DG ECHO LEAPFROG
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Deliverable B.5: Report on Autonomous Functionalities

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1 Introduction

Autonomous technologies on drones are not yet at a level to completely replace human emergency response systems, although, the level of autonomous functionalities currently can complement existing emergency response operations greatly by accomplishing tasks faster, much more effectively at a lower cost and in most cases safer than conventional methods. By introducing technological advancement in both software and hardware into the field of emergency response has been proved beneficial and very promising so far by boosting the current old-fashioned tactics and methods of these kind of operations. This report focuses on highlighting current state-of-the-art autonomous functionalities using Unmanned Aircraft Systems (UAS) that could potentially be used in emergency response operations. Operations that could benefit from the use of UAS can vary from Search and Rescue, prevention/preparedness of disaster and post disaster situational awareness and restoration.

2 Intelligence in UAS

UASs have already been widely used to thousands of applications just because of their extreme capabilities as platforms with respect to manned aircraft. By adding some degree of intelligence to these platforms; their capabilities are extended much further. Intelligence may include some degree of autonomous functionalities to perform a number of tasks either partially or fully autonomously. This can be extended one step further by implementing intelligence to multiple of UAS that could cooperate with each other to perform multiple tasks at the same time.

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Partially autonomous functionalities are usually used to aid the operator of the UAS to perform assigned tasks easier and faster. For instance, integrated camera field of view to the map can be used to help the operator quickly identify which area the camera is monitoring by interpolating the field of view of the camera to the map. This functionality greatly improves the navigational awareness of the pilot especially in unknown challenging terrains.

Fully autonomous functionalities on the other hand allowing the UAS to perform various tasks completely autonomously while allowing the operator to focus only in monitoring the entire mission. A great example of this kind of functionality is a swarm of UAS cooperating each other to autonomously search and navigate a region of interest and automatically detect and identify possible targets of interest.

2.1 Integrate camera field of view to the map

Integration of camera field of view to the map could be a very handy tool for a first responder to quickly identify the exact position of an object of interest in the map as well as greatly expands the navigational and situational awareness of the pilot. Figure 1, illustrates an example of this technology. This software based intelligent addition, can be achieved by analyzing the actual position of the UAS camera in 3-Dimensional space in real time (e.g. rotational angles of the gimbal, focal length of camera etc.) while at the same time extracting depth features from the image its self to superimpose them in the map. In simple flat terrains this technology can easily been implemented and performed with relatively high accuracy, however, in complicated shapeless terrains this could be really challenging to be applied and it may be requiring multi-sensor data acquisition. Multi-sensor data fusion could be used for complicated environments by getting data from various sensors simultaneously such as LiDARS and multispectral image sensors.

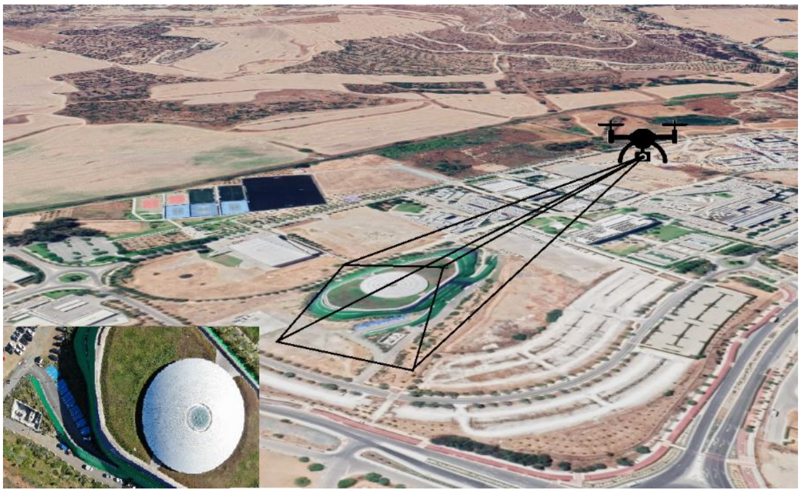

Figure 1: Integrated camera field of view on the map

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2.2 Terrain depth map

Another feature that could be easily combined with the integrated camera-map technology described before, is the terrain depth map. By using multispectral cameras, the terrain depth can be extracted and be used for autonomous real time navigation into 3-Dimensional space. This feature can be used to aid the first responder pilot to easily fly in challenging, complicated terrains (e.g. between mountains, trees etc.) while allowing him/her to focus on the main target. This autonomous functionality can greatly improve situational awareness of the first responder. Figure 2 shows an example of a 3-Dimensional representation using multispectral camera sensor of a forest area in Cyprus.

Figure 2: Terrain depth map

As clearly seen from the Figure 2, the 3-Dimensional reconstruction could very handy for detection or identification of hard spots such as bushes, ravines, trees or rocks. This could be used to analyze the terrain and help the first responders to prioritize their operation depending on the depth map, which otherwise it may be very difficult to do so using 2-Dimensional imagery. Additionally, this depth map could be used for performing autonomous navigation flights at very low altitudes and allowing the UAS to maneuver its self between trees and ravines with the aid of ultrasonic avoidance sensors. This autonomous functionality not only mitigates the risk of first responders trying to walk around challenging environments searching for possible victims, but also greatly reduces time required to perform these kinds of missions while at the same time gives the opportunity to navigate in inaccessible areas.

