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VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

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DEPARTMENT OF FOREIGN LANGUAGES
ÚSTAV JAZYKŮ

DRONES (UAVS) IN THE AREA OF EMERGENCY SERVICES (INTEGRATED RESCUE SYSTEM)
DRONY - BEZPILOTNÍ LETOUNY POUŽÍVANÉ V OBLASTI INTEGROVANÉHO ZÁCHRANNÉHO SYSTÉMU

BACHELOR'S THESIS
BAKALÁŘSKÁ PRÁCE

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Bakalářská práce

bakalářský studijní obor **Angličtina v elektrotechnice a informatice**

Ústav jazyků

Student: Jan Bobek ***ID:*** 203522
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NÁZEV TÉMATU:

Drony - bezpilotní letouny používané v oblasti integrovaného záchranného systému

POKYNY PRO VYPRACOVÁNÍ:

Vytvořte přehled různých typů dronů (bezpilotních letounů). Popište použitou technologii a specifické oblasti, v nichž jsou letouny používány. Zaměřte se zejména na drony používané v oblasti složek integrovaného záchranného systému.

DOPORUČENÁ LITERATURA:

Olson, E. (2017). Drones (Modern Engineering Marvels). Minneapolis: Abdo Publishing

Steffens, B. (2020). Medical drones. San Diego: Reference Point Press Incorporated

Nakashima, N., Ahmed, A., Ro S.-C. & Soshino, Y. (2020). Fukuoka: Institution of Engineering and Technology

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ABSTRACT

Drones are being used more widely in the field of emergency services, thanks to their better availability and price. In the police field, drones are used for surveillance of various event or monitoring suspicious areas. Police drones are also used for reconstruction of a traffic accident. In the firefighting field, drones are used mainly for monitoring fires and gathering information about the fire for the pilot, but several drones are also designed for suppressing the fires. In emergency medicine, drones are used to transport equipment and blood samples in places where it is not possible to do so by means of grounds transportation or if the transportation is complicated. The aim of the bachelor thesis is to provide a list of drones used in the integrated services and to describe technologies associated with the drones.

KLÍČOVÁ SLOVA

Dron, typy, konstrukce, rotor, VTOL, radiofrekvenční záchranné složky, policie, hasiči, Ehang, medicína, Zipline, HiRO, telemedicína, armáda, covid, AED, automatický

ABSTRAKT

Drony jsou v oblasti integrovaného záchranného systému používány stále častěji, díky jejich lepší dostupnosti a ceně. V policejní oblasti jsou drony využívány k monitorování různých akcí nebo hlídání podezřelých oblastí. Policie drony také využívá k rekonstrukci dopravních nehod. V hasičské oblasti se drony používají hlavně k monitorování požárů a předávání informací pilotovi dronu, ale jsou vyvíjeny i drony určené k hašení požárů. V urgentní medicíně jsou drony využívány k přepravě vybavení a krevních vzorků v místech, kde to pozemními prostředky není možné nebo to je obtížné. Cílem této bakalářské práce je poskytnout přehled dronů využívaných v oblasti integrovaného záchranného systému a popsat technologie související s těmito drony.

KEYWORDS

Drone, types, design, rotor, VTOL, radiofrequency, emergency services, police, firefighting, Ehang, medicine, Zipline, HiRO, telemedicine, military, covid, AED, autonomous

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PROHLÁŠENÍ

Prohlašuji, že svoji bakalářskou práci na téma Drony – bezpilotní letouny používané v oblasti integrovaného záchranného systému jsem vypracoval samostatně pod vedením vedoucí bakalářské práce a s použitím odborné literatury a dalších informačních zdrojů, které jsou všechny citovány v práci a uvedeny v seznamu literatury na konci práce.

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V Brně dne ....

(podpis autora)

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INTRODUCTION

A drone (or UAV) is an unmanned aerial vehicle without a human pilot. Today's drones usually consist of propellers, motor, main body, energy source, receiver, and many drones are also equipped with GPS systems and cameras. Unmanned aerial vehicles have multiple categorizations, the most common one regarding their way of flying being fixed-wing, multirotor, single rotor, and fixed-wing hybrid VTOL.

The development of drones started in the military. They were experimented with in World War 1 as radio-controlled aerial aircraft that could be piloted into an enemy target. However, the experiment was never deployed directly into the battlefield. In World War 2, Germany was the first to start to develop missiles, with many countries doing the same. Missiles were faster, more precise, and harder to shoot in the sky. This was the main reason why drones were not as popular as they used to be in the military during World War 2.

With the advancing technology and better availability, drones are used more widely in many areas, for example, military, delivery services, or medicine, but even for surveillance. Medical drones can monitor areas damaged by natural disasters and evaluate the extent of damage so adequate help could be sent. They can be used for delivering medical supplies or blood samples in countries where the roads are not in a suitable state for driving. They are also a better option for delivering antivenoms in African countries, as they are faster than an ambulance or a helicopter, especially in remote areas. The main advantage of medical drones is their speed. A study by the Karolinska Institute (2016) conducted a comparison between the speed of the drone and the Emergency Medical Service (EMS). A geographic information system was used to simulate the response times of an AED (Automatic External Defibrillator) drone in rural and urban areas. The calculations showed that in urban areas, the drone arrived sooner than EMS in 32% of the cases, and the amount of time saved was 1.5 minutes. In rural areas, the drone arrived before EMS in 93% of the cases, and the amount of time saved was 19 minutes. This shows that drones are more effective, especially in rural areas, meaning they can potentially save more lives.

Similar to medical drones, firefighting drones can be used to monitor areas damaged by natural disasters. They also provide an "eye in the sky" to monitor fire, which is also the main purpose of firefighting drones nowadays. Some drones used in firefighting are also able to extinguish fires, especially those that are hard to approach. There is also a possibility that in the future, “swarm of drones” will be extinguishing flames. The technology, which is still unexplored will be able to extinguish spreading fires using 100 (or more) self-organized drones. However, comparing the three main integrated services – medicine, firefighting and the police, drones in firefighting are used the least, despite their potential to save lives.

One of the first fields (apart from military) where drone was used was the police field. The first police drone was used for searching for a missing person in America. The person was not found, however, this police investigation showed, that drone can be a valuable asset in the police field. Nowadays, the police use drones mainly for surveying areas and events. For example, they survey riots to have more control over the situation or they can survey certain areas to look for wanted suspects. But with the increasing number of drones used in the police field (or in other job fields), one can concerned about his privacy and the collected data.

The bachelor thesis aims to list and describe drones used in integrated services. The first chapter deals with the technology associated with drones – their design and counter measurements that are used against the drones. The second chapter describes the general and potential use of drones in the field of integrated services and the first subchapter describes the legal aspects of using drones for service purpose (focused on the medical field). It describes the usage of drones in the police field and how it makes the job of police officers more effective. Second subchapter of the second chapter describes two drones that are used in firefighting. The first drone described is able to suppress fire in the buildings, the second drone described can efficiently monitor the fire or even look for survivors trapped in a building. A future technology – self-organized swarming drones is also introduced and described. The third subchapter describes drones that are used in emergency medicine. Several drones are listed, with their technology and use being described. Also, an example of a drone helping during coronavirus crisis is listed. Fourth subchapter describes drones used in telemedicine, introducing two drone projects that are used in this field. The last part focuses on drones used in other working fields. It describes the use of drones in delivery services and lists several drones that are used in the military.

1 Drone technology

The first chapter tries to describe technology that is associated with drones. As mentioned earlier, the drones were mainly used in the military in the past. The newest and most expensive technology is still available only for military purposes, such as accurate autonomous systems, or high-quality systems used for surveillance. The first subchapter deals with design types, which is concerned with their flying abilities. It describes their efficiency and the possibility of hovering in one place.

As the drones became more available to the public, many people use drones to illegally collect information or to disturb one's privacy. They can also unintentionally fly to secured areas, where drone can possess danger to others, such as airports. That is why on places like this, counter measurements against the drones are used to successfully neutralize them or to detect their precise location.

1.1 Design types

The most common classification of drones is the classification by their design. The design of drones affects their take-off, way of flying, speed, and ability to hover in one place. There are five main designs - multi-rotor, fixed-wing, single-rotor, VTOL, and flapping-wing; and some of the designs are divided into more subcategories (see Fig. 1).

