UAV: A MULTIDISCIPLINARY TOOL TO ACCESS EXTREME ENVIROMENTS

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ABSTRACT

In the recent years UAV have become an important tool for monitoring and sampling activities in a wide range of applications. Last December an UAV was used for the first time to survey the Lusi volcano (Indonesia). The aim was to take mud and gas samples, aerial photographs, videos and contact temperature measurements.

Two different prototypes of remote controlled gas containers were available; in particular one prototype is a real-time telemetry and gas sampling system that returns to the ground station sensors and positioning data and receives and executes commands for the gas sampling.

Another important application consists to equip the UAV with hyperspectral cameras and develop appropriate electronics in order to permit the ground station to have also a preview of the hyperspectral images during the survey.

1. INTRODUCTION

INGV took part in the project LUSILAB, an European project managed by the University of Oslo that aims to perform a multidisciplinary study using Lusi as a unique natural laboratory [1]. In fact for the scientific community it is a chance to study the evolving geological process of a mud volcano. In the past mud volcanologists could only study existing or ancient mud volcanoes during dormant periods, thus Lusi is a rare occasion and unique opportunity to conduct scientific experiments to further understanding. The spectacular Lusi eruption started in northeast Java in May 2006, following to a 6.3 M earthquake [2] and/or some drilling activities. Initially, several gas and mud eruption sites suddenly appeared along a reactivated fault system and within weeks several villages were submerged by boiling mud. At its peak Lusi spewed up to 180,000 m³ of mud per day [3]. To date Lusi (fig. 1) is still active and erupting gas, water, mud and clasts. It is expected that the flow will continue for the next 25 to 30 years. Although the mud flow has been contained by levees since November 2008, resultant floodings regularly disrupt local highways and villages, and further breakouts of mud are still possible[4].

INGV supplied the flying device to access the crater and to sample the erupted gases [4], [5]. The UAV was an hexacopter and the payload, designed by INGV, is a real-time telemetred gas sampling system.

Fig. 1 The Lusi volcano

2. LUSI SURVEY BY UAV

In December 2013 INGV performed the first aerial survey of the LUSI volcano (Indonesia, East Java) using a UAV (fig. 2), equipped with three gimbaled cameras that can complete video, photogrammetry, and thermal surveys during the missions.

The UAV is a hex-rotor aircraft, the model chosen (DJI S800) is characterized by high stability, long flight time, high agility and fast assembly. The most significant flight parameters are:

- hover power consumption 720W (@ take-off weight 6 kg)
- take-off weight: 7.5 kg
- load weight: 2 kg
- hover time: 16 minutes max @ 6 kg weight with 10Ah 6S battery

Fig 2 The take off of the UAV

For the gas sampling two different systems of remote controlled gas containers were available, they can vacuum multiple samples when required. The first one consists directly of the use of two IsoTubes® ; the valves opening for the gas sampling is obtained by sending a remote command to servomotors connected to them. The second one is a real-time telemetred gas sampling system.

The gas samplers are directly connected to the lower part of the vehicle, close to the turbulence induced by the propellers. Under these conditions the measurements will give a reliable result only if the UAV is immersed in homogenous cloud of gas to be sampled. On the contrary in presence of a non homogeneous cloud of gas to be sampled the samplers must be moved away from the UAV through a winch.

For the temperature measurements and the mud sampling, the UAV was equipped with a remote controlled winch (fig. 3). The system is able to deploy 1) a logger to monitor high temperature (up to 250°C) variations of erupted fluids (water-gas) and 2) a specifically designed sampler to collect fluid specimens at preselected coordinates.

