Autonomous Drones for Assisting Rescue Services within the context of Natural Disasters

Ludovic Apvrille[1], Tullio Tanzi[1], and Jean-Luc Dugelay[2]

[1]Institut Mines-Telecom, Telecom ParisTech, LTCI CNRS, CS 50193, 06904 Sophia Antipolis cedex, France, {ludovic.apvrille, tullio.tanzi}@telecom-paristech.fr

[2]EURECOM, CS 50193, 06904 Sophia Antipolis cedex, France,
jean-luc.dugelay@eurecom.fr

Abstract

Information plays a key role to correctly handle consequences resulting from natural disasters. Discharging rescue teams from gathering that information, and automatically guiding rescue teams to most urgent sub-situations is an open issue in which mini-drones can be useful. Yet, the control of such vehicles is not straight forward to users and can be time consuming. Thus, our contribution is to bring autonomy to drones: to fly autonomously, e.g., scanning and covering a given area, and to realize some tasks (e.g., identifying groups of disabled persons). Last but not least, autonomous drones shall be able to perform both outdoor and indoor missions.

1. Introduction

When a natural disaster occurs in a populated zone, a fast and effective organization of the disaster management is necessary to assist the population, to reduce the number of victims and to limit the economic impact [2], [3], [4]. At all phases, one of the first actions to be taken is to set up a disaster cell for coordination. A non-optimal organization causes supplementary losses and delays to come back to, or even prevent, normal situation. (http://www.un-spider.org/).

During such an event, maintaining a communication link between victims on one hand and the various actors of the response on the other hand is crucial. This link remains essential even in non-catastrophic circumstances, for instance, a major black-out in a network (electricity, water, etc.). Emergency management starts both with search and rescue, and then with the stabilisation of the overall disaster situation. At any time, the rescue teams need immediate and relevant information concerning the situations they have to face: disaster evolution, surviving persons, critical zones, access to refugee camps, spread assistance tools, etc. Required information is provided by a comprehensive data handling system, called the Geographical Information System (GIS) fed by files generally produced by organizations and space agencies involved in the International Charter “Space and Major Disasters”.

The detection and the monitoring of the impact of natural disasters are mainly done by space borne and air borne remote sensing surveys through radio and optical instruments. Due to limitations in the time window observation attached to optical instruments (i.e. no observation at night or in presence of cloud cover), radio observations (available ~ 24/7 and relatively insensitive to atmospheric conditions) are particularly useful during the “Response phase” of the disaster management cycle where information must be delivered to the disaster cell in the shortest time possible [5], [6], [7]. As explained in [3], new approaches and the use of new technologies are required for more efficient risk management [3], before, during and after a potential crisis. Every specific action at each step of the crisis must be taken into account and dedicated tools are necessary. New methodologies are needed to conceive systems that mix the use of telecommunication tools, remote sensing for instance [8], and space/temporal-oriented databases which implement dedicated rules regarding risks [9].

In this context, Information-Technologies (IT) oriented communications, nowadays commonly used in risk management studies (without prejudging of the efficiency of the methods) are a worthy contribution [10], [11]. Thus, many studies and specific researches yield to renew the range of possibilities, although the efficiency remain to be assessed. Many technological innovations (social networks, wireless internet, internet objects, robots, drones, etc.) are now common in our society. Do they forge a true new trend for crisis and risk managers, taking into account their vulnerability? How can they support the activity before (prevention), during (management) or after (resilience) the crisis? The usage of drone in that scope is discussed in the rest of the paper. In particular, we present several scenarios in which drones could play a key role, and we present early results we obtain to reach a good level of autonomy.

2. Drones

Drones, also known as UAV (Unmanned Aerial Vehicle) are flying machines which are remotely controlled. They are generally used for surveillance purposes and to collect information. Drones are currently mostly used for outdoor applications, and, apart from the user interaction, their guidance is GPS-based.

The popularity, availability and range of applications attached to Micro Air Vehicles (MAV) – especially quadcopters – has been steadily increasing over the last few years. MAV research connects a diverse range of topics such as control systems, computer vision, sensor fusion and artificial intelligence. While the mechanical performance of rotor-driven models has long been satisfactory, enabling applications like localization, mapping and autonomous flight using minimal sensors and infrastructure still presents various R&D challenges: Especially for MAVs, on-board sensors as well as processors should be inexpensive, but also lightweight and energy-efficient. Applications must therefore be able to cope with limited and noisy inputs. At the same time, either their complexity needs to be compatible with the on-board processing, either their robustness against signal latencies and interruptions has to allow for remote operation.

Since they are naturally much smaller than regular drones, mini drones are more likely to be used for indoor applications. Unfortunately, the GPS signal cannot be efficiently used inside buildings, and so, mini-drones must permanently be remotely controlled, which strongly reduces their interest.