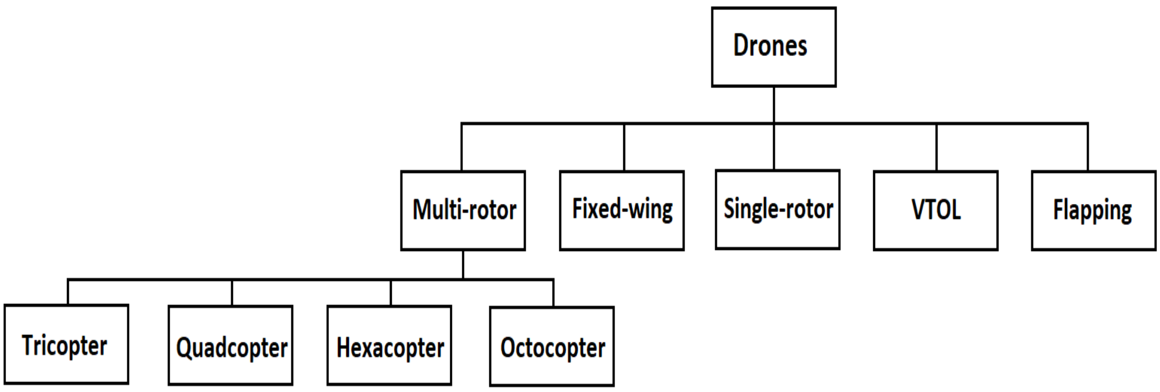

Figure 1. Classification of drones by design

1.1.1 Multi-rotor drone

Multi-rotor drones (shown in Fig. 2) are the most common and most used drones. They are equipped with multiple propellers on the side of their body. Their main advantage is that they can hover in one place and are easy to control. As a site CircuitsToday (2018) describes, they are also very cheap, available and their design is not very complex, so its production is easier. This type of drone is mainly used for taking photographs and shoot videos on camera, as they cannot be used for surveillance or long-distance flights. This comes from the fact that multi-rotor drones are not economic, as they need to counter the gravity for the full duration of their flight and need to stabilize themselves. Based on the number of propellers, multi-rotor drones can be further categorized as tricopter (three rotors), quadcopter (four rotors), hexacopter (six rotors), and octocopter (eight rotors). According to CircuitsToday (2018), quadcopter is the most common variation of multi-rotor drone and the average drone can fly for an average duration of 30 minutes.

Figure 2. A multi-rotor drone reprinted from: https://www.circuitstoday.com/types-of-drones

1.1.2 Fixed-wing drones

The design of fixed-wing drones (shown in Fig. 3) is similar to the design of airplanes. They utilize their energy needed for flying more efficiently (unlike multi-rotor drones), so their flight duration can be several hours, as CircuitsToday (2018) describes. This means they can be used for long-distance flights. However, same as airplanes, they need to be in constant motion to fly, as they do not have the ability to hover in one place. Another downside is that fixed-wing drone needs a runway for both take-off and landing and is harder to control, so an experienced pilot should fly it. The drone is also more expensive than the multi-rotor drone.

Figure 3. A fixed-wing drone, reprinted from https://www.circuitstoday.com/types-of-drones

1.1.3 Single-rotor drones

The design of a single-rotor drones (see Fig. 4) has a resemblance to a helicopter. They are equipped with two propellers, the bigger one being at the front and the smaller one being mounted on the tail of the drone to ensure stability. Circuitstoday (2018) describes the advantages and downsides of single-rotor drones. One of the advantages is that the single-rotor drone is more efficient and stable than multi-rotor drones, as it has only one rotor, which leads to a lesser spin of the drone. Herrick (2017) also claims that single-rotor drones are very durable and can carry heavy payloads. However, they are usually more expensive, as they are more complex. They also possess a potential danger, as there have been confirmed cases of fatal injury caused by the spinning blade.

Figure 4. A single-rotor drone, reprinted from https://www.circuitstoday.com/types-of-drones

1.1.4 Hybrid VTOL drones

VTOL (vertical take-off and landing) is a hybrid drone combining the advantages of a fixed-wing drone and multi-rotor drones. They can take-off vertically, meaning they do not need any runway or catapult as fixed-wing drones do. As Gu, Zhang, Ximing, Li, Shen (2017) describe, to take-off in such a way, the drone is equipped with four rotors on the sides of its body, which will lift the drone from the ground. When the drone reaches the desired altitude, the lifting rotors turn off, and the drone starts flying like a fixed-wing drone, with the help of pusher rotor. These components are illustrated in Fig. 5. This results in longer flying-time due to better efficiency. These drones play a significant role in autonomous flying and are mainly used in drone systems that use automated drones.

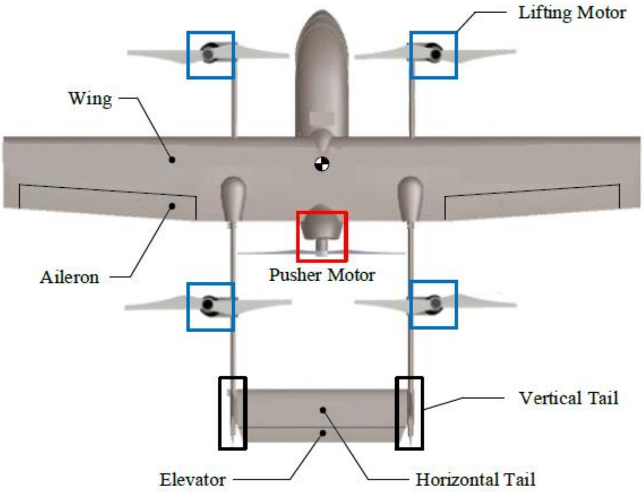

Figure 5. A hybrid VTOL drone, reprinted from https://www.researchgate.net/publication/317933218_Development_and_Experimental_Verification_of_a_Hybrid_Vertical_Take-Off_and_Landing_VTOL_Unmanned_Aerial_VehicleUAV/figures?lo=1

1.1.5 Flapping-wing drones

One of the newest types of drones is a flapping-wing drone (shown in Fig. 6). The drone flies similarly to birds, pushing its wings back and forth at high speed. According to Ackerman (2020), the wings of a bird are much more efficient than the rotors of a rotary drone. The wings also allow the drone to be very agile. Flapping-wing drones are also safer, as wings cannot do significant harm, unlike the propellers of the rotary drone. One of the most significant disadvantages of a flapping-wing drone is its complexity, as it is harder to create the precise motion of the wings so the drone could stay in the air. The drone has not any practical use yet, but Ackerman (2020) claims that it has already shown its potential by its ability to fly quietly, its agility, and mainly by its better efficiency than rotary drones.

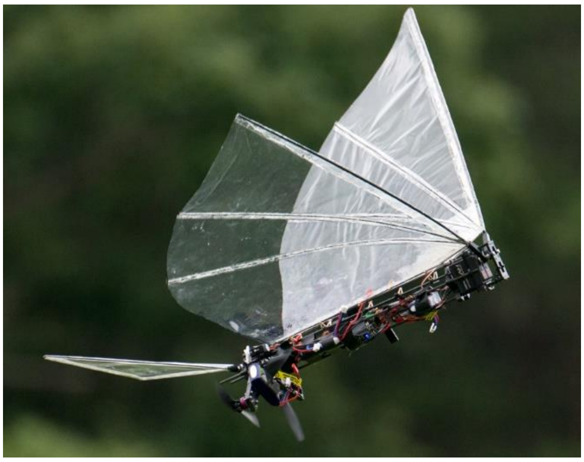

Figure 6. A flapping-wing drone, reprinted from https://www.asme.org/topics-resources/content/engineering-a-robotic-bird-like-no-other

1.2 Counter measurements against the drones

With drones used more widely, there was a need of tracking (or even jamming) the drones, so the drones will not disturb one's privacy or monitor areas where it is not allowed. For example, a journalist may use his drone to fly to secured or private area to gather photos or some compromising evidence. One would then have a proof that the journalist was trespassing if one would file a lawsuit against him. As the drone technology is being rapidly developed, the counter measurements are too, so they can ensure that people will secure their privacy and no drone will do harm to others.

1.2.1 Detecting the position

Systems that can detect drones are used mainly for providing proof if a drone was trespassing certain area. If one would detect the position of the drone, some systems can successfully detect the position of the person controlling it.

1.2.1.1 RF analyzers

One of the ways to track the drone is to locate them using RF (Radio-frequency) signal, as the same type of signal is used by the drone and the controller to communicate. As RobinRadar (n.d.) site describes, RF analyzers are equipped with one or more antennas (which receive the radio waves) and a processor to analyze the RF spectrum. Some analyzers can retrieve the MAC address of the drone and even the address of the controller. This provides evidence that the drone was active in the given time. Expensive analyzers can triangulate the position of the drone and the controller, as RobinRadar (n.d) site adds. Their most notable advantages are their low price, no need for a license (as they are passive), and the possibility to catch multiple drones at once. However, their coverage area is low and they are less effective in areas crowded with radio waves. They also cannot determine the drone position, unless using expensive analyzers and cannot catch autonomous drones. A military RF analyzer can be seen in Figure 7.

