The Use of Unmanned Aerial Vehicles for Forest Fire Monitoring

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Abstract **– With the use of Unmanned Aerial Vehicles negative impacts of forest fire can be significantly reduced. Through this research it is shown how UAVs can contribute to reducing probability of errors made by tactics on the ground and in air, reaction time, accuracy in decision making and load of people and equipment in peak days. Review of the challenges for using small UAVs was made for the regulations in the Republic of Croatia, also with the detail described proposed system architecture including module for communication, data receiving module, video play module, fire detection module and GIS display module.**

Keywords **– UAV; Natural Disaster; Forest Fire, Regulative**

I. Introduction

A forest fire is a natural disaster that has a negative impact on the environment and affects the economic state of government. This extremely complex phenomenon depends on a number of natural factors, such as, the type of forest, orthography terrain and weather conditions. A forest fire is a relatively common occurrence in coastal parts and on islands in Croatia. It is particularly dangerous because it is unpredictable with extreme rapid expanding that leaves severe consequences. The risk of forest fires dramatically increases in the summer months due to the increase of temperature and decrease of precipitation.

The total number of forest fires in Croatia in recent years has been growing with climate change contributing to it, but also a lack of systematic approach to establish a modern organization that, in terms of fire protection, follows world trends in the development and introduction of new technologies to improve the monitoring system forest fires. One example of that kind of technology is the application of the system of unmanned aerial vehicles- UAV.

UAV is defined as an aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expandable or recoverable, and can carry a lethal or nonlethal payload. It is controlled either autonomously by on-board computers or by remote control of a pilot on the ground. Its usage is currently limited by difficulties such as satellite communication and cost. A drone that can be operated by radio frequency controller and send live audio-visual feedback has been built.

For effective coordination of air and ground forces it is necessary timely exchange critical data for safe fire extinguishing [1-3]. In order to reduce the potential adverse consequences, reaction time of services responsible for the control and prevention of the aforementioned natural disasters should be as short as possible and made decision has to be as precise as possible.

To help in the decision-making process of the assignment type, disposition and number of fire power at the fire site can greatly help with the implementation of the various types of unmanned aircraft equipped with the appropriate sensor systems.

In this research, the second paragraph describes examples of practical use of unmanned aircraft in fire protection, third paragraph lists the most important challenges for UAVs inclusion into flight traffic, fourth paragraph describes existing regulative in Republic of Croatia, fifth paragraph gives a proposition of system architecture, and in the conclusion significant contribution of UAVs application is explained.

II. The Need for Application of Unmanned Aircraft in Fire Protection

Drones have been recognized as a technology of the future that has great research potential and the possibilities of using unmanned aircraft are still being discovered [5-7]. The European Commission is undertaking significant efforts in order of correct and acceptable manner of introducing UAV into use. The three main areas of application of unmanned aircraft state civil defense, security and environmental protection.

Forest fires in the coastal areas of the Croatian are relatively common in the summer months, and the existing tactical solutions of fire extinguishing require application of modern technologies.

Existing practice comes down to tactics arrival at the fire site numbering as many it is possible, for fire to be extinguished in a shortest time with minimal potential of consequences. In most cases, due to the impossibility of adequate supervision, errors occur with fire commanders on the ground who engage greater number of operational forces and aircraft than it is really necessary. Also, it happens that types of operational forces and invited aircrafts are not adequate for certain fire site. Often what happens is that only pilots of firefighting planes notice that there is no smoke because the fire is extinguished or brought under control. At the end, aircrafts are returning to air base without any need for them in the air. Because of the inability of adequate assessment of the field, in the above example an additional problem can occur with fire commander inviting Air Force too late or inviting in a much smaller number than needed, with fire getting out of hand with enormous consequences.

Firefighting power with the help of aircrafts for days is extinguishing this type of fire by bringing available crew resources to the limit of endurance. Ultimately, it can happen that the expenditure of funds is much larger than the damage caused by fire.