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2.3 Automatic object detection and identification

Automatic intelligent object detection and identification is the process where computer vision and machine learning algorithms are combined to provide automatic analysis of images or video using some kind of processing unit for detecting objects of interests such as vehicles, boats, people, collapsed buildings, flooded areas or spot fires and smoke. Figure 3, shows a human automatic detection using the optical camera sensor of the UAS. This technology can be used to perform fully autonomous flights by scanning large amounts of geographical areas effectively while at the same time allowing the first responders to focus on monitoring and evaluating the data gathered by the UAS. Computer vision algorithms can achieve that by analyzing the camera's imagery in real-time to detect and avoid obstacles. Hence it enhances the navigational ability of a UAS thus enabling it to navigate in more complex and time-varying environments without relying solely on GPS signal. For example, this enables autonomous indoor flights and even flights in collapsed buildings in aid of detecting victims. Moreover, machine learning can be used to further enhance an autonomous flight by intelligently monitoring areas in the most efficient way that increases the potential of finding survivors during the daytime by utilizing optical cameras and during the nighttime by utilizing thermal and near-infrared cameras.

Figure 3: Human detection from a UAS

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2.4 Swarm of unmanned aircrafts

Swarm of unmanned aircrafts is one of the state-of-the-art automatic functionalities that has started to evolve exponentially. In emergency response operations, this functionality could implement autonomous distributed aerial platforms consisting of two or more unmanned aircrafts systems that collaborate to complete a given tasks.

Swarm of unmanned aircrafts have multiple applications in emergency response, such as a) searching an area for detecting and tracking for possible targets, b) situational awareness and c) network restoration. The swarm of unmanned aircrafts, works in order to efficiently cover an area of interest using state of the art path planning algorithms while being able to detect and track any desired targets found in that area. This functionality greatly reduces the critical time of finding any survivors after a disaster. A multi-UAS system can also be used in mapping missions in order to provide situational awareness of the current state to the first responders in significantly less time and simultaneously covering a larger area. Another use of multi-UAS systems are the deployment of temporary communication networks after a disaster. Multiple UASs can be deployed while carrying antennas and software defined radios in order to simulate a small local communication network providing the power of communication to the first responders.

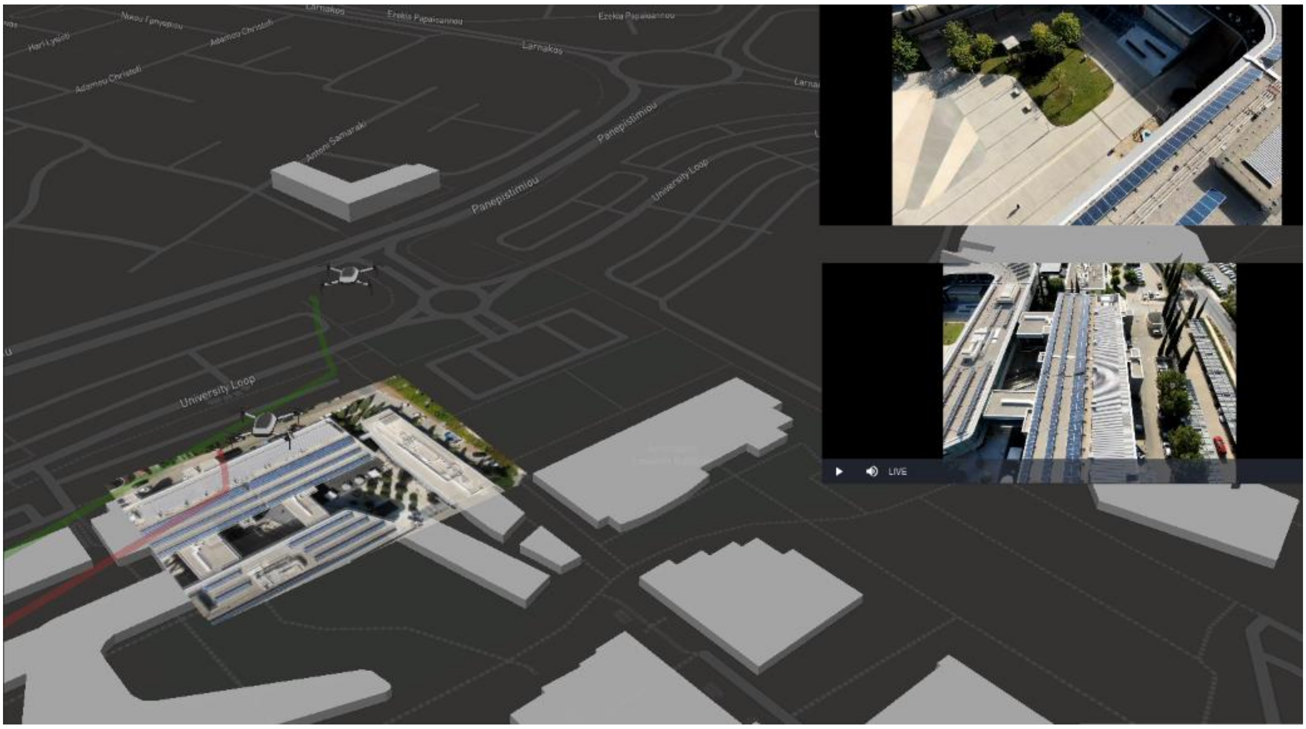

Figure 4: Swarm of UAS platform

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2.5 Post disaster telecommunication network restoration

