Emerging methods for early detection of forest fires using unmanned aerial vehicles and LoRaWAN sensor networks

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***Abstract* — Forest fires are occurring throughout the year with an increasing intensity in the summer and autumn periods. These events are mainly caused by the actions of humans, but different nature and environmental phenomena, like lightning strikes or spontaneous combustion of dried leafs or sawdust, can also be credited for their occurrence. Regardless of the reasons for the ignition of the forest fires, they usually cause devastating damage to both nature and humans. Forest fires are also considered as a main contributor to the air pollution, due to the fact that during every fire huge amounts of gases and particle mater are released in the atmosphere.**

To fight forest fires, different solutions were employed throughout the years. They ware primary aimed at the early detection of the fires. The simplest of these solutions is the establishment of a network of observation posts – both cheap and easy to accomplish, but also time-consuming for the involved people. The constant evolution of the information and communication technologies has led to the introduction of a new generation of solutions for early detection and even prevention of forest fires. ICT-based networks of cameras and sensors and even satellite-based solutions were developed and used in the last decades. These solutions have greatly decreased the direct involvement of humans in the forest fire detection process, but have also proven to be expensive and hard to maintain.

In this paper we will discuss and present two different emerging solutions for early detection of forest fires. The first of these solutions involves the use of unmanned aerial vehicles (UAVs) with specialized cameras. Several different scenarios for the possible use of the drones for forest fire detection will be presented and analysed, including a solution with the use of a combination between a fixed-wind and a rotary-wing UAVs.

In the next chapter of the paper, we will present and discuss the possibilities for development of systems for early forest fire detection using LoRaWAN sensor networks and we will analyse and present some of the hardware and software components for the realisation of such sensor networks.

The paper will also provide another point-of-view, which will present the involvement of students in the development and in the use of both systems and we will analyse the advantages and the benefits, which the students will gain from their work on and with these solutions.

Keywords* — *early forest fire detection, LoRaWAN, sensor network, unmanned aerial vehicles, drones

I. INTRODUCTION

Forest fires have been and still are serious problem for the European Union and for all other countries in Europe. In the year 2000, the EU has established the European Forest Fire Information system (EFFIS) [1], which will soon become part of the European Emergency Management Service, maintained by the Copernicus Earth Observation Programme [2]. This system provides valuable near real-time and also historical data on the forest fires in Europe, the Middle East and North Africa. Currently EFFIS is being used and supported with data by 25 EU member states and by numerous other countries. According to the annual report of EFFIS for 2016 [3], more than 54 000 forest fires have occurred all around Europe and they have led to nearly 376 thousand hectares of burnt areas. If we compare these values to the average values from the EFFIS reports for the period 2006-2015, the number of forest fires have decreased by 13327 or by nearly 20%. This decrease can be explained with the more severe actions and sanctions towards the arsonists and with the introduction of more advanced technical solutions for early detection of the fires. Even though their number is decreasing, the forest fires continue to be extremely devastating events and they have destroyed just 27 thousand hectares (or 6.6 %) less than the average burnt areas for the period 2006-2015, according to [3]. Confirmation for this are the devastating forest fires form 2018, which took place in the Attica region of Greece and led to more than 90 fatalities and to more than 200 injured people, as well as to the destruction to thousands of buildings [4].

The most important factors in the fight against the forest fires include the earliest possible detection of the fire event, the proper categorisation of the fire and fast response from the fire services. Several different types of forest fires are known, including ground fires, surface fires and crown/tree fires [5]. Each of these types of forest fires is specific and the proper counteractions against it must be considered and implemented to successfully fight it. Over the years the detection of forest fires has been conducted in different ways, ranging from the use of forest outposts to fully automated solutions.

In the last decade many improvements in the forest fire detection technologies have been made. The modern IR cameras provide steady and reliable detection of the fires, but the real focus is set on the possibilities to detect the fires by analysing wider areas for smoke or by sensing the environmental parameters before the actual spread of the fire.

