Forest Fire Prevention and Aftermath Using Drones

Project Final Report

IEEE Robotics and Automation Society's Special Interest Group on Humanitarian Technology (RAS-SIGHT)

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***Abstract*—The project aimed to develop a drone based vision system capable to inspect the forests to assess the current state of forest cleaning, rural roads, firebreaks, etc. The same drone based vision system was then equipped with a thermal camera to detect re-ignitions during forest fires aftermath. The inspection performed by the drone will then be used to develop risk assessment plans, to be used by the Portuguese Civil Protection Authority. Risk assessment maps are used to prioritize monitoring areas during the summer firefighting campaign. During forest fires aftermath, fire fighters can use the drone, during their work, to visualize with a birds-eye view the surroundings of the fire and detect high temperature points in the terrain. The drone, following a pre-defined path, performs the first task automatically; the second task (during the fire aftermath), currently, is performed by tele-operation.**

***Keywords*—Drone, Inspection, Forest Fire, Thermal Imaging.**

I. INTRODUCTION

Forest fires represent a serious humanitarian issue in Portugal, and broadly in the Mediterranean area. In Portugal, the last official data available issued 118945.5 Ha of burned area [1]. Forest fires have great impact in the environment, and consequently in people lives. In figure 1, is presented the fire issues in the center of Portugal, where it can be depicted the large impact in the territory.

Forest fires are part of rural ecosystem, and small size fires are seen as part of nature dynamics. During the last decades, this trend had ended due to intentional fires, climate changes and also because people are leaving rural land (leaving the forest uncleaned).

The government response to forest fires is mainly concentrated in fighting strategies, including advanced technological tools, rather than preventing its appearance and also to diminish its rapid propagation.

It is also very important to note that due to irregular terrain and lack of risk assessment plans, civil population, fire fighters and other authorities die each year, in fighting forest fires.

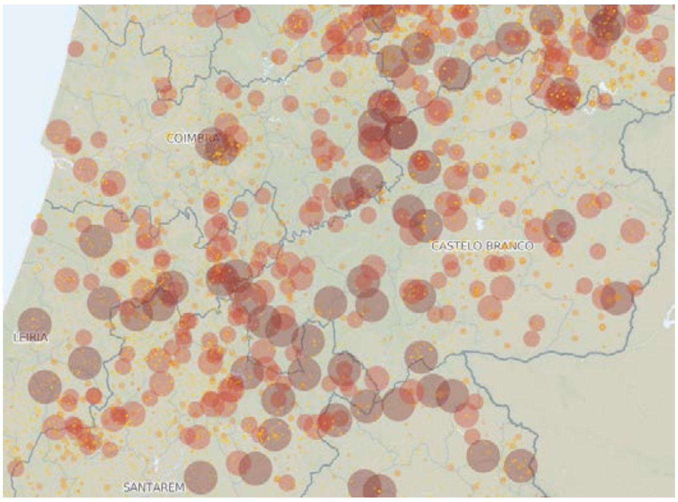

Fig. 1. Large fire events in center Portugal.

Previous to the summer forest fire fighting campaign, a forest fire risk assessment should be performed every year to detect problematic areas, i.e., areas where forest fires can quickly propagate. These areas are mainly characterized by:

- deficient forest cleaning,
- lack of rural roads,
- lack of firebreaks, etc.

The previous rationale justified the development of the first part of the project, i.e., preventive measures in firefighting during the hot summer days. In summary the causes and goals to achieve by the first part are depicted in Figure 2, where risk assessment plans can be obtained from the usage of the developed framework.

The aftermath of a forest fire is the scenario of the second part of the project. The drone is being used as a tool to inspect the fire aftermath to detect the hot-spots, that can ignite and re-initiate the fire. The summary of this part is depicted in the lower part of Figure 2.

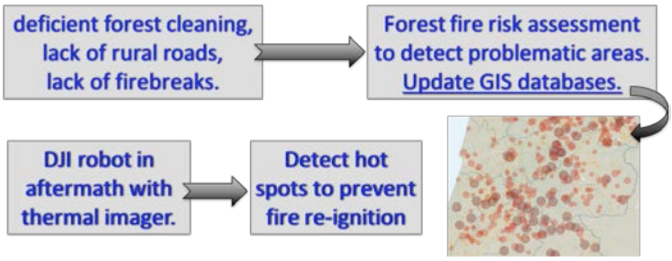

Fig. 2. Scope of the project.

In the following section is presented the framework developed, hardware and software based. Section 3 presents the results obtained from the developed framework in real scenarios. Finally, section 4 presents the conclusions and lessons learned, obtained from the project.