3. Autonomous navigation

Three scenarios have been identified. They are progressive in their complexity, and also progressive in the support they could provide to rescue teams.

In the first scenario, a drone must fully scan and cover a given area (e.g., all corridors of a building, or an outdoor field of operation). The drone therefore requires to autonomously fly in various conditions (narrow corridors, devastated buildings, etc.). By "covering", we mean that the expected output is a map of the explored area. The covering capability is reused in the next two scenarios. In the second scenario, the drone has to identify groups of disabled persons, and to make a clear distinction between adults and children. That distinction makes sense because the support that rescues teams shall bring to adults or children strongly differ. Such triage must be compliant with international and local ethical policies. Tracking a specific group might also be of interest to understand its velocity and expected position in a near future. Thus, the last scenario intends to guide rescue teams to the most probable locations where to go and search for victims, in general, after an earthquake, based on the localization of personal connected objects. In particular, drones could embedded several printed antennas with the goal to trace the source of emissions of these connected objects.

To support those three scenarios, the drone must be autonomous during its fly, and tasks it has to do. For reaching a good level of autonomy, two technical contributions are now explained: the environment identification, and people identification. Both contributions were developed in the scope of the *drone4u* project [13].

4. Environment identification

To be able to autonomously navigate within buildings, or outside of collapsed building, going from one GPS point to another one is not feasible, just because too many (eventually moving) obstacles may be present and source of collisions. Reaching a good level of autonomy therefore requires to correctly identify the environment. In the scope of autonomous cars, the issue is not the same since this is possible to embedded several various sensors (e.g., camera, Lidars, etc.). Because of the power consumption and weight limitations of drones, we therefore have assumed that only one 720p camera was onboard the drone. Thus, we propose to emulate more complex sensors by evaluating monocular images before and after a modification in flight altitude. While saving one camera's weight and power consumption, this approach also introduces algorithmic challenges as well as some inherent limitations. Thus, our work consists in reconstructing the environment of the drone in 3D, and to navigate according to that reconstruction. Two different approaches are investigating:

- The drone makes a **dense 3D scan**. That approach relies on the computation of an estimated distance for most pixels of images. This mode of operation unfortunately implies the use of an exclusive and dedicated flight control in order to virtually create a vertical stereo camera through a change in altitude (see Figure 1). Because regular flight needs to be interrupted for this manoeuvre, results are dense in space but sparse in time.

- On the contrary, **sparse3D** may be used continuously during regular flight and therefore is our preferred method of perception. It relies on the spatial locations of few hundreds of distinct feature points in images, see Figure 2. Their accuracy largely depends on the drone's motion: Vertical and sideways movements are particularly beneficial, which is why our associated control strategy superimposes an oscillation in those directions, hereby creating a c*orkscrew-shaped flight trajectory*.

We implemented and tested the two approaches (Sparse3D and Dense3D) with an ARDrone2. Images are sent by the drone to a remote PC that computes flight commands from image processing and then sends back to the drone. Both types of autonomous flights with environment perception can be seen in on online video in the scope of indoor navigation [13].

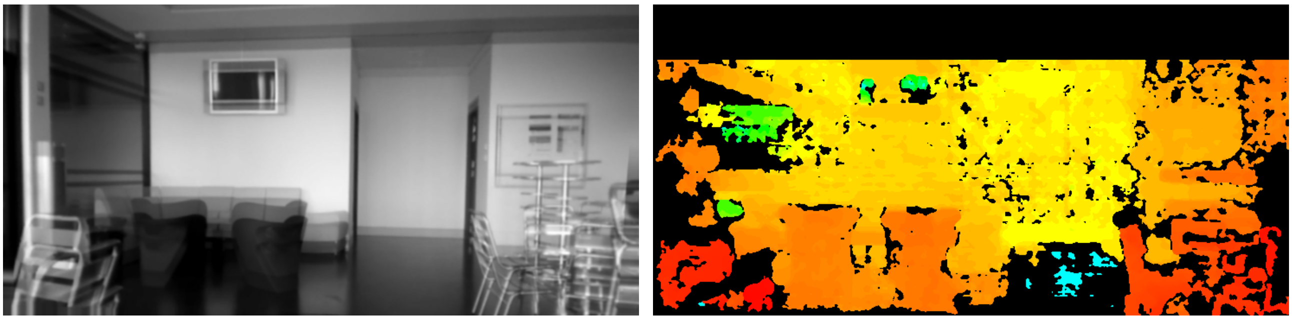


Figure 1: Dense3D reconstruction The overlayed rectified images before and after the height change visualize the precision of the estimated camera motion (left). Therefore, any standard implementation for distance reconstruction, e. g. [12], may be used without modification (right).