978-1-5386-7711-7/18/$31.00

II. EARLY FOREST FIRE DETECTION USING UNMANNED AERIAL VEHICLES

The use of aircrafts for early forest fire detection and prevention is not a new idea. According to several sources [6 and 7], aerial firefighting began around 1920 with the first attempts for dropping water from aircrafts onto ongoing forest fires. In these early years for the aviation, the use of planes for actual extinguishing of fires was not so successful, so the focus turned on their use for forest fire detection. In the decades after World War II, the use of aircrafts for forest fighting was resumed [6] and by the late 1960s many airplanes and helicopters [7] were actually involved in it. The use of aircrafts for forest fighting however has proven to be expensive and also dangerous, as the aircraft pilots are pushed to their limits and are expected to fly in dangerous conditions and extremely close to the fires. Numerous accidents with firefighting aircrafts were recorded throughout the years and this has raised the public alert about their reliability and the actual benefits from their use.

The recent advances in the development of the unmanned aerial vehicles (UAVs) provided the possibility to use them in the fight against the forest fires as a replacement of the piloted aicrafts. Over the years different types and numbers of UAVs have been used and evaluated as solutions for early forest fire detection [8]. Krüll et al. [9] for instance presents the possibility to use a multi-rotor drone and a blimp for observation and sensing of areas susceptible to forest fires.

Project “Forest Monitoring System for Early Fire Detection and Assessment in the Balkan-Med Area” (SFEDA) [10], project code 2263, financed under the transnational Cooperation Programme INTERREG V-B "Balkan-Mediterranean 2014-2020", co-funded by the European Union and the National Funds of the participating countries, is currently investigating several options for the use of UAVs for early forest fire detection and observation.

The lead beneficiary of the project is the Mechanical Engineering and Aeronautics Department from the University of Patras (Greece), while project partners are the Decentralized Administration of Peloponnese, Western Greece and Ionian (Greece), the Forest Research Institute at the Hellenic Agricultural Organization DEMETER (Greece), the University of Ruse "Angel Kanchev" (Bulgaria), the Directorate of Nature Park Rusenski Lom (Bulgaria), the Cyprus University Of Technology (Cyprus) and the Pano Platres Community Council (Cyprus). The goal of this project is the evaluation of several configurations of the proposed THEASIS system for early forest fire detection and observation, which implements ground based cameras and both fixed wing and rotary wing UAVs [11].

The most basic configuration of the system involves the use of a network of ground cameras, which provide constant observation of the targeted forest areas. The used cameras within the project are dual lens and provide both standard and IR images. The challenges here are the actual locations where the cameras will be installed, as the planned areas involve territories within national parks and within Natura 2000 sites. Another challenge is the fact that the camera-based systems have proven themselves to present large number of false-positive alerts.

To further develop the system and solve some of these issues, the Greek and Cyprus project partners will enhance the system by introducing a multi-rotor UAV, which will be kept in stand-by mode and will be sent only to investigate the reported by the ground cameras areas where fire might have occurred. This will significantly reduce the false-positive alarms and will provide means for better initial assessment of the situation in terms of type and size of the forest fires. Additionally, as the drones have limited flight time (10 to 35 minutes), their on-demand use will be much more efficient.

The most extensive configuration of the system involves primary the use of fixed wing and rotary wing UAVs. This configuration of the THEASIS system will be deployed and tested in the Rusenski Lom Nature Park in Bulgaria by the University of Ruse “Angel Kanchev”. The general conceptual model of this system configuration is presented in Fig. 1. The used ALTi vertical take-off and landing (VTOL) fixed wing UAV [12] and its ground control station are presented in Fig.2.