II. Developed Framework

In this section is presented the developed framework based on commercial available devices, i.e., a drone and vision sensors with remote operation capabilities. Moreover, a low-cost framework was pursued from the very first beginning of the project.

Fig. 3. The DJI, equipped with the FLIR ONE attached to the IPHONE.

A. Hardware Platform

It was intended since the project proposal that the solution should use commercial available 'low-cost' hardware from the robot side (drone) and from the vision side (thermal and RGB cameras). As such, the hardware platform used in this project was:

- a DJI Phantom II Vision Plus, quadcopter, purchased with the sponsorship from IEEE-RAS-SIGHT. The purpose of the platform was to fly over forests to obtain sensor data to be used in a high level reasoning engine.
- a FLIR ONE thermal vision sensor, connected to a IPHONE5s mobile phone, to be mounted airborne in the drone. This solution proved to be the most adequate because it allowed the use of a low-cost thermal vision sensor, attached to computational machine (iphone) with proper communication capabilities. Moreover, this solution can be deployed to similar robots, capable to deal with the payload of the system.

In Figure 3 is depicted the hardware platform for the aftermath scenario, i.e., the DJI Phantom equipped with the FLIR ONE and the IPHONE5s.

The sponsorship of IEEE-RAS-SIGHT allowed the project to purchase the three devices DJI (1199€), FLIR (248€) and IPHONE (487€), along with 220€ for the field tests displacements and the consumables to fix the FLIR+IPHONE to the DJI. The Instituto Politécnico de Castelo Branco and IDMEC provided the software licenses, and the remainder of the field test displacements needs.

B. Software Platform

The software used/developed in the project comprises several parts, that are suited for drone control and image capturing, mapping, land features detection and hot-spots detection in the aftermath.

- For *Done Control and Image Capture*, the commercial software from Pid4D, 'Capture P2V'. A pre-defined trajectory is defined in the software, that can be monitored during the flight, along with the image capture positions, as depicted in Figure 4.

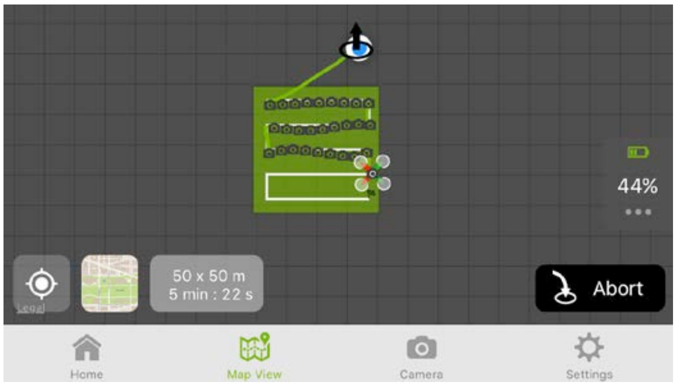

Fig. 4. Snapshot from Pixd4D, 'Capture P2V,'software. Planned trajectory, versus drone trajectory and image capture.

- For *Mapping*, the commercial software Pix4D, 'Pix4dmapper', that allows to obtain an orthomap from the images obtained from the drone.
- For *Land Feature Detection*, software modules were implemented in Matlab, using image processing algorithms. Those use color segmentation and mathematical morphology, to extract rural roads or rivers from each captured image from the drone.
- For *hot-spots detection in the aftermath*, a software was developed to capture thermal images from the FLIR ONE sensor, to send the airbone captured images, via wi-fi to a ground station. Finally, a software module was implemented in Matlab, using color segmentation

to identify the hot-spot, from each captured image from the drone.

III. RESULTS AND DISCUSSION

In this section are presented the results obtained from the developed framework, regarding: forest mapping, risk assessment, fire aftermath. From the results obtained from this three areas, a discussion is performed, related with the actual and further usage of the framework.

A. Forest Mapping

For forest mapping a state-of-the-art approach was performed. The final output of the project is an orthomap, that can be integrated into a GIS system for further analysis, planning and management.

The orthomap generation include the following phases: image processing and pairing, mesh generation, and finally the orthomap creation, based on texture and colors.

The described processes are implemented in the commercial software Pix4D, 'Pix4Dmapper'. From the software, can be observed the 3D drone camera locations where each image was captured, as depicted in Figure 5.

