities [11]. Furthermore, the use of the integrated approach in the application of smart city technologies can be considered the basic principle [9]. It can be definitely stated that the direct consequence of a higher degree of integration is the appearance of a larger number of digital platform devices and systems in urban management. It is not difficult to come to a conclusion that such a situation results in an increasing demand for energy that should be generated in all cases in an economically efficient and environment-friendly manner provided that we want to fit in with the smart city concept. Obviously, one of the plausible solutions to meet the demand for energy is the application of technologies for renewable energy generation. It can be stated that there is no smart city without renewable energy generation. At the present moment, the most dynamically developing area is connected with photovoltaic power generation solutions, which are able to generate electricity for the grid and can be easily implemented into local, decentralised urban environments as well. The pre-condition for the uninterruptible and reliable power supply lies in regular and professional maintenance and inspection; an UAV equipped with a thermal camera can become a cost-effective tool of such an activity, taking into consideration the specifics of photovoltaic power generation [12].

3. Hobby use for civil purposes in the light of smart cities

According to the Aviation Act (Hungarian: Lt.), the use of UAS (Unmanned Aircraft Systems) means: the use of an unmanned aircraft for recreational purposes, not being in connection with the economic use and execution of governmental tasks [8]. In practice, this type of application is limited to a very narrow scope, for example, photography and aerial video recording. However, in terms of smart cities, photos and videos taken by a large number of hobby drones can be one of the input sources of a big data system, in case of an appropriate regulatory basis. Exactly for this functional possibility it should be emphasised that it is not the use of these unmanned aircrafts that may pose a data protection problem, but the atypical data management with additional accessories that can be attached to these devices.

The difference as compared to the previous data management method is that even with the intended use, the infringement of privacy (or even a significant disturbance) can pose a high risk since the device collects data about everything and everyone "on its way" without any distinction [13].

4. Industrial and commercial use in the light of smart cities

Two interesting uses are worth mentioning in this area of use.

4.1 Installation, operation and maintenance of solar cells

Having completed the installation of solar cells, it is recommended to record a zero-energy state of the system after some 10 operating hours. First of all, it means testing with the use of a thermal camera aimed at revealing defects that can be traced back to damages, installation errors or even a design error that may result in a significant loss of power output. Figure 1 shows the damage caused during installation by a 5 x 5 cm piece of tile, which cannot be noticed by the naked eye. This damage deteriorates the solar cell efficiency and can lead to further degradation, which may even result in the loss of energy generation by the entire solar cell string. After the identification and elimination of installation errors, as times passes, some small or large surface contaminations appear on the photovoltaic (PV) elements during operation. The rate and extent of emerging contaminations depends on several environmental parameters and on the installation angle. It is obvious that solar panel manufacturers place great emphasis on ensuring such surface designs that – when exposed to rain effects – guarantee that the dust layer will be washed away as a self-cleaning function. However, this self-cleaning function is not sufficiently efficient in case of stronger contaminations like bird droppings or soot deposition from burning wood or coal fuels in a suburban environment. Furthermore, this self-cleaning function does not work in case of installation inclination angles below 25° due to low rainfall run-off rate. In such cases, occasional or even regular cleaning of solar cells may become necessary to assure and maintain their continuous maximum energy performance [14]. Failure to perform cleaning of the solar cell surface can result in the reduction of performance characteristics of up to 6%. The inspection of solar cells should be carried out with the pre-determined frequency in order to ensure continuous trouble-free operation, to identify failed elements, to determine the need for cleaning based on the inspection result or to reveal the corrosion process. Performance of inspections and maintenance activities is a time-consuming and cost-intensive process – due to the specifics of installation and location of solar panels, which are typically installed on roofs in urban environments. A ladder or a basket lift truck is required to perform the inspection, which increases costs. There may also be hard-to-reach locations making the performance of this task almost impossible or extremely expensive. As the number of installed solar cells increases, more and more companies are providing all-in-one solutions throughout the entire life cycle. In order to achieve efficient operation and low maintenance costs, many service providers perform inspections with the use of drones, offering many advantages in comparison with traditional procedures. By means of placing thermal cameras on unmanned aerial vehicles and further development of artificial intelligence-based temperature measurement technology, UAVs offer infinite possibilities both in industry and in healthcare applications, as one can read in "Légből kapott segítség a Covid-19 ellen" [Help Received from the Air against Covid-19] by Béla Kiss and Gábor Major [15].