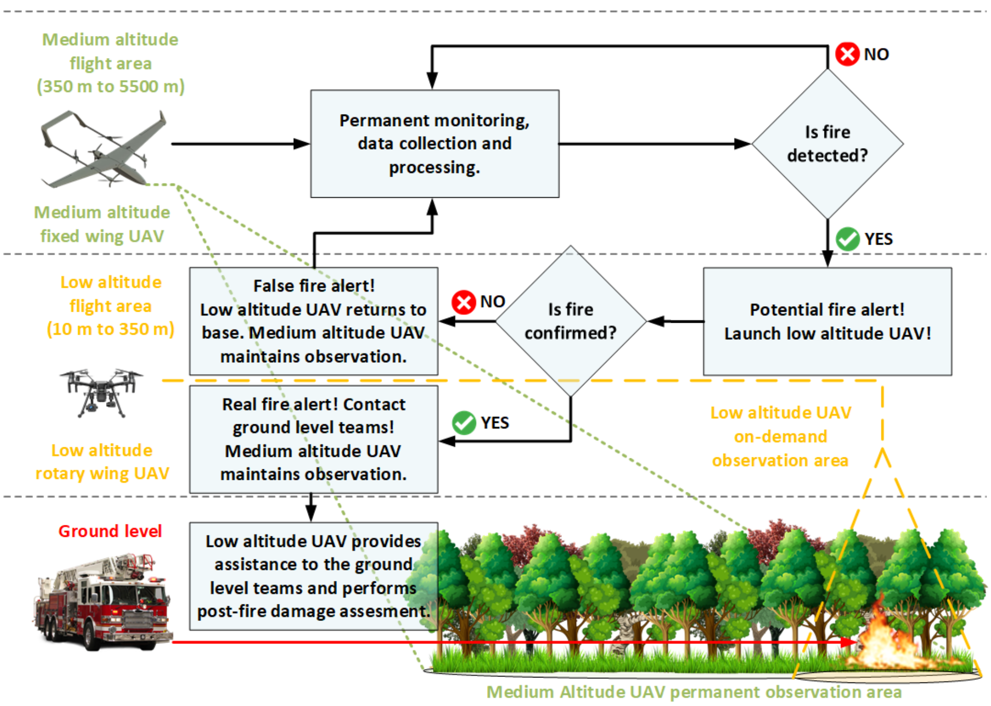

Fig. 1. Conceptual model of the early forest fire detection system with use of fixed wing and rotary wing UAVs

Fig. 2. ALTi Transition vertical take-off and landing fixed wing UAV and its ground control station

The terrain of the Nature Park Rusenski Lom involves a steep canyon along the Rusenski Lom River covered by very dense forest vegetation. The altitude variates from the ground level (0 meters) at the riverbed to 150-170 meters at the highest points of the canyon. This makes the location very difficult for observation using ground cameras, as their placement should be on higher grounds to provide wider overview of the area. The installation of the cameras is however allowed only in specific areas of the park, which are outside of the protected habitat zones and this makes their use impossible. As a last resort, the Directorate of the Nature Park will install just one camera at the rooftop of a local facility.

To provide an overall overview of the park and to observe its difficult terrain, we have decided to use a fixed wing endurance UAV. After a careful market analysis, we have selected the ALTi Transition VTOL UAV [12]. The dimensions of the aircraft are 3000 mm wingspan, 2300 mm length and 525 mm height and its maximum take-off weight is 16 kg, which allows it to carry several different types of payload simultaneously. Its flight time is from 8 to 10 hours with average sized payload, which allows it to be used for long observations of the targeted forest areas. The drone is equipped with a NightHawk 2 EO/IR camera with 20x zoom and thermal resolution of 640x480.

As presented in Fig. 1, this VTOL fixed wing UAV will provide long term observation of the forest areas on the territory of the Nature Park Rusenski Lom. Once the UAV detects increased temperature levels, it will immediately raise an alarm and will send the GPS coordinates of the area to its base station. The drone will however not stop its observation functions and will continue to patrol over the park.

To confirm the detection of the fire we have planned to use two smaller rotary wing drones – the DJI Matrice 600 Pro (Fig. 3) [13] and the DJI Matrice 210 RTK (Fig. 4) [14].

Fig. 3. The DJI Matrice 600 Pro rotary wing UAV

Fig. 4. The DJI Matrice 210 RTK rotary wing drone with its dual downwards gimbal with mounted IR (XT) and regular (X5S) cameras

The Matrice 600 Pro drone is larger and can carry up to 5 kilograms of additional payload, which make it suitable as a development platform. Unlike it, the Matrice 210 RTK is more sophisticated and is equipped with a dual gimbal with one IR and one standard/zoom camera. The RTK extension, allows this drone to be precisely localized and also to precisely pinpoint any location on the ground. Another huge advantage of the Matrice 200 series of drones is the fact that they are IP 43 certified, which means that they can withstand humidity and can fly in foggy or rainy conditions.

The use of both rotary wing UAVs will provide the possibility for close inspection of the potential forest fire location and to perform the initial assessment of the situation.