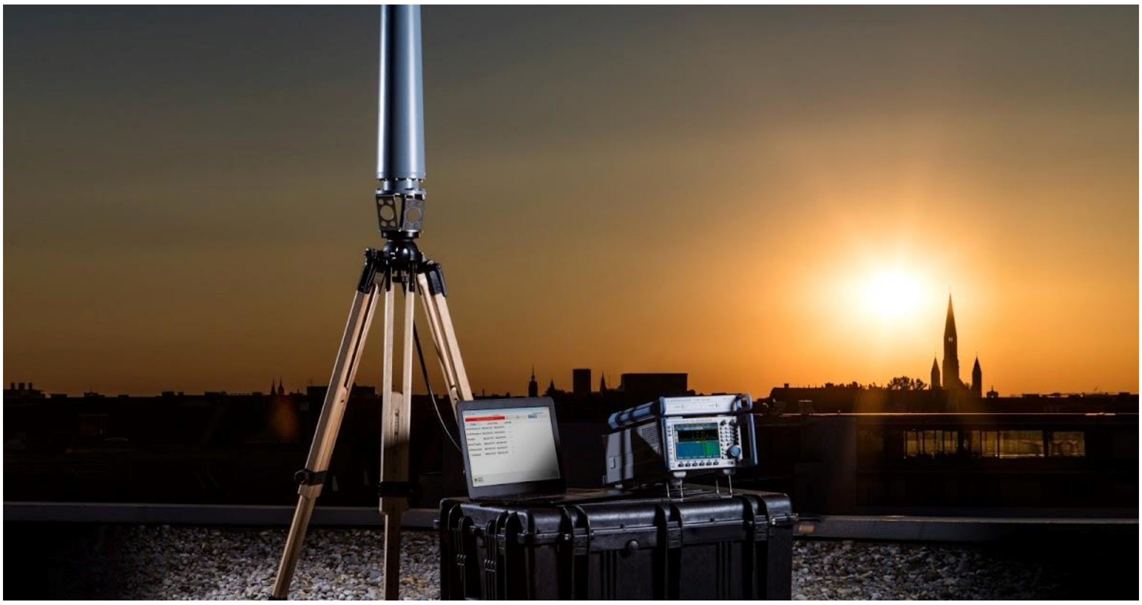

Figure 7. A military RF analyzer, reprinted from https://www.robinradar.com/press/blog/9-counter-drone-technologies-to-detect-and-stop-drones-today

1.2.1.2 Acoustic sensors

Robinradar (n.d.) discusses another means of tracking, which is to use an acoustic sensor. This sensor consists of many microphones detecting the sound of the drone, from which it then calculates the position of the drone. This type of sensor works well in detecting drones near the ground, while other types of sensors may have problems. However, as the Robinradar (n.d.) site adds, they are not effective in noisy environments, and they have a small coverage area (maximum of 500 meters). Square head acoustic sensor can be seen in Figure 8.

Figure 8. Acoustic squarehead sensor, reprinted from https://www.robinradar.com/press/blog/9-counter-drone-technologies-to-detect-and-stop-drones-today

1.2.1.3 Optical sensor

The most basic optical sensor used to detect drones is a classic camera. However, the problem with using a camera is that using a camera purely for detection and triangulating a position is difficult, as RobinRadar (n.d.) describes. To effectively survey drones hovering in the air, a person would be needed to constantly check on the camera as the camera would have a problem with automatically detecting a drone. One of the major disadvantages of the optical sensor is its low efficiency in foggy weather. They are also inefficient at night. This disadvantage can be solved by using an infrared or thermal camera.

1.2.1.4 Radar

Another way of tracking a drone is to use radar (see Fig. 9). The radar sends out a radio signal, which then reflects from the flying object. With the reflection, the radar can accurately calculate direction and position. However, almost all radars are designed to track larger objects (such as aircraft). This means that they are not able to track ordinary small drones but are mainly used to track the military flying UAVs. As Robinradar (n.d) adds, a radar system can accurately track the drone over a very long distance and can handle hundreds of vehicles simultaneously. However, the radar may not distinct a small drone from a bird, making the tracking less effective.

Figure 9. A radar used against low-flying drones, reprinted from https://www.unmannedsystemstechnology.com/2019/09/counter-drone-radar-enhanced-against-low-flying-and-small-uas/

1.2.2 Neutralizing the drones

In some cases, when drones are trespassing a secured area or private property, jamming (and possibly neutralizing) the drones may be a more suitable option over tracking them. This ensures that the drone does not escape.

1.2.2.1 RF jamming

As RobinRadar (n.d.) describes, RF (radio-frequency) jammer is a static handheld device that emits a controlled strong RF signal towards the drone. This signal will collide with the RF signal from the controller and damping the controlling signal. This action will result in the falling of the drone to the ground. However, some drones may be programmed against such interference, so when they lose the signal, they may fly to a safe point or safely land on the ground. The drone can also fly unpredictably, as the jamming signal can alter the controller signal. Another disadvantage is that this type of jamming might jam other RF signals. This type of jamming is not expensive and offers a neutralization, which does not possibly destroy the drone by its jamming. A hand-held RF jammer can be seen in Figure 10.

Figure 10. A hand-held RF jammer, reprinted from https://www.robinradar.com/press/blog/9-counter-drone-technologies-to-detect-and-stop-drones-today

1.2.2.2 GPS spoofing

Another means of neutralizing the drone which RobinRadar (n.d.) describes is to spoof its communication with GPS satellites, which leads to making the drone think it is in a different location. This solution possibly cannot destroy the drone, as the drone will still receive its RF signal. This solution will keep the drone away from the covered area. However, this solution is effective only against autonomous drones, as they are using GPS satellites for communication. However, RobinRadar (n.d.) adds that as in the example of RF jammer, GPS spoofer (see Fig. 11) may also jam other RF communications.

Figure 11. GPS spoofer sending a new signal to the drone, reprinted from https://www.robinradar.com/press/blog/9-counter-drone-technologies-to-detect-and-stop-drones-today

1.2.2.3 HPM devices

HPM (High-power microwave) devices specialize in remotely destroying the electronics of the drone. According to Robinradar (n.d.), the device generates EMP (Electromagnetic pulse), which then overloads the electric circuits of the drone. This destroys the drone, as it cannot use electricity due to the damaged circuits. However, the EMP may destroy other electronic devices near the drone, resulting in unintentional damage.

1.2.2.4 Net

One of the most effective kinetic neutralization of the drone is to fire a net at the drone. The shooting can be completed in three main ways.

One way is to shoot the drone from the ground with net cannon (handheld or turret-mounted, seen in Fig. 12). As RobinRadar (n.d.) says, the net can be shot up to 300 meters far and can be equipped with a safety parachute, so the drone will not get destroyed by the fall.

Another means of shooting the drone with the net is to deploy another drone, which can shoot the web from a safer distance. According to RobinRadar (n.d), it may be a problem to capture a moving drone. As in the former example, the net shot by the drone is equipped with a safety parachute.

The last method of capturing a drone by a net is to leave a hanging net below a capturing drone. The drone will then maneuver to successfully capture another drone and then carry it to the desired location. In the case of the drone being too heavy, the net can be released, as the net is equipped with a safety parachute.

Figure 12. Hand-held net gun, reprinted from https://www.robinradar.com/press/blog/9-counter-drone-technologies-to-detect-and-stop-drones-today

1.2.2.5 Birds

As Robinradar (2019) describes, eagles have been successfully trained to capture COTS (Commercial off the shelf) and UAS (Unmanned aerial systems). This solution requires minimum technology. However, training an eagle to successfully hunt a drone requires a lot of time (minimum of one year). As RobinRadar (2019) adds, training eagles is similar to training military dogs, so the eagles can be utilized similarly. Also, another disadvantage of this solution is limited scalability, as the number of birds needed is high and there are not enough of them.

2 Drones used in emergency services

The second chapter focuses on describing drones used in emergency integrated services. As the technology is rapidly developing, many agencies try to implement drones to help them with their work.

The most notable advantage of drones used in firefighting is that they can effectively monitor the fire, providing the necessary information, so the firefighters can react accordingly to the fire. The chapter also discusses drones used solely for extinguishing purposes.

One of the fast-developing and promising areas where drones are used is medicine. In remote areas, an ambulance may not reach the patient in time. As mentioned before, speed is the key advantage of drones when it comes to saving the lives of people. Today, the vast majority of drones are used for surveillance or delivering medical supplies and equipment. However, their potential has not been fully recognized yet, as their technology is still developing, the same as the regulations regarding flying the drones, which some perceive as too limiting.

2.1 Regulations regarding drones

The use of drones in the field of integrated services has not been developed properly yet. That is why many of the integrated services drones are in the development or testing phase. One of the difficulties of developing a drone is not just the technology, but the drone has to meet certain regulatory requirements, so it is allowed to fly legally.