An example of such a fire broke out on the mountain Svilaja end of August 2012. It burned 6,382 hectares of forest and shrubs, with no endangered lives and property, and the damage from the fire was less than the consumption of resources by aircrafts. The fire could not be extinguished with the use of earthly forces because of its inaccessibility. After six days of fire extinguishing from the air and spent 94 hours flying aircraft Canadair CL - 415, or 57 hours of its operation Air Tractor AT - 802 (a total of more than 150 flight hours), the fire was left to burn since it could not spread further and did not pose a threat to people and property.

From these examples, it is evident that the need for the application of UAVs can contribute to reducing probability of errors, shortening reaction time and increasing accuracy in decision making, and shortening load of people and techniques in peak days.

III. CHALLENGES IN FOREST FIRE MONITORING WITH SMALL UAVS

The idea of forest fire monitoring with small UAV opens a wide range of societal issues including technical, legal, safety and security, economic, environmental, organizational, and architectural related questions that have to be addressed and built into policies for UAVs. Questions which need to be answered are: What regulations and policies have to be adapted / institutionalized for this kind of aerial support?; How should infrastructure and monitoring centers be planned and organized?; What are the implications of UAVs for individual safety and security?; What business models for UAVs are feasible and likely to be employed in forest fire monitoring?;What environmental issues including air pollution and threats for and from wildlife arise with aerial traffic and how can they be sustainable? Most important challenges for UAVs inclusion into flight traffic are:

- Detect, sense and avoid (DSA) technology at its current state is not mature enough.
- Reliable data links which will prevent loss of control during flight from on-the-ground pilots are currently not established.
- Radio frequencies and standard protocols aren't adapted to the specifics of UAV traffic.
- Drone certification (especially in the sense of adequate DSA technology, but also in general, whether some UAV is safe for inclusion into aerial traffic) are not institutionalized.
- Pilot and assistive personnel qualifications including flight schools and specialization are missing.
- Standardization of on-the-ground equipment is in its infancy.
- Traffic rules of conduct and traffic control are not yet developed.
- There exist serious safety and privacy problems mostly due to lack of regulations.

Review on the basis of these challenges has been made for the regulations in the Republic of Croatia.

IV. REGULATIVE IN REPUBLIC OF CROATIA

Expansion of civilian use of drones gained insight into the many dangers that may occur. In order to regulate the use of unmanned aerial vehicles, many countries have adopted specific legislation on the subject or the laws are in the making. The laws were passed primarily for the safety of people whose lives could be endangered by the use of drones. In order to allow their proper implementation in the Republic of Croatia in May 2015 the Regulations on the systems of unmanned aircraft has been made. This Regulations lay down the general, technical and operational conditions for the safe use of unmanned aircraft, unmanned aircraft systems and aircraft models and the conditions to be met by persons involved in the management of these aircrafts and systems. The provisions of the Regulations apply to systems of unmanned aircraft, unmanned aircraft operating mass (total weight at the time of take-off) up to and including 150 kilograms which are used on Croatian territory. Croatian Agency for Civil Aviation is responsible for determining compliance with the flight operation systems of unmanned aircraft safety requirements for flying unmanned aircraft. For obtaining the authorization it is necessary to comply with the conditions laid down in the Regulations on the systems of unmanned aircraft. For obtaining all other licenses and permits responsible are some other institutions. So, on bases of Law on defense, the Regulation on shooting from the air was adopted. The Republic of Croatia also participates in the joint European regulatory framework in which the European Union recognized the importance of unmanned aircraft. The European Commission should define the specific measures in the context of Horizon 2020 and COSME in order to develop the market of UAVs and ensure that involved entities have comprehensive access to these tools. The plan is the gradual integration of UAVs in the air navigation system by 2016, but significant efforts are needed and exhaustive research so that their integration could be successful. It is believed that UAVs represent a new market which would generate economic growth and jobs.

V. SYSTEM ARCHITECTURE

Network communication can use TCP/IP protocol, using transceiver transferring remote image data from the plane through the net exporting to the protocol conversion computer, then transferring image data to fire monitoring software by switch, or by optical fiber network (fig. 1) creating a Software Interface Relationship [8-10] .