Fig. 3 The winch connected to the UAV

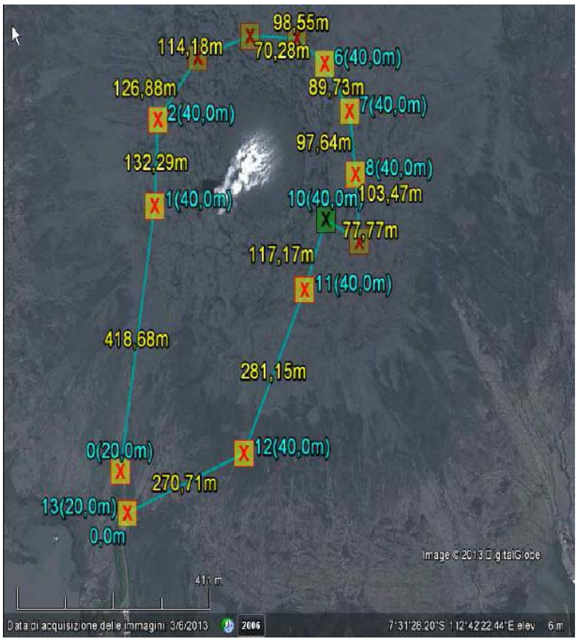

Fig. 4 The automatic flight survey

A GPS-connected software allows to pre-plan the full mission of the UAV and to constantly communicate and monitor its position. In fig. 4 a screen of an automatic flight survey performed during the mission.

The Lusi UAV has been successfully used at the active Lusi eruption site in Indonesia and proved to be an excellent tool to study harsh environments, where operations with more conventional methods are too expensive, dangerous or simply impossible.

3. THE REAL-TIME TELEMETRY AND GAS SAMPLING SYSTEM

The telemetry module is composed of: a microprocessor, a GPS receiver, pressure and temperature sensors, a wireless module (XBee PRO).

The wireless module has an Outdoor/RF line-of-sight of 1.6 Km. The module returns to the ground station sensors and positioning data in real-time. In fig. 5 is visible the top side of the gas sampler, where are visible the electronic components of the telemetry module.

Fig. 5 The top side of the gas sampler

The gas sampling system is composed of six gas sampling tubes (pre-evacuated), hermetically sealed by thin membranes, and three servomotors. Each servomotor drives two needles, one per tube; when the ground station sends the command for a gas sampling, the microprocessor drives the servomotor to thread the needle through the membrane in order to permit the gas capture. In fig. 6 is visible the bottom side of the gas sampler, where are visible the tubes and the three servomotors.

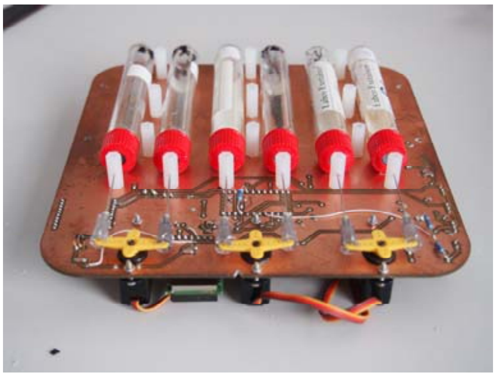

Fig. 6 The bottom side of the gas sampler

The system is powered by own batteries, this is an important feature in the event that the system must be moved away from the UAV for the gas sampling operations.

4. THE THERMAL CAMERA

A thermal camera was connected to the UAV (fig.7) to acquire thermographic images during the survey.

The camera is a commercial model (i7) by FLIR, the lens does not require autofocus, so for having a snapshot it was sufficient to drive a servomotor connected to the camera. The camera measures up to +250°C and detects differences in temperature of only 0.1°C.

Fig. 7 The thermal camera connected to the UAV

5. PHOTOGRAMMETRY

The UAV was equipped with a GOPRO camera for capturing photos and videos. An OLYMPUS camera (fig.8), model E-PM2, was used for photogrammetry.

Fig. 8 The camera used for photogrammetry

The camera has a 4/3’’ Live MOS sensor and 16.1 Megapixels. In fig. 9 an example of photogrammetry performed through the postprocessing of 12 pics.