Several states are implementing the regulations, so the drones would not possess any harm to civilians or objects. The sub-chapters deal with the regulations in three states - USA, Nepal, and Poland. The states represent a certain milestone in developing legal aspects of drones. The USA was one of the first countries to develop legislation for delivery purposes of drones. Nepal was one of the first countries where drones helped when an earthquake struck, but there were no legislations, so there was a need for one. Regarding Poland, it was one of the first countries to make legislation for flying drones generally, and their legislation is still being updated to use medical and other drones.

2.1.1 Regulations in the USA

As Balasingam (2017) discusses, in the United States, the Federal Aviation Association (FAA) has established certain rules for the use of drones. One of these limitations includes the drone being in the visual line of sight (VLOS) and always having a remote pilot, which means that autonomous drones are not allowed. These rules affect various stakeholders, from large companies like Amazon to smaller emergency care facilities. Many consider the FAA as too limiting and that it is slowing the development of drones in healthcare. Until new regulation legislation takes effect, the stakeholders have the opportunity to apply for exemption from the current legislation, so they can use drones for various purposes. And many healthcare organizations do so.

2.1.2 Regulations in Nepal

As Sharma (2016) describes, in Nepal, there were no regulations regarding the drones, so when an earthquake struck Nepal in 2015, there was uncertainty within the government and aid agencies about how to use the drones. Following the earthquake, the authorities claimed that unregulated drones were a burden, as they were everywhere, provided no feedback to the government, and it was hard to control them. Therefore, the Central Aviation Authority of Nepal (CAAN) prohibited the flying of a UAV without its permission. Also, the maximum flying time can be 15 minutes, and no-fly zones above houses, security agency buildings, religious sites were introduced. It was also specified that the drone can only be a maximum of 300 meters from the pilot and at a maximum of 100 meters altitude. This may slow the development and the use of drones.

2.1.3 Regulations in Poland

According to Konert, Smereka, and Szarpak (2019), Poland was one of the first countries to allow the usage of drones legally. As they describe, until 2019, the Aviation Law allowed flying drones only in the visual line of sight. For flying beyond visual line of sight (BVOL), it was allowed only in separated airspace and one must file a motion to the Polish Air Navigation Services Agency (PANSA). In 2019, a new regulation entered into force, which changed the law for visual line of sight operations and introduced new rules for beyond visual line of sight flights. For BVOL operations, the drone has to be now registered and approved through an entry in the register of files in the Civil Aviation Authority (CAA). The second change regarding the BVLOS operations is that the drone has to weigh a maximum of 25 kilograms. They also need to be provided with anti-collision lighting, same as on aircraft with a pilot. They also must have a camera detecting its surroundings and devices constantly maintaining altitude and keeping the drone in maximum allowable distance from the pilot. Moreover, it has to be able to provide an emergency location in case of lost control or other difficulties. The drones also need to be able to continue to fly along the programmed course during an emergency, as well as perform safe landing and be able to fly to a preprogramed position. This change also allows the drone operation to be performed out of the separated area. This allows the legal use of drones in medical field, flying in the altitude of up to 120 meters and there has to be at least 5 kilometers visibility, with two persons performing the flight.

2.2 Drones used by the police

As police are implementing more drones to survey suspicious areas, more people are concerned about their privacy. As Greenwood (2020) claims, even though American law enforcement forces embraced the use of the drone for surveillance, there is no national framework watching over their use and how the police use the collected data. That is why American cities and states wrote a set of rules, which allows for easier governing the use of drones. Another usage of the police drones is crime scene analysis or reconstruction of collision traffic. As Greenwood (2020) claims 70% of agencies that bought drones between the years 2017 and 2020 were police departments.

2.2.1 Surveillance

As mentioned earlier, police are used mostly for surveillance. They provide situational awareness in potentially dangerous or volatile situations. Police drones are less expensive options to a helicopter, providing the same surveillance and data. This is also an excuse presented by law enforcement agencies why they fly drones over alleged drug deals, homeless encampments, or over the riots in America against police violence against black people, as Greenwood (2020) adds. As Greenwood (2020) continues, some police agencies say that aerial surveillance is less intrusive a may result in fewer altercations during riots, as patrolling police officers could build more distrust in people. Police also use drones not to just survey the ground area, but also the aerial area, as Greenwood (2020) claims. The reason for this is that reporters or journalist may use their drones to gather photos and data. The police drones in the air may discourage the journalists from using their drones in the air.

2.2.2 Reconstruction of an traffic accident

Dukowitz (2020) describes how drones are used in reconstructing a traffic accident (seen in Fig. 13). It significantly reduces the time needed for a full reconstruction of the accident. Before the implementation, the investigators had to use a pencil and tape for measuring and manually identifying important points of the accident by marking them by an "X" or an "O". Accident reconstruction did by this approach usually took about 6 to 8 hours, which resulted in traffic congestion. Dukowitz (2020) says that one of the upgrades implemented in the reconstruction of traffic accidents was using a laser scanner. However, with these devices, the reconstruction still took up to three hours. This solution was better but stopped the traffic for a considerable amount of time, too. As Sequin (2019) claims, a drone developed by Purdue University can map the scene of a traffic accident significantly faster. Sequin (2019) says that the reconstruction of a traffic collision can take five to eight minutes, allowing police officers to open the traffic much quicker. As Dukowitz (2020) continues, the most common drone used is the Chinese drone DJI Inspire 2, using Zenmuse X7 camera and paired with Phantom 4 Pro drone. However, different types of drones are also used in traffic accident reconstruction, as Dukowitz (2020) adds. Sequin (2019) says that it was John Bullock, who developed field procedures and post-processing of images to create orthorectified images. These images clearly illustrate the position of vehicles, infrastructure, and general terrain adjacent to the crash site. To provide an accurate scale map, the drone is set to take 100 photos every 2 seconds, resulting in a frequency of 50 Hz. One of the most important aspects of traffic accident reconstruction according to Dukowitz (2020) is accuracy. That is because, in traffic collision reconstruction, an accurate description of the accident has to be acquired, as even the slightest inaccurate measurement can result in a different evaluation of the traffic accident. As Dukowitz (2020) continues, the Purdue University partnered with Tippencaoe Sherrif Department (located in Indiana). He claims that in 2018, the department used the drone in twenty different reconstructions.

Another important aspect discussed by Dukowitz (2020) is the need for quick accident reconstruction, so the traffic does not get congested a lot. That is because, for every minute of congested traffic, the chance of a secondary crash is increased by three percent.

According to Sequin (2019), the most vulnerable drivers are those at the end of a queue, as an approaching driver, who is not paying attention can crash into him. That is why drones can potentially save lives, as their fast accident reconstruction can help to reduce the queues and the amount of time waiting.

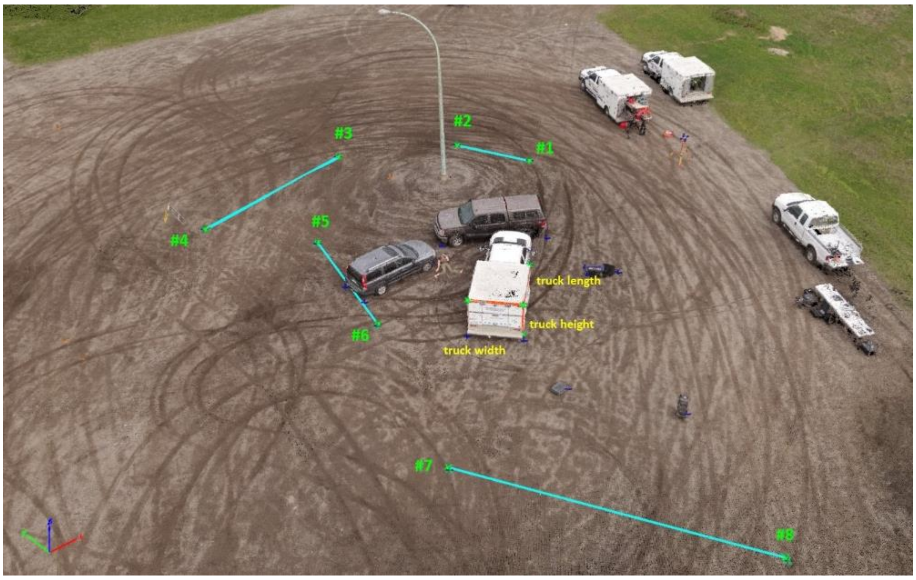

Figure 13. An example of drone reconstruction, reprinted from https://uavcoach.com/drones-accident-reconstruction/

2.2.2 Shooter investigation

As the site DroneFly (2020) describes, one of the uses of police drones is active shooter investigation and localization. Police officers using drones for this purpose can efficiently locate active shooters, allowing them to adapt to their position and use it to their advantage. However, the drones used for this purpose have occurred mainly in the United States so far. This strategy is highly efficient, as it can potentially save the lives of the police officers.