The implementation of the system is currently ongoing and is performed under the supervision of several university professors. Besides them, several PhD students and more than a dozen regular Bachelor and Master students are or will be involved in the project. All of them will participate in two training events with topics about the characteristics of the UAVs and their application areas. The drones will be assembled, tested and piloted by the university staff and the PhD students, but all interested students will be allowed to study and test them. Following the successful implementation of the system we hope to collect significant database with images, which will then be used by the students to reconstruct and create ortho-photo images, digital surface models and 3D maps of the targeted areas. This will increase their knowledge about the possible applications of the drones and will provide them with new knowledge about the modern image processing software and tools.

As directions for further development of the THEASIS system, we are planning to integrate Intel Movidius [15] neural compute sticks or modules with the UAVs. This will allow us to investigate the possibilities to use deep learning and artificial intelligence (AI) for on-board image processing of the raw camera data and for much faster and automated detection of the potential forest fires. This is again going to be implemented and studied in two stages – by students as their graduation projects and by PhD students for enhancement of their skills and for development and testing of AI based image processing algorithms.

Fig. 5. The Intel Movidius Neural Compute stick

III. Early Forest Fire Detection Using LoRaWAN Sensor Networks and Devices

The Long Range (LoRa) digital wireless communication technology and the closely related LoRaWAN networks are known for their long range communication capabilities and are extremely suitable for sensor and telemetry applications. The improved range makes these network also suitable for many new applications, including forest fire detection, environmental sensing and long term air-quality analysis.

In order to provide LoRaWAN connectivity in the region of Ruse (Bulgaria), the Department of Telecommunications, at the University of Ruse, has established a network of different LoRaWAN gateways. Two types of gateways were installed – IMST iC880A concentrators [16], which were mounted on Raspberry Pi 3 Model B+ microcomputers and Pycom LoPy modules with extension boards (Fig. 6).

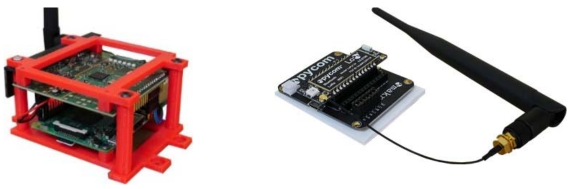

Fig. 6. LoRaWAN gateways – IMST iC880A mounted on Raspberry Pi 3 Model B (left) and Pycom LoPy (right)

The gateways were able to receive data from more than 6000 LoRaWAN devices. Driven by the ambition to fully utilize this network, several students, under the supervision of their university professors, started the development of small-sized sensor stations equipped with sensors for temperature, humidity and atmospheric pressure (Fig. 7). A further improvement and upgrade of these stations is underway and will provide them with sensors for analysis of different gasses and sensors for measurement of particle matter. This upgrade will make the stations suitable for both early detection of the forest fires and for post-fire damage assessment in terms of the released pollutants in the atmosphere.

Fig. 7. LoRaWAN sensor station for monitoring of various parameters

Conclusions

In this paper we have briefly presented two new methods for early forest fire detection, including part of their characteristics and main components. We have also analysed some of the benefits, which these methods can provide to the involved Bachelor, Master and PhD students. Both solutions are still under development, but they show great potential and work on their development and improvement will continue in the following years.

Acknowledgment

This publication is developed within the frame of Project “Forest Monitoring System for Early Fire Detection and Assessment in the Balkan-Med Area” (SFEDA), project code 2263, financed under the transnational Cooperation Programme INTERREG V-B "Balkan-Mediterranean 2014-2020", co-funded by the European Union and the National Funds of the participating countries and within the frame of Project BG05M2OP001-1.002-0008-C01 “Centre for Competence and Intelligent Solutions for the Creative and Recreational Industries" (INCREA), funded within Operational Programme “Science and Education for Smart Growth (2014-2020)” and with support from the European Union. This publication reflects only the views of the authors and do not necessarily represent those of the European Union or the European Commission.

The work presented in this paper is completed as partial fulfilment of a PROJECT 2018 - FEEA - 02 “Development and evaluation of a methodology for sensing, analysis and visualisation of open data through LoRaWAN based communication infrastructure”, financed under the Scientific Fund of the University of Ruse.

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