As of today, there are already examples of how water required for the cleaning of solar cells can be supplied to the upper surface of solar cells with the help of a sprinkler head attached to the drone. What has not been mentioned so far is that most of the pre-order field surveys are carried out with the help of drones equipped with a video camera.

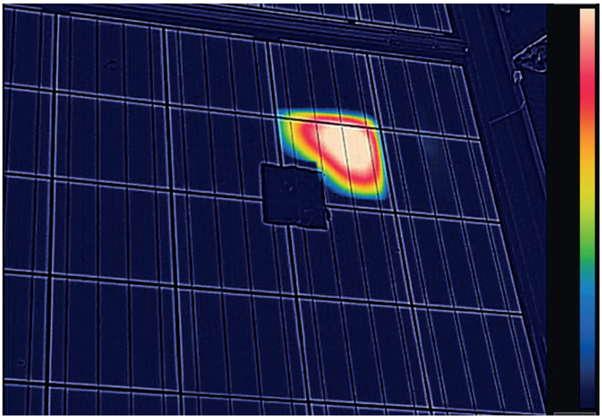

Figure 1
Thermal camera image showing a solar cell damaged during installation [24]

4.2 Air transportation

Several directions for development appeared in the field of personal aviation in the 20th century. The first mentionable flight was executed with the use of different types of jetpack airplanes (rocket pack, rocket belt) developed in the 1960s; another direction for development emerged later on in the 1990s, as a result of great technical achievements, and laid down the basics for the Aeromobil concept. In practice, it is nothing else than a flying car appearing from the combination of auto and airplane technologies. Technically, both aircraft types are pilot-driven and powered by the energy source other than renewable energy, so they cannot be considered drone technology but can still be considered a forerunner of passenger drones [16]. The first passenger drone named EHang 184 – being a major breakthrough in this field – was shown in 2016 at the Consumer Electronics Show (CES) by the Chinese-based EHang company [17]. Designers of passenger aircrafts have to face major challenges such as noise reduction, increased payload, increasing short flight times, harmonisation of airspace rules, aeronautics and drone traffic. Successful implementation of innovative developments could result in the rapid and extensive use of civil drones in the air transport of large cities. Seol can boast with the first test flight of the drone taxi carried out in the urban environment. The testing process was completed with the acquisition of a Special Certificate of Airworthiness (SAC) issued by MOLIT for an autonomous aerial vehicle (AAV) class. The above step is likely to have paved the way for South Korea to launch the market of Urban Air Mobility (UAM) services in the short term. In such a way, the manufacturers of AAV contribute to the rapid infrastructural development of smart cities. In the recent past, United Airlines parked huge investments in a start-up company focusing on the development of electric vertical take-off and landing (eVTOL) aircrafts. Should this project progress according to the schedule, these air taxis will be available to transport passengers between the airport and city centre as early as in 2024 [18]. An air taxi can transport passengers, luggage and medicines above the congested highways in a fast and environmentally friendly way, yet the importance of human safety oversight is unquestionable in the beginning. Owing to the development of autonomous and artificial intelligence, within a few years, the "transport robot" will be able to perform its pre-programmed flight activities on its own. However, a reasonable question may arise at this point, asking what should be the boundary for the autonomy of aerial means? [19] [20]