Simmie (2021) describes an incident, where a drone helped a pinned down police officers to safely change position. This incident occurred in Oklahoma, where an old man was sporadically shooting and kept several police officers and civilians pinned down. They did not change position and remained hidden for two and half hours. However, this has changed when a drone arrived at the scene to monitor the situation. Even though the drone should have provided situational awareness, it became a target (Simmie,2020). This distraction allowed the police officers and civilians to escape to a safe location. The scene of shooting can be seen in Figure 14.

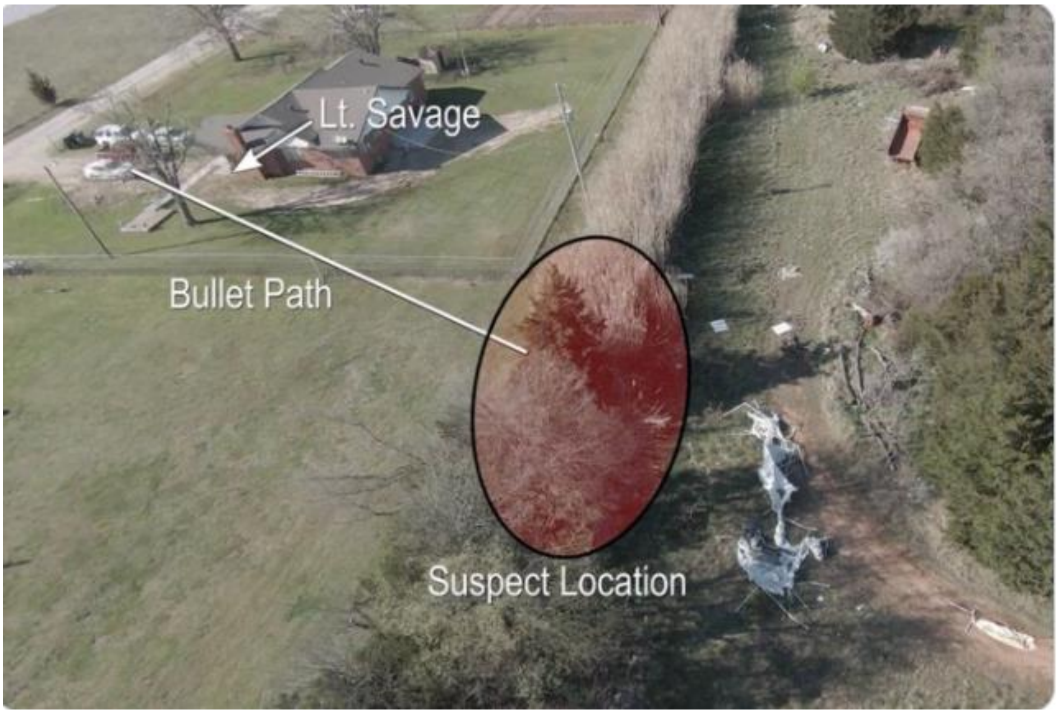

Figure 14. The scene of shooting, reprinted from https://dronedj.com/2021/04/16/police-drone-distracts-shooter/

2.3 Drones used by firefighters

Drones also allow extinguishing fires without any risk of human lives. Utsav (2020) describes the general use of drones in firefighting. When a fire breaks out, firefighters usually do not know the extent of the fire. That is why they can use drones to monitor the fire and react accordingly. Another of the many uses of the drone in the firefighting field is searching for people during disasters. For example, during an earthquake, the drone can fly above the fallen structures and look for survivors trapped under fallen rocks. According to DroneFly (2020), 347 agencies in the United Stated bought drones for their work between years 2009 and 2017. Out of these agencies, 67 agencies were firefighting departments, showing that drones are an important part of saving people's lives.

According to Schaft (2018), drones could use swarming technology in the future. This means that a large flock of drones could supervise the affected area. The drones would behave like a flock of birds, communicating between themselves and no ground operator would be needed, as the drones inside the flock would be able to react to incoming danger.

2.3.1 Ehang

Ehang company launched a new drone called Ehang 216F (See Fig. 15). As McNabb (2020) describes, it can transport 150 litres of foam and six fire extinguisher bombs and will be used to extinguish fires in high buildings, as it can fly at an altitude of 180 meters. According to Ridden (2020), the drone can operate within a five-kilometre radius from its base. The drone can also fly at an altitude of 600 meters, can reach a speed of 130 kilometres per hour, which allows the drone to arrive at the fire with low delay. The drone can also fly for up to 21 minutes, as Ridden (2020) adds. Ridden (2020) then explains its procedure during a high-rise fire. When Ehang 216F arrives at the place with the fire, it uses a visible zoom light camera to locate the fire, the hovers in a stable position. Then it is programmed to use a laser guidance system, which also fires an object to destroy the window. This procedure is followed by extinguishing bombs and after the bombs have been deployed, the drone can use extinguisher foam. Despite the recent launch, drones are still mainly used for monitoring actions during the fires, as it is more effective.

Figure 15. Ehang 216F, reprinted from https://dronelife.com/2020/07/31/ehang-launches-a-firefighting-drone-for-high-rise-fires/

2.3.2 Self-organized swarming drones

Innocente and Grasso (2019) discuss the possibility of using autonomous swarms of firefighting drones to successfully suppress fires. One of the terms associated with self-organized drones is Swarming Intelligence (SI), which is connected to Artificial Intelligence (AI). The behavior of the drone swarm comes from the social behavior of organized animals, such as birds. As Innocente and Grasso (2019) say, "SI is the branch of AI that deals with the collective behaviour that emerges from decentralised self-organising systems, where individuals only interact locally with one another and with the environment. Swarm robotics (SR) is an approach to the self-coordination of large numbers of simple robots which emerged as the application of SI to multi-robot systems. It differs from other SI studies in that it emphasises the physical embodiment of individuals, and from distributed robotics in that it promotes scalability." Innocente and Grasso (2020) also explain certain problems if firefighters were to use drone swarms. There are strict requirements for drones used in drone swarm, that is why there is a low number of drones that can be used in that way, as they need to be controlled remotely, coordinated for autonomous behavior, and they need to efficiently suppress the fire. But as Innocente and Grasso (2020) claim, the use of these autonomous drones results in a flying system, that can adapt "to uncertainties, errors, local perturbations, and the failure or loss of a few units" (Innocente and Grasso,2020).

Also, Innocente and Grasso (2020) performed a simulation to show the effectiveness of swarm drones. In the simulation, they applied 100 drones, which were deployed 20 seconds after the ignition of a fire. In the Figure 16. there are four snapshots of the simulation, at timestamps of 19,50,100 and 480 seconds. As can be seen in this figure, the fire is successfully suppressed after 480 seconds. However, as Innocente and Grasso (2020) observed, approximately 25 drones are destroyed during the suppression of the fire. As they say, the first drone was destroyed in thirty seconds, followed by a destruction of a drone every 15 seconds. Figure 17 shows the only unsuccessful attempt, when the swarm deemed the fire as extinguished when it was not. The fire then spread again, as can be seen in the figure.

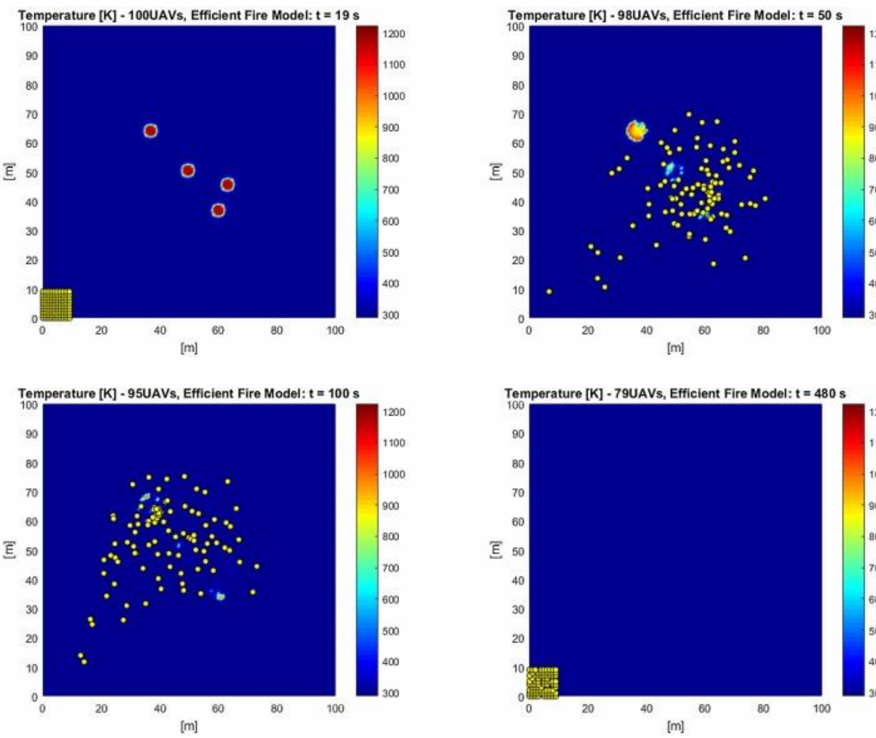

Figure 16. Four snapshots of suppresing fire by a swarm of drones, reprinted from https://www.sciencedirect.com/science/article/pii/S1877750318310238#tbl0030