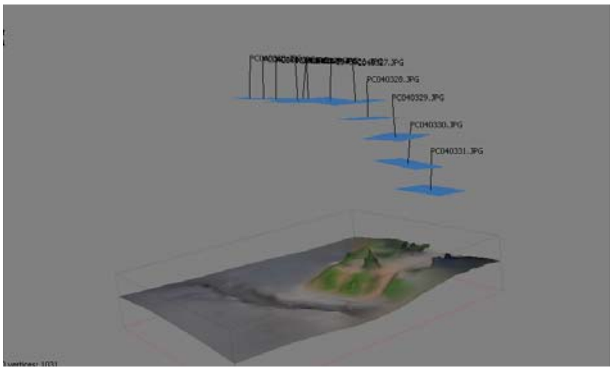

Fig. 9 An example of photogrammetry

6. TEMPERATURE MEASUREMENTS

The UAV was equipped also with an high temperature thermometer with integrated data logger (MadgeTech). The sensor can be completely submerged and is built for applications that require extreme temperature monitoring. The sensor has a thermal shield capable of withstanding temperatures of up to 250°C. Data allowed to complete contact measurements, estimate the emissivity of the mud and the calibration for the thermal camera. During testing it was determined that it is not necessary to have a prolonged contact: the measurement tends to an asymptote that can be easily calculated even if the sensor is not fully thermalized.

7. CONCLUSIONS

The use of the UAV has proved crucial to perform monitoring and sampling activities in a prohibitive environment such as that of the Lusi volcano. Instrumentation also has passed the field test, all the flying system worked properly. The successful conclusion of the scientific mission has allowed us to acquire gas and mud samples, temperature measurements, images and video (HD), thermographic images.

In order to improve the performances of the entire system an important development for the future applications is the FPV (First Person View) piloting applied to the UAV. With this technique, with the assistance of a video transmitter and receiver the user will see what the Remote Controlled vehicle sees from a virtual pilot seat. This gives the user a real sense of controlling his vehicle, this feature would be very useful during the mud sampling operations, to verify directly the filling of the sampler.

Another development will be to provide the UAV of an automatic winch (for the mud and gas sampling), that will be activated by the waypoints of the planned mission (by the GPS-connected software).

Moreover a future application would be to install onboard a hyperspectral camera and to design dedicated electronics to permit the ground station to have also a preview of the hyperspectral images during the survey.

8. REFERENCES

[1] Mazzini A., Svensen H., Akhmanov G.G., Aloisi G., Planke S., Malthe-Sorenssen A. and Istadi B., (2007). *Triggering and dynamic evolution of the LUSI mud volcano, Indonesia*. Earth and Planetary Science Letters, 261(3-4): 375-388. doi:10.1016/j.epsl.2007.07.001.

[2] Mazzini A., Nermoen A., Krotkiewski M., Podladchikov Y., Planke S., Svensen H. (2009). *Strike-slip faulting as a trigger mechanism for overpressure release through piercement structures. Implications for the LUSI mud volcano, Indonesia*. Marine and Petroleum Geology 26 (9): 1751–1765. doi:10.1016/j.marpetgeo.2009.03.001.

[3] Davies R., Mathias S., Swarbrick R. and Tingay M., (2011). *Probabilistic longevity estimate for the LUSI mud volcano, East Java*. Journal of the Geological Society 168: 517–523. doi:10.1144/0016-76492010-129.

[4] Amici S., Turci M., Giulietti F., Giammanco S., Buongiorno M.F., La Spina A. and Spampinato L. *Volcanic enviroments monitoring by drones mud volcano case study* International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-1/W2, 2013-UAV-g2013, 4 – 6 September 2013, Rostock, Germany.

[5] Amici S., Turci M., Giammanco S., Spampinato L. and Giulietti F. *UAV Thermal Infrared Remote Sensing of an Italian Mud Volcano* Advanced in Remote Sensing, 2013, 2, 358-364.