During a natural disaster such as earthquake, flood or even a fire, telecommunications are most likely to be partially or completely destroyed. During the panic of such situation affected people could potentially get disoriented or they may need urgently help and don't be able to communicate with the authorities. Figure 5, shows a deployment of temporary telecommunication network in an affected area. Combining the swarm of unmanned aircrafts automatic functionality described earlier equipped with open-source communication systems such as software-defined-radios (SDRs) a temporary telecommunication network could be achieved covering the desired affected area quickly and effectively. Figure 6, illustrates an example of a Software Defined Radio equipment.

By definition, software-defined radio is a communication system where components that have been traditionally implemented in hardware are instead implemented by means of software on a personal computer or embedded system. Such device can easily get installed to a UAS and could be used for many other applications beside telecommunication network restoration. For instance, it could be used to broadcast a specific SMS message to all the cell phones in the area, providing to the victims of a disaster some useful information that may be proved vital in such an event. Another application of software-defined radios is to track and locate a missing person. By scanning an area using a UAV equipped with SDR, it could be possible to force the victim's cell phone connect to the SDR and locate him accurately.

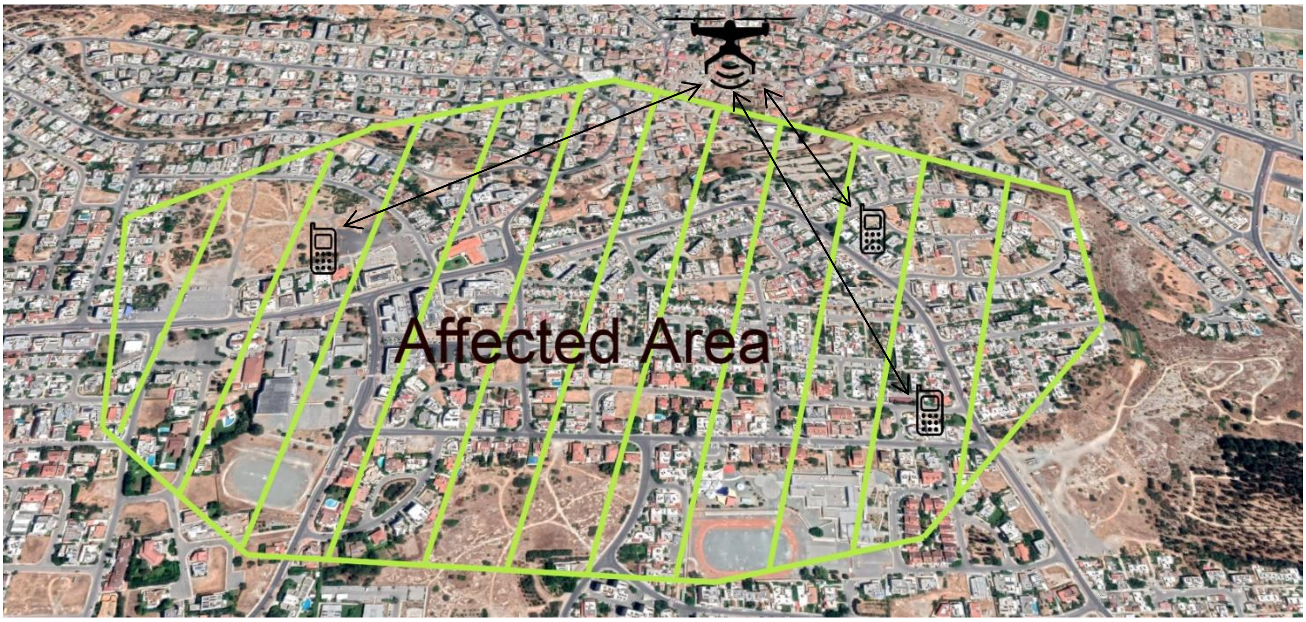

Figure 5: UAS telecommunication restoration in an affected area

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Figure 6: Software Defined Radio equipment

3 Conclusion

Autonomous functionalities implemented in UAS provide a completely new technological solution in the hands of a first responder. This report focused on the current state-of-the-art technology autonomous functionalities that completely transform the old-fashioned ways of Search and Rescue, disaster monitoring, disaster prevention, mitigation and restoration. Not only these functionalities aid the first responders in terms of allowing them to stay focus on their targets while all the necessary workload of flying the UAS is minimized by the autonomous functions, but also the time required to perform important tasks is minimized which could be vital in these kinds of operations.

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