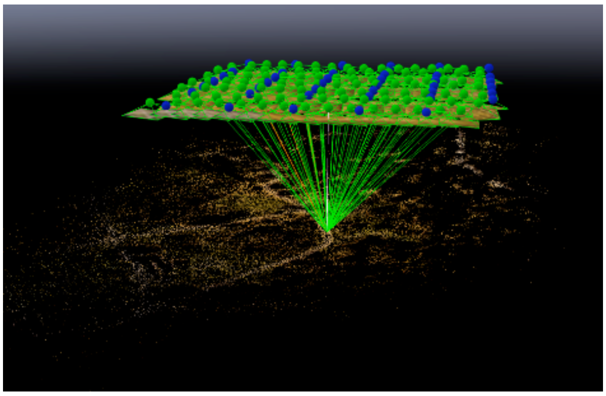

Fig. 5. Snapshot from 'Pixd4Dmapper' software. Planned trajectory, and drone image capture locations in 3D.

The final output of the mapping procedure is the orthomap. An example is given in Figure 6, where 470 drone images were used. In the image is present rural words, terrain with and without trees. The images were captured at 40 meters' altitude, which gave a 4cm per pixel resolution. This resolution is aligned with the best practices in forestry mapping, as presented in Pix4Dmapper reference manual.

B. Risk Assesment

The risk assessment is performed by the Civil Protection Authority, before the fire campaign start, and is based on the GIS database available, and the historical knowledge from past summers fires. As such, a tool capable to rapidly update and/or complement the available data is welcome.

For this purpose, the project proposes to use the drone images captured during the forest mapping to automatically output the rural roads and fire-breaks, along the rivers that do exist in the mapped area. As such, images/data from the roads / fire-breaks can be imported to the GIS database. This procedure will enrich the available GIS database.

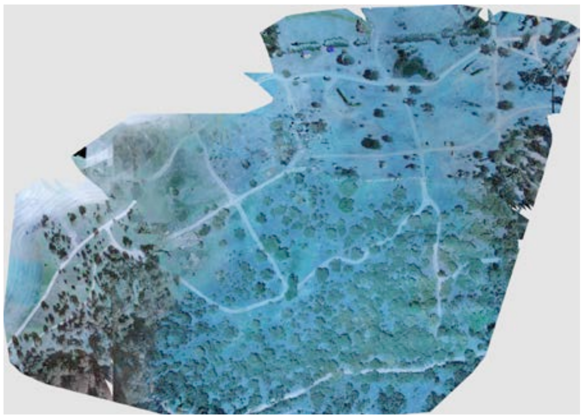

Fig. 6. An orthomap obtained from 470 drone images, using 'Pix4dmapper'.

In Figures 7 and 8 are presented two examples, where roads and rivers are identified. Since the approach developed is based on color segmentation, is simple to identify each of the two features, e.g., the rivers are darker and have large color saturation. Mathematical morphology was used to obtain more robust results.

Fig. 7. Heavy machinery in the aftermath scenario, to secure hot-spots. Left: RGB image. Center: rutal road detectio. Right: river detection.

Fig. 8. Heavy machinery in the aftermath scenario, to secure hot-spots. Left: RGB image. Center: rutal road detectio. Right: river detection.

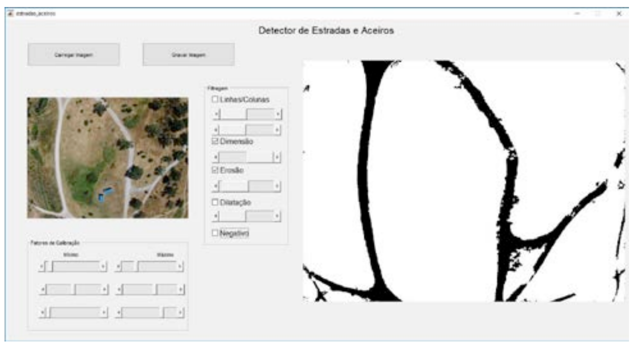

Fig. 9. Heavy machinery in the aftermath scenario, to secure hot-spots.

The software tool developed in Matlab is depicted in Figure 9, e.g., is presented the training tool of the parameters of the system.

C. *Fire aftermath*

The fire aftermath is a very important stage in a forest fire. In Figures 10 and 11 depicted a typical task undertake by firefighters and heavy machinery to secure the burned are against re-ignition, e.g., by completely extinguish fire in tree roots. A need for this task is to identify burning tree roots, because there is no flame to accompany the fire.

The solution for this case was to attach to the DJI a thermal camera solution (based on FLIR ONE and IPHONE5s). Today the FLIR ONE can also be used with an Android system.

Fig. 10. Aftermath work by the fire-fighters

Fig. 11. Heavy machinery in the aftermath scenario, to secure hot-spots.