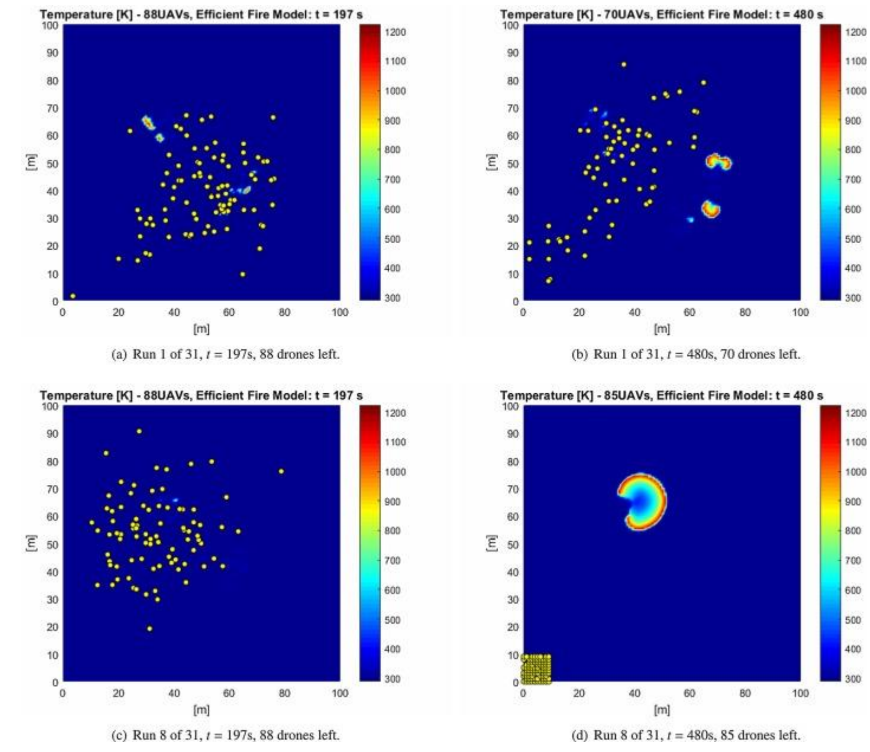

Figure 17. Unsuccefull attempt of suppresing the fire by a swarm of drones, reprinted from https://www.sciencedirect.com/science/article/pii/S1877750318310238#tbl0030

2.3.3 Matrice 210 V2

DslrPros (2019) claims that the drone which is best suited for firefighting purposes is the Matrice 210 V2 drone. It is equipped with a dual Zenmuse XT2 camera and one Zenmuse Z30 visual camera. As DslrPros (2019) adds, the thermal camera can operate in an environment with heavy smoke from the fire, finding potential survivors. The visual camera provides a clear image of the disaster for the operator with a refresh rate of 30 Hz. Another advantage described by DslrPros (2019) is the ability to fly in rainy and windy weather. The drone has a rating of IP43. The first number means that the electronics in the drone are resistant to objects larger than 1mm. The second number means that the drone is resistant to sprayed water. The drone can also withstand a wind of 42 km/h, according to DslrPros (2019). The drone is also equipped with front, bottom, and upper sensors to efficiently avoid obstacles. As DslrPros (2019) adds, the drone has to be able to avoid firetruck ladders. The drone is also equipped with an ADS-B receiver. The receiver uses DJI AirSense technology, allowing the operator to see other planes or helicopters. This information may be crucial in natural disasters, where there may be other flying objects.

2.4 Drones used in emergency medicine

As stated before, the main use of drones in emergency medicine is transporting blood samples or delivering antivenoms. One of the ideas for drones is that they should be able to transport people. But none of the drones in medicine are transporting people, as they are still in development and are not approved by the governments. According to Konert, Smereka, and Szarpak (2019), one of the first medical uses of drones was in Maine, when it delivered life jackets to people trapped on rocks in the Little Androscoggin River. As DeAmicis claims (2015), the first government-approved medical delivery was in the USA, where it carried medical supplies to a clinic in rural Virginia.

2.4.1 Advantages and needed changes

Balasingam (2017) describes the advantages and needed future changes in drone technology used in medicine. Balasingam claims that the drones are saving and will save lives by providing life-saving supplies to areas affected by a disaster, resulting in quicker response times. Another usage of drones will be delivering blood samples or equipment to hospitals in need, as well as delivering predicaments and medical supplies to people in remote areas. He also mentions delivering AED to people having a cardiac arrest and potential delivery of telemedicine with diagnostics. The possibility of delivering ultrasound devices is also mentioned. However, three main disadvantages (or needed changes) of using drones in the medical field are discussed. First is the need to update regulations, which include legislation concerning predetermined flight corridors, where drones need to fly in the line of sight. In emergencies, the drones need to take the fastest route, which possibly means flying out of sight. Also, the effectiveness of the drones will depend on the individuals delivering help, as it can be a layperson and not an expert administering medical treatment. This may be a setback compared to traditional transport methods and transportation of medical supplies. Transportation and storage of medical drugs or specimens need to be carefully monitored, as the storage temperature and duration of transportation may affect the effectiveness of the given medicine drug.

2.4.2 Carrying Covid samples in Scotland

Coronavirus plays a major part in deploying drones to carry the necessary equipment. As Hay (2021) describes, drones are being used to deliver Covid samples to remote islands in Scotland in a trial project. The drone project, operated by Skyports, was permitted by UK CAA (Civil Aviation Authority). As Hay (2021) adds, the drone can carry up to 3 kg of medical supplies, protective equipment, or the mentioned Covid samples. They can also travel a distance of up to 64 kilometres. Hamamdjian and Jones (2021) also say that the drone can reach 1 500 meters of altitude and can fly up to 160 kilometres per hour. This ensures that the patients do not wait for their Covid test as long as they would wait by a different type of transport. As Hay (2021) adds, the drone decreased the delivery time from 36 hours to 15 minutes.

2.4.3 Drone delivering an AED

In the city of Grotehsburg, located in Sweden and its surrounding villages, a multi-rotor drone system created by the Everdrone company is used, which is delivering automated external defibrillators (AED) for those in need. *Out-of-hospital cardiac arrests affect some 275,000 individuals in Europe each year and carry a low survival rate of about 10% and research suggests when CPR and early defibrillation are initiated within the* *first few minutes, the survival rate could potentially increase to as much as 70%* (Sällström,2020). The system responds to the 112-emergency call, with the drone being dispatched at the same time as the ambulance. As Sällström (2020) describes, when the drone arrives at the emergency call, it lowers the AED (as shown in Fig. 18), and then it hovers at 30 meters altitude, so no potential harm is done to others. Also, the drone is equipped with Intel RealSense technology. RealSense cameras feature three lenses, a standard 2D camera for regular photo and video, along with an infrared camera and an infrared laser projector. The infrared parts allow RealSense to see the distance between objects, separating objects from the background layers behind them and allowing for a much better object, facial and gesture recognition than a traditional camera. This technology allows the drone to avoid obstacles, such as trees or rocks, because of the depth perception capability of the drone. Moreover, it features an intelligent route planning system, allowing the drone to reach the destination more quickly, according to Sällström (2020). Also, drones generally are prone to bird attacks or technical failures, which lead to drones falling, potentially damaging people. To prevent this, the emergency drone is equipped with a certified parachute system. This drone system is currently reaching 80,000 residents and is planning to go international, starting with Denmark in the spring of 2021.

Figure 18. Drone delivering an AED, reprinted from https://uavcoach.com/everdrone-defibrillators/

2.4.4 Zipline

Another drone, called Zipline (shown in Fig. 19) is delivering blood samples, vaccines, and emergency medicine started in Rwanda. Currently, it also operates in Ghana. According to Bright, (2020) Zipline is operating 30 drones from 4 operation centres and is distributing life-saving medications across 2,000 health facilities in Ghana daily. The fixed-wing drone can fly up to 300 kilometres on a single battery charge. According to Lewis (2020) Zipline also played a major role during rising coronavirus cases, as it was able to deliver tests more quickly. Due to the coronavirus, Zipline also expanded to the USA. The drone is making 32-mile flights delivering protective equipment and medical supplies between two points - drone centre in Kannapolis and medical centre in Huntersville, as Lewis (2020) adds.