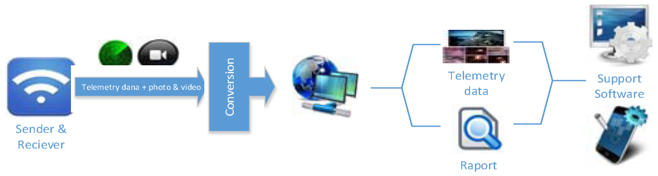

Figure 1. Software Interface Relationship

The software can include data receiving module, fire detection module, video playing module, fire source location and analysis module, GIS display module, and report generation module.

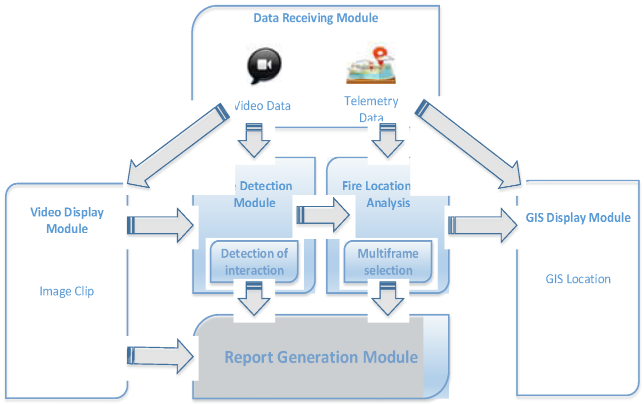

Figure 2. The Information Flow of Software Module

The information flow between the modules is shown in Fig. 2. Data receiving module can receive the video and telemetry data from the UVA; Video play module can decode video and refreshes display. According to the user need to call the fire detection module, real-time detection display can show results in the video providing screenshot function; the fire source location and analysis module can calculate the geographic coordinates of fire source according to the test results and the telemetry data.

Via communication protocol, Data Receiving Module continuously receives raw data of telemetry image from fixed station. Afterwards these data, including infrared and visible light data, are saved to local disk in video format.

Videos files in the video play module can use 8 threads on the playing area to refresh the display interface. At first, each thread decodes frame of the new mj2k format video, then transforms it into a same size picture, calling the fire detection module, circling the fire source area in the picture if it exist, finally coping it into the video refresh area. All the threads of video refresh zone are synchronous.

Video play module can also provide a screenshot function which could be used to generate test report.

The Fire detection module can be called before the video refresh. According to the user interaction, the working mode of the Fire detection module can be divided into the automatic detection and artificial auxiliary detection, fig. 3. Automatic detection mode can detect the whole picture under the condition of user not to circling source area, segmenting and highlighting the edge of the suspected source area. Auxiliary detection is performed by fire detection in a rectangular box user circled; this method can further confirm the suspected source of fire, segmenting and highlighting the edge if the fire source is confirmed.

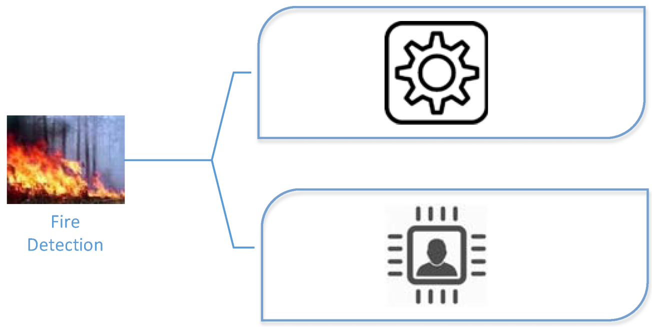

Figure 3. Fire detection Method

The fire source location and analysis module can convert fire source position and size information according to the latitude and longitude, size and altitude information under the geodetic coordinates. According to the aircraft telemetry data location and height information, can be calculated by the module using image pixel scaling, and then transforming the fire source position into the geodetic coordinate, also calling the GIS display module positioning to the interface view, fig. 4 [8]. These actions can be performed by the Fire Detection Module.