Figure 12 shows a terrain with a abnormal heat source under the terrain, to simulate in a real scenario a tree root burning. The next Figure, 13, shows the detected root slowly burning, using the FIR ONE attached to the drone. As such the system is capable to detect hot-spots at 4 meters height. This is a major limitation of the current system, because of the specifications of the thermal camera used. In consequence the drone should be flying over the burned area for a long time, to scan large areas. To decrease the time that the drone is flying, great altitude of flight should be used, and in consequence a thermal camera with high precision should be used, which leads to a major increase of the developed framework budget.

Fig. 12. Heavy machinery in the aftermath scenario, to secure hot-spots.

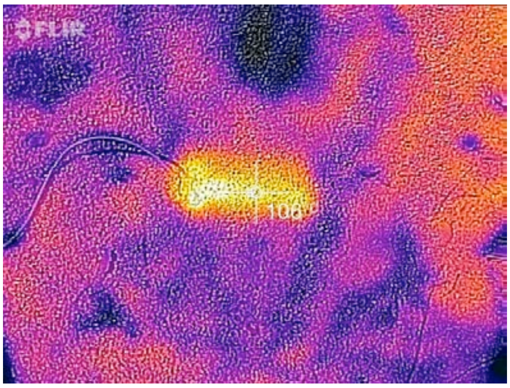

Fig. 13. Heavy machinery in the aftermath scenario, to secure hot-spots.

D. *Societal Impacts*

The system was developed to aid the fire-fighters and the civil protection authority, to be used during the planning for the summer fires season, and during the combat scenario.

The major societal impact, of such a system, is the contribution to decrease the annual burned area. This indicator is very difficult to measure, because the annual burned area depends of a myriad of variables.

Portuguese population is very concerned with forest fires, because the forest is a very important resource of the country, e.g., the sector employs 3% of the active Portuguese population and the paper pulp industry is the 3rd ranked in Europe. As such, the societal impact of innovative solutions is very important, e.g., to help protect forest against fires is very welcomed by Portugal.

A societal impact that must be taken into account is the privacy when using thermal aerial images, during the aftermath scenario, because by using this type of cameras no person identification can be done.

At 40 meters and using 4cm per pixel is not possible to identify persons during mapping, which count for a good societal impact in terms of privacy.

E. *Project Sustainability*

The project was developed following the needs of fire-fighters and civil protection authority to add new types of data in the decision making process. The knowledge of the fire combat scenario is essential to prepare the summer fires campaign, and more importantly the combat scenario when a large fire, in complex terrain, ignites. The outputs of the mapping system are orthomaps that can be integrated to the commonly used GIS databases.

The system is sustainable by itself because is ease of use, was tested by fire-fighters. Moreover, the usage of new technologies to place the professionals to an upper level of operation is very welcomed by the interviewed persons, at whom the system was presented.

The new Portuguese laws regarding drone operation allows the use of the developed framework, because the works performed using the system were done at 40 meters of maximum altitude and the operation of the drone was done in areas of low concentration of persons, i.e., less than 12. This is a very good indicator of sustainability of the system, which can operate with no special authorization of the aviation authority.

Before the developed framework to be adopted in real operating scenarios, pilots using the developed technology must be performed.

IV. CONCLUSIONS

The proposed project successfully proposed a drone based solution to:

- map forests,
- extract features like roads and/or firebreaks from aerial images,
- identify hotspots in the aftermath scenario, e.g., burning tree roots.

The developed system is low-cost and can be easily operated by fire-fighters and the civil protection authority. This fact allows better usage and sustainability of the proposed framework.

During the project and after several mapping attempts, it is concluded that the DJI should not be used for capturing images for mapping the forest, mainly because its autonomy and speed limitations. A fixed wing drone solution should be used instead, that allow a large area to be mapped.

For small areas, and for minor updates in the existing orthomaps, the drone solution should be used for its simplicity and ease of setup, e.g., small areas for take-off and landing are required.

From the aerial images captured for mapping, the developed framework was capable to identify rural roads, firebreaks, and rivers, to add and/or update existing civil protection authority GIS databases.

Following discussions with the authorities, the developed framework for the aftermath, although can be used easily, is not to be used at large sale in the combat scenario. Only few should be used to not interfere with other airborne machines in the scenario, and not to take much fire-fighters to operate them. An autonomous solution can be developed for this purpose in future works.

ACKNOWLEDGMENT

The current work was supported by IEEE-RAS SIGHT, and by FCT, through IDMEC, under LAETA, project UID/EMS/50022/2013. Special thanks to the Instituto Politécnico de Castelo Branco students: João Gaspar and Renato Ferreira, and colleague Paula Pereira.

REFERENCES

[1] http://www.incendios.pt/ , consulted in 15th October 2014.