Figure 19. Zipline drone, reprinted from: https://en.reset.org/blog/zipline-continues-medical-drone-deliveries-expanding-ghana-04292019

2.4.5 Ehang

In China, a drone called Ehang 216 (see Fig. 20) showed its potential use by transporting medical supplies to an affected hospital as a response to the coronavirus crisis, as Ehang (2020) company shows. The drone is not only designed for transporting medical supplies but also for transporting people. According to McNabb (2020),the Ehang company joined Ambular, an international project to design medical drones, which is approved by the International Civil Aviation Organization (ICAO). Ehang is still being implemented in healthcare. The date of government approval and full implementation is still unknown.

Figure 20. Ehang 216, reprinted from https://transportup.com/ehang-216/

3 Drones used in other fields

Integrated services are not the only field where drones are used. Drones are useful in many other fields, such as agriculture, where they can survey the area and can also determine the quality of crops. Another area where drones have been used over the last decade is film-making industry, as a camera attached to the drone can provide high-quality camera shots from high altitude. The subchapters will describe the fields where drones are used the most, which are delivery services, telemedicine and military.

3.1 Delivery services

According to the site Fehr and Peers (2020), there are many possible advantages of delivery drones over delivery vehicles. One of the potential benefits would be lesser traffic congestion, as there would be fewer delivery vehicles, allowing for smoother traffic. Another benefit is reducing the greenhouse effect, as delivery trucks are contributing to the greenhouse effect by a vast amount, whereas drones produce zero emissions. The last of the many benefits would be faster delivery of packages, as drones would not be stopped in congested locations, unlike the delivery drivers.

However, the site also discusses the possible drawbacks and limitations of using delivery drones. For example, drones would not be able to carry heavy or large packages, resulting in delivery by a delivery vehicle. Also, with more delivery drones flying in the air, adequate airspace regulations and airspace control need to come into force. Another drawback is the battery life of the drone, meaning the flight distances are limited. Also, the drone is possibly prone to bad weather and collision with birds, creating potential damage to humans or the delivered object.

3.2 Drones in telemedicine

According to Thomas (2018), the term telemedicine suggests that a doctor can provide medical services without actual physical contact with the patient. This can be accomplished by a web camera or even an ordinary telephone.

Telemedicine is a field where drones are still developing and are not used properly. One of the drones used in telemedicine was already described in the previous chapter - the drone delivering AEDs. However, no drone is diagnosing patients yet with immediate response to the given diagnosis, as this technology was not developed properly, but would surely change the way how are the patients getting diagnosed.

One of the general factors leading to the faster development of telemedicine is the coronavirus crisis. According to Koon (2020), drones equipped with infrared thermometers were used to check the temperatures of residents living in tall buildings. This resulted in a faster and more detailed overview of the coronavirus crisis.

3.2.1 Telemedicine UAV in Mexico

Wulvovich, Rivas, and Matabuena (2018) describe a project focusing on using telemedicine units in Durango located in Mexico. The location medically suffers from its low population density; therefore, it is harder to provide medical supplies and medical needs. The project will focus on various medical needs, where adequate medical help and medical response is not available. The drone will be equipped with basic health systems, so it will be able to monitor EKG activity, blood pressure, temperature, and oxygen in the blood.

3.2.2 Healthcare Integrated Rescue Operations

One of the most promising systems in telemedicine is HiRO (Healthcare Integrated Rescue Operations) project introduced in 2017. As Lilian (2017) describes, it is designed to be used in disaster situations to provide necessary medical supplies and to allow medical physicians to help with the situation remotely. The drone can deliver a Microsoft Hololens headset, which has an augmented reality interface, which allows the remote physician to see the situation firsthand. The drone is also equipped with an automated medical box with compartments, which can be opened by the remote physician, allowing the people struck by disaster access medicament or equipment. Holographic electronic health record system is also part of the drone, which allows the remote physician to monitor multiple patients on the field.

Figure 21. HiRO drone, reprinted from https://www.suasnews.com/2017/10/telemedicine-drone-integrates-holographic-technology-connect-doctors-lifesaving-drugs-survivors

3.3 Military

As stated earlier, the roots of drones are in the military area. Drones allow to supervise areas for 24 hours every day, use them as target decoys. Drones can also spy or deliver the necessary equipment without risking human lives. However, as Fervimax (2020) site claims, military drones are much more expensive, as they need to be more precise and have to make minimum mistakes. Drones have always been mainly used in the military until their accessibility to the public over the last decade due to lower prices of their components.

3.3.1 Global Hawk

One of the most notable UAVs designed for the military is the RQ-4 Global Hawk drone (see Fig. 22). As Airforce-Technology (2021) site describes, it can fly at high altitudes and can provide the army with constant high-resolution and real-time surveillance of large geographic areas.

According to the U.S. Airforce site (2014), the maximum fuel capacity is 7.8 tons) and also adds that the maximum gross take-off weight is almost 15 tons. The maximum payload that the drone can carry should be lower than 1400 kilograms. According to Northrop Grumman (n.d), Global Hawk set a world record in 2013, when it completed a 34-hour flight at 18,2 km altitude.

According to the Airforce-Technology (2021) site, it is equipped with high-resolution sensors, including infrared electro-optical systems, which allows the drone system to survey an area of 100 000 square kilometers over 24 hours. As Airforce-Technology

(2021) adds, six Global Hawk vehicles were deployed in Afganistan in 2002 and completed over 4300 combat hours.

Figure 22. Global Hawk drone, reprinted from https://cs.wikipedia.org/wiki/Northrop_Grumman_RQ-4_Global_Hawk#/media/Soubor:Global_Hawk_1.jpg

3.3.2 Ultra LEAP

Another military drone used in the field of the military is the Ultra Long Endurance Aircraft Platform (Ultra LEAP). As Pawlyk (2019) says, the drone is equipped with anti-jam GPS, which is a critical aspect for the drone in the field of the military. As Pawlyk (2019) adds, the dimensions of the drone have not been announced, but it is expected to have a similar wingspan to the Global Hawk (which is 40 m). As Pawlyk (2019) continues, the drone is equipped with a variety of ISR (Intelligence, Surveillance, Reconnaissance) sensors to make the drone more effective. Pawlyk (2019) also says that the drone is commercial, which means that many parts can be easily manufactured to suit the needs of the air force.

Figure 23. Ultra LEAP drone, reprinted from https://insideunmannedsystems.com/one-ultra-endurance-leap-for-uavs/

3.3.3 XQ-58A Valkyrie

One of the cheaper drones manufactured for the military is the XQ-58A Valkyrie drone (see Fig. 24). According to Pawlyk (2019), one XQ-58A Valkyrie drone costs about 2 to 3 million dollars. This option is much cheaper compared to the Global Hawk drone, which costs about 130 million dollars, as Pawlyk (2019) adds. According to Trevithick (2019), the XQ-58A Valkyrie does not need any runway for take-off. Trevithick (2019) adds that a launching platform for the drone is in development. The launching platform (along with the drone) can be stored in a standard ISO container and the rails on the floor allow the launcher to easily slide out of the container and then launch the drone upwards, as Trevithick (2019) adds.

Figure 24. XQ-58A Valkyrie Drone, reprinted from https://www.armadninoviny.cz/roboticky-bojovy-wingman-xq-58a-valkyrie.html

3 CONCLUSION

The bachelor thesis aimed to describe drones used in integrated services and describe the related problems. As the technology is still developing and is new, there was a limited research regarding the fields separately. The research was limited the most in the field of firefighting and medicine, as these two fields are the newest to use drones in their profession. Police was the first to use drones in their profession, as one of the first uses of the drone was to survey desired areas. However, the first usage of a drone in the police field was to find a missing person, as mentioned in the thesis.

The first chapter of the bachelor thesis described the technology associated with drones. First, the categorization of drones by their design was introduced. Five main designs of drones were introduced, and the advantages and disadvantages of each design were discussed. The second part of the chapter described counter measurements, that can be applied against the drones. Four the most effective technologies used to detect a position of a drone were introduced – RF analyzers, acoustic and optical sensor, radar, with their advantages and disadvantages, as well as the situations where they are the most efficient. Following the subchapter, an introduction of technologies used to stop (and possibly neutralize) a drone was also discussed. Their advantages, disadvantages, as well as their efficiency was described.

The second chapter focused on the use of drones in the integrated services. The first part of the chapter described the legislation problem of using drones for service purposes (mainly focused on medical field), with three examples of the USA, Nepal, and Poland.