5. Use of drones for public service purposes

The use of a drone implementing a smart city function can be considered the use for public service purposes if such a use assists or substitutes the work performed by an individual involved in the execution of public functions. In accordance with the Hungarian Act CXCV of 2011 on public finance: A public function is a state or local government task defined by the legislation. Pursuant to Section 459 (12) of the Criminal Code of Hungary, persons entrusted with public functions shall mean the following occupations:

- policemen
- civil guards
- ambulance workers
- members of fire brigades
- healthcare employees
- postal service personnel

The above listing does not include all public functions specified by the Act; it refers only to those aimed at performing state tasks relevant in terms of the urban environment. In addition to the above, one should also mention some other public tasks assigned to the scope and competence of local municipalities, such as urban management and refuse disposal services. Most important and best-known municipal public tasks to be fulfilled by the local municipalities are operation of parking lots, supervision of public areas, cleaning of public roads and refuse disposal.

5.1 Support of police actions

There are more and more cases when police activities may require the audio-visual recording of implemented actions, providing additional information for subsequent procedural activities. There is a chance that the person affected by the police action may file a complaint regarding police misconduct or may even commit an act of violence against the official acting in the course of official actions. In both cases, the availability of a recording can simplify and clarify the situation. For this purpose, several countries use body-worn cameras providing certain additional information but having significant limitations compared to a drone-mounted camera. The disadvantage of body cameras is that there is no possibility for real-time streaming at the police department; the camera may fall down in case of a scuffle and only a narrow-angle shot will be taken due to the camera position. In contrast with the above, aerial footage recorded by the drone captures the entire action and the drone can be continuously directed to the most appropriate position from the control centre. Real-time connection can be established with the control centre and responding police officer [21]. In addition to law enforcement tasks, drones can also be used during the activities related to crime prevention, detection and arrest.

5.2 Support for civil guard associations

By means of an example of several civil guard activities, it can be stated that they can be efficiently supported in the performance of their duties by the use of drones equipped with audio-visual media. In case of settlements where local municipalities operate space surveillance systems with the involvement of civil guards, it is possible to make systems made up of static cameras dynamic by using a civil guard drone. Safety and security systems used for event management and supplemented with drones can also be of great help in organising and supervising the events.

5.3 Support of fire department actions

The history of organised firefighting dates back hundreds of years; however, there is still a chance that some special situations would occur in the city that pose great challenges to firefighters. One of such typical problematic situations is the fire in high-rise buildings in large cities. Needless to say, that high-rise buildings and skyscrapers are equipped with active and passive fire protection systems; however, these are less effective in case of façade fires. Firefighters arriving at the fire location have to cope with several obstacles. First and foremost, by the moment of the fire brigade's arrival to the scene, the size of fire may become difficult or impossible to control [22]. The extinguishability of façade fires propagating to upper floors is determined by the maximum height of fire service ladders, which is often limited to one side of the building. The Ehang 216F firefighting drone has been developed specially for extinguishing fires in high-rise buildings; with a maximum flight attitude of 600 metres, the 216F can carry up to 6 firefighting bombs and 150 litres of firefighting foam. The drone guarantees the possibility of rapid deployment at the fire location and fire-extinguishing at high altitudes; it can also be used for first response even before the firefighters arrive, significantly reducing the risk of urban fires.