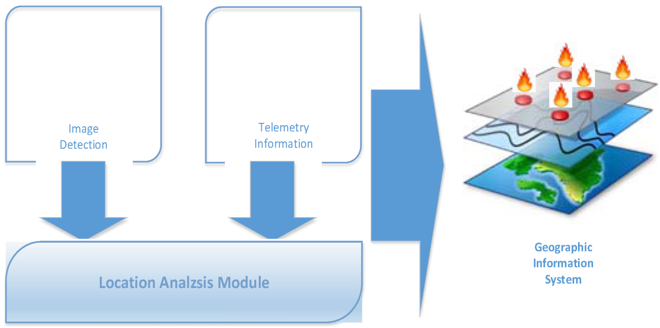

Figure 4. The Information Flow of Fire Location and Display

The module can also provide frame selection mechanism, updating the longitude and latitude, altitude and other geographic information according to the effective frame that user confirmed.

The GIS display module integration with software can display geographic information of the earth satellite image, using software that provides a drag, zoom, and positioning and measurement operation for the user. When the fire is detected, GIS module will display real-time fire location to the GIS interface thru the Data Receiving Module, which user can also carry on the monitoring to remote areas that is not easy to reach due to the software expanse the user's perspective.

Report Generation Module forms the fire monitoring report in details according to the fire location, analysis and other data. It mainly includes the following aspects: fire geographical position display which shows state of the fire on the map in detail; latitude and longitude of fire source, fire area, the length of the fire line and other data; according to the distance and range of fire analysis required of firefighting resources.

VI. CONCLUSION

The consequences of forest fires, both material and human, are incalculable. For many years' weather forecasts are not optimistic at all. When you take into account the state of development and equipment of other countries in relation to the Republic of Croatia, it can be concluded that the current system control forest fires should be supplemented with additional systems for decision support to enhance the existing system. In that way, increase of efficiency, reducing response time, and reducing the cost of individual tasks. In support of these efforts, application of UAVs significantly contributes. Such systems can contribute to reducing the probability of errors, shortening reaction time, increasing accuracy in decision making, and shortening load of people and techniques in peak days.

REFERENCES

[1] L. Merino, F. Caballero, J. R. Martínez-de-Dios, I. Maza, and A. Ollero, "An unmanned aircraft system for automatic forest fire monitoring and measurement," *Journal of Intelligent & Robotic Systems,* vol. 65, pp. 533-548, 2012.

[2] S. Basiratzadeh, M. Mir, M. Tahseen, A. Shapsough, M. Dorrikhteh, and A. Saeidi, "Autonomous UAV for Civil Defense Applications," 2016.

[3] A. Restas, "Drone Applications for Supporting Disaster Management," *World Journal of Engineering and Technology,* vol. 3, p. 316, 2015.

[4] R. Teguh, T. Honma, A. Usop, H. Shin, and H. Igarashi, "Detection and verification of potential peat fire using wireless sensor network and UAV," in *Proceedings of the International Conference Information Technology and Electrical Engineering, Yogyakarta, Indonesia*, pp. 6-10, 2012.

[5] D. W. Casbeer, D. B. Kingston, R. W. Beard, and T. W. McLain, "Cooperative forest fire surveillance using a team of small unmanned air vehicles," *International Journal of Systems Science,* vol. 37, pp. 351-360, 2006.

[6] D. W. Casbeer, R. W. Beard, T. W. McLain, S.-M. Li, and R. K. Mehra, "Forest fire monitoring with multiple small UAVs," in *American Control Conference, 2005. Proceedings of the 2005*, pp. 3530-3535, 2005.

[7] L. Merino, F. Caballero, R. Martinez, I. Maza, and A. Ollero, "Automatic forest fire monitoring and measurement using unmanned aerial vehicles," in *VI International Conference on Forest Fire Research DX Viegas (Ed.)*, 2010.

[8] L. Zhang, B. Wang, W. Peng, C. Li, Z. Lu, and Y. Guo, "A Method for Forest Fire Detection Using UAV," 2015.

[9] L. Zhang, B. Wang, W. Peng, C. Li, Z. Lu, and Y. Guo, "Forest Fire Detection Solution Based on UAV Aerial Data," *International Journal of Smart Home,* vol. 9, pp. 239-250, 2015.

[10] C. Yuan, Y. Zhang, and Z. Liu, "A survey on technologies for automatic forest fire monitoring, detection, and fighting using unmanned aerial vehicles and remote sensing techniques," *Canadian journal of forest research,* vol. 45, pp. 783-792, 2015.