The second subchapter described the usage of drones in the police field. It focused on two main usages of police drones, and then with one topic dedicated to the usage of drones in shooter investigation.

The third part of the chapter focused on firefighting drones. It described two drones used in the firefighting field. The first drone was described to show the capability of a drone to suppress high-rise fires. The second drone described was not a drone that can suppress fire, but a drone that can efficiently monitor the fire. The drone was described to show the technology that is used when looking for survivors or monitoring the fire. Also, the subchapter also described future technology for the firefighting drones – self-organized swarming drones, which can potentially suppress fires in the future.

The fourth part of the chapter focused on the drones used in the urgent medicine, providing an overview which drones are approved by the governments, and describing their use and the technologies which some of the drones use. Four drones were described, emphasizing the efficiency of some drones during the coronavirus crisis.

The fifth part of the second chapter described the use of drones in telemedicine, as telemedicine can be also associated with integrated services. Project focusing on using telemedicine units in Mexico was introduced to improve the medical infrastructure. Moreover, a drone named HiRO (Healthcare Integrated Rescue Operations) was introduced, which is one of the most promising projects in the field of telemedicine. However, the search on the subject of telemedicine was limited, as there were not many sources describing this topic.

The last part of the chapter showed two fields where drones are used – delivery services and military. It discussed advantages, but also possible drawbacks of using the drones in delivery services.

To summarize the thesis, it shows how the drones help to survey suspicious areas, monitor ongoing riots in the police field, observe and even suppress spreading fires in the firefighting field. In the field of emergency medicine, drones show their potential in saving lives. As mentioned in the bachelor thesis, their most notable advantage is their speed, especially in rural areas. Although the drones are not used widely, developing technology and availability of the drones can change that. Also, the thesis showed how are drones used in medical field and how they can save lives.

Rozšířený abstrakt

Drony v oblasti integrovaného záchranného systému jsou používány stále častěji, protože zefektivňují záchranné operace a disponují možností pracovat bez přestání. Drony se v oblasti integrovaného záchranného systému (a také v ostatních pracovních oblastech) nepoužívají příliš dlouho a technika dronů se stále rapidně vyvíjí. Vývoj dronů začal během první světové války. Letouny bez pilota byly pomocí rádiové komunikace naváděny proti nepřátelským objektům. Během druhé světové války ale byly vynalezeny rakety, které nahradily drony kvůli jejich vyšší přesnosti a rychlosti. Cílem této práce bylo vytvořit seznam dronů používaných v oblasti integrovaného záchranného systému a popsání technologií souvisejících s drony. K získání potřebných informací byly využity hlavně odborné výzkumy, vědecké články a odborné publikace.

Bakalářská práce je rozdělena do tří hlavních kapitol. První kapitola pojednává o technologiích, které souvisejí s drony. První část této kapitoly popisuje různé typy dronů a popisuje jejich vlastnosti. Prvním popisovaným dronem je „multi-rotor“ dron. Tento typ dronu je nejrozšířenější a ke svému pohybu využívá několik vrtulí připevněných k jeho konstrukci. Ačkoliv se tento dron může vznášet na jednom místě, kvůli svým několika vrtulím je neefektivní a ve vzduchu vydrží maximálně 30 minut. Dron typu „fixed-wing“ se svou konstrukcí podobá klasickému letadlu. Jeho největší nevýhodou je že se nemůže vznášet na jednom místě. Naproti tomu jeho nejvíce důležitou výhodou je jeho efektivita, ze které pramení i vysoká výdrž baterie. Díky těmto vlastnostem je tento typ dronu používaný pro dlouhé lety. Dalším typem, který je v bakalářské práci popsán je „single-rotor“. Konstrukce tohoto typu nejvíce připomíná helikoptéru. Oproti dronu vybaveným několika vrtulemi je tento dron více stabilní, protože má jen jednu vrtuli na vzlet a jeden menší rotor na balancování. Tyto drony jsou zároveň nejvíce odolné. Dalším typem dronů je „hybrid VTOL“. Tento typ dronu kombinuje výhody „multi-rotor“ a „fixed-wing“ typů, jelikož dokáže vzlétnout bez vzletové dráhy a poté dokáže létat stejně efektivně jako „fixed-wing“ typ. Posledním typem je „flapping-wing“ drone. Tento typ je nejnovější z uvedených typů a snaží se napodobovat let malých ptáků. Druhá část první kapitoly se věnuje technologiím, které se dají použít proti dronům, pokud se drony pohybují v zakázaných oblastech nebo narušují soukromí. Jsou popsány řešení pro sledování dronů, konkrétně radiofrekvenční snímače, akustické senzory, optické senzory a radar. Druhá část první kapitoly se potom věnuje řešením, které mohou být použity pro účinné neutralizování dronu. Konkrétně popisuje radiofrekvenční rušiče, přístroje pro narušování (a změnu) GPS signálu, přístroje vysílající silné elektromagnetické signály a jako poslední popisuje přístroje vystřelující sítě.

Druhá kapitola se zabývá samotnými drony a jejich použitím v oblastní integrovaného záchranného systému. První podkapitola se zaobírá právními aspekty používání dronů v pracovních oblastech a zaměřuje se hlavně na používání dronů v urgentní medicíně. Kapitola popisuje tři státy, které představovaly určitý milník v utvoření právních legislativ pro používání dronů – USA, Nepál a Polsko. Druhá část této kapitoly popisuje používání dronů v policejní oblasti. Zmiňuje a popisuje hlavní náplň policejních dronů – sledování a monitorování. Jako druhé použití je zmíněno zrekonstruování dopravních nehod. V této policejní oblasti jsou drony velice důležité, protože zrychlují rekonstrukci nehod. Normální postup pomocí laserového skeneru může trvat až tři hodiny. Použití dronu tuto dobu může zkrátit na 10 minut. To má poté za následek plynulejší dopravu a méně potenciálních nehod, protože je mnoho případů kdy přijíždějící řidič narazil do stojícího auta v koloně. Další část druhé kapitoly se věnuje dronům používaných v hasičské oblasti. Drony v této oblasti můžou být použity dvěma způsoby – k hašení ohně nebo k jeho monitorování. Jako dron, který je schopný uhasit oheň je popsán čínský dron Ehang, který byl vyvinut pro hašení požárů ve vysokých budovách. Dalším popisovaným dronem je Matrice 210 V2, který disponuje vybavením schopným monitorovat oheň. V této podkapitole je také popisována budoucí technologie dronů, tzv. „swarming drones“. Ta spočívá v tom že skupina dronů (o počtu např. 100) nepotřebuje pilota, drony dokáží komunikovat mezi sebou a společně pracují na uhašení požáru. Poslední část druhé kapitoly se věnuje dronům používaných v lékařství. Na začátku jsou popsány výhody používání dronů v této oblasti a také související problémy. Poté je popsán dron, který pomáhá během pandemie koronaviru doručovat Covid testy na odlehlé ostrovy. Tento dron dokáže testy doručit do 15 minut oproti lodím, kterým to trvá až dvě hodiny. Další část této kapitoly se věnují dronu, který je schopný pacientům doručovat automatický defibrilátor, protože dron je schopný dorazit na místo nehody v rychlejším čase než záchranná služba. Dalším popisovaným dronem je dron Zipline, který přepravuje krevní vzorky v afrických oblastech, kvůli nedostatečné kvalitě afrických cest. Posledním popisovaným lékařským dronem je dron Ehang, který je schopný přepravovat až dvě osoby nebo doručovat lékařské vybavení.

Třetí kapitola se věnuje dronům používaných v jiných pracovních oblastech. Jako první oblastí jsou popisovány kurýrní služby. Hlavní část této podkapitoly se věnuje tomu, jaké výhody (ale i nevýhody) s sebou přináší používání dronů k doručování zásilek oproti autům. Další oblastí, kde se drony využívají je telemedicína, která je úzce spjatá s urgentní medicínou. Telemedicína spočívá v tom, že dron vyslaný na místo určení je zároveň schopný komunikovat s pacientem. V této podkapitole je jako první popsán projekt, kde dron bude schopný přiletět k pacientovi a změřit mu různé tělesné hodnoty, jako teplotu, okysličení krve nebo tlak. Další popsaný dron HiRo (Healthcare Integrated Rescue Operations) je schopný pomáhat lidem postiženým přírodními katastrofami. Poslední popisovanou oblastí ve třetí kapitole je armáda, kde jsou drony používány odjakživa. Zde jsou popsány tři drony, které jsou využívány americkou armádou.

Drony ještě stále nejsou velmi rozšířené v pracovních oblastech, ale díky jejich technologii a větší dostupnosti budou jistě součástí několika pracovních odvětví. Tato bakalářská práce poskytla přehled dostupných dronů v integrovaném záchranném systému a také v ní bylo zmíněno několik technologií souvisejících s drony.

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