5.4 Support of ambulance services

Ambulance services are constantly running the race against time during their everyday activities. During the period of time between the emergency call and arrival at destination, the control centre can provide instructions to the caller who can potentially increase the chances of survival of the person in need of help; however, it is highly dependent on the stress resistance and action skills of the administrator. By implementing the Ambulance Drone prototype designed by Alec Momont into regular emergency patient care, the chances of survival in case of an out-of-hospital cardiac arrest (OHCA) can be increased from 8% to 80%. This drastic difference is due to the magnitude of the response time. Time required to arrive at the scene of emergency may require up to 10 minutes in an urban environment, which is considered a fast response time; however, in case of accidents coupled with cardiac arrest certain neurological consequences may occur typically 4–6 minutes after the event. In this case, if the emergency care is supplemented with the Ambulance Drone, the required help can arrive within 1 minute at any point within a 2-kilometre radius. Owing to the two-way video connection and communication, ambulance personnel guide and control the use of the automated external defibrillator (AED). The successful use of a defibrillator by laymen is only 20% but with the application of Ambulance Drone communication technology, this figure can be increased to 90%. By means of designing a compact UAV network, it is possible to expand the entire emergency infrastructure of the city, as a result of which the efficiency of saving the lives of residents will be significantly increased [23]. Application of UAVs and AAVs is also possible at the subsequent phase of emergency care, during the transportation from the accident scene to the hospital. To be more specific, the Ambular Project led by volunteers is seeking for potential possibilities hidden in eVTOL technologies aimed at rapid transportation of individuals facing medical emergencies. Last year, the Ehang company joined the project, which means an important milestone in the development of this technology as the aviation authorities of several countries have already issued a test flight permit for the taxi. Furthermore, Ehang 216 was used several times to transport medical equipment and personnel to hospital during the management of the Covid situation in China.

6. Summary

The integration of drone and ICT technologies in terms of smart cities is getting more and more important and increases the efficiency of built-in services. This paper focused on the description of such areas of drone application that have functions increasing the sense of security in smart cities and provide effective solutions for the performance of operational tasks arising from the application of these technologies. Application areas have been presented with the focus on user groups, with the aim of inspiring the population, city management and commercial sector to learn more about this hidden potential. It should be noted that a wide spectrum of applications and possibilities has been presented in the paper, including already existing drone applications, prototypes and devices that have successfully performed test flights, which can predict the development directions for the cities of tomorrow. To meet drone taxis, air ambulances, or even an automatic maintenance drone in the everyday lives of smart cities, rapid and large-scale development is needed in many other areas, as well. The issue concerning the integration of drones into the air traffic should also be addressed. Service systems network should be developed and elaboration of drone-related regulatory basis supporting the sustainable development should be carried out. Full implementation of all conditions will result in happier citizens, more efficient urban management, prosperous businesses and a liveable environment.

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Drónok az okosvárosokban

Az (IKT) infokommunikációs technológiák rohamos fejlődése hazánkban az okosvárosok kialakulásának is óriási teret biztosít az elkövetkező években. Hasonló vagy akár még nagyobb léptékű fejlődés tapasztalható a pilóta nélküli légi járművek piacán. Az utóbbi években a pilóta nélküli légi járművek (Unmanned Aerial Vehicles, UAV), a köznyelvben használatos nevén a drónok, a kormányzati, illetve ipari felhasználáson túl rohamos elterjedést mutat a lakossági szférában is. A drónok több mint 1700 típusából válogatva, szinte bármelyik webáruházban beszerezhető. A típusok sokaságából egyenesen következik az eszköz sokrétű felhasználhatósága a mezőgazdasági ágazattól a biztonságtechnikán keresztül a piaci/polgári szolgáltatásokig. Kicsit eltávolodva az eszközdimenziótól és átlépve a rendszerek dimenziójába, a funkciókat megvalósító berendezések integrációjával költséghatékony, fenntartható és magas kényelmi szintet biztosító komplex rendszerek valósíthatók meg. A két innovatív fejlesztési terület egymásba ágyazódása hatványozza a technológiák alkalmazhatóságát és felhasználhatóságát a mindennapokban.

A cikkben bemutatok a drónok és az okosváros-technológiák integrációjából adódó néhány alkalmazási lehetőséget a teljesség igénye nélkül, fókuszálva a biztonsági szerepekre, illetve az okosvárosok üzemeltetéséből származó új feladatokra.

Kulcsszavak: *UAV, IKT, okosváros, UAM, jövő városai, AAV*

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