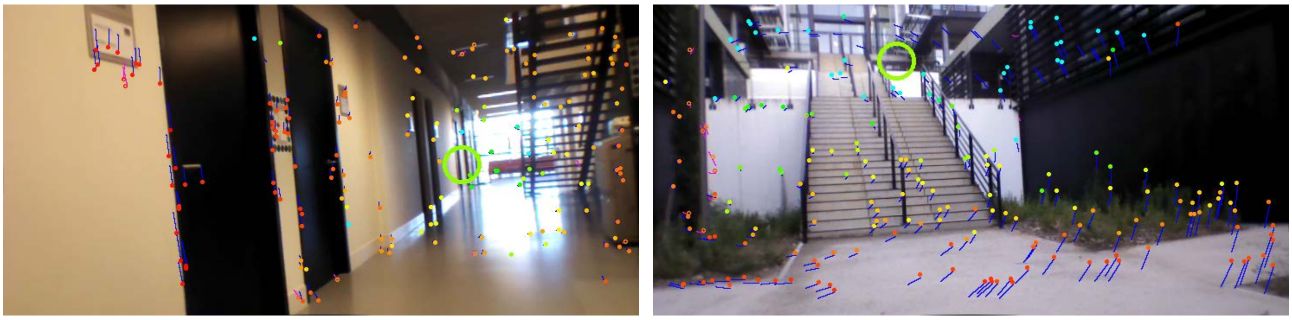


Figure 2: Sparse3D indoor (left figure) and outdoor (right figure) reconstruction based on a few dozens of points. Blue/purple lines show optical flow vectors consistent/ conflicting with the camera's motion. The points in color represent their longitudinal distance – red indicates 1 meter or less, cyan for 10 meters or more. A larger green circle marks the flight direction targeted by the drone, which is computed according to the furthest possible distance with no potential obstacles.

5. Groups identification

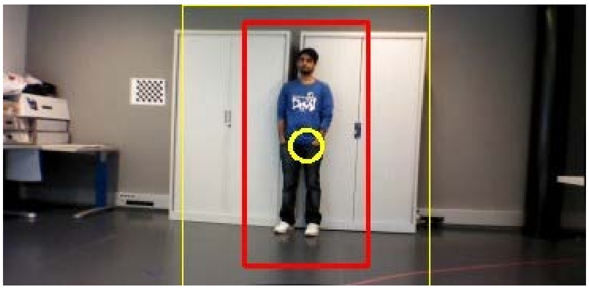
Identifying groups of victims is necessary so as to better predict the assistance to bring. For such a complex task, several subtasks are defined:

- To detect people.

Our approach is based on Histogram of Gradients (HOG) to extract Regions of Interests (RoI).

- To evaluate the composition of the group (adults, children).
- To estimate the direction of a group, and its velocity.

It requires to be able to focus on a given person of that group in order to follow it for a while in order to estimate its destination by tracking and prediction. To do so, we couple a HOG detector (see Figure 3, left part) with a Rao – Blackwelissed particle filter (Figure 3, right part). Basically, the particle filter estimates a posterior probability density over the state space conditioned on the data previously collected. Thus, the particle filter is focused on the person to follow, and the command-control of the drone is adapted so as to focus on the particle filter of the selected person.



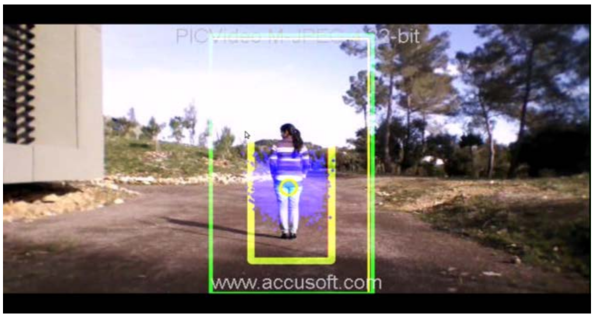


Figure 3. Tracking a person. On the left picture, a HOG transform is used to detect a region of interest. In the right picture, a particle filter is used in the region of interest to know whether the same person is being followed.

6. Conclusion

Among all the high tech objects of our modern environment, drones have an impressive high potential to offer fast and efficient responses in rescue conditions, even if some difficulties must be tackled. The new applications, such as the intervention in hostile environments requires an effective autonomy of mini drones concerning the energy (duration of the mission) and the control-command (decisional autonomy). Hardware and software issues have to be addressed: which algorithmic architectures to adopt? Which embedded system configuration is the most suitable one? Which kinds of GUI are the most appropriate fro victims, being in front of the drone? How can a drone help to appease people in critical conditions or to provide useful information?

The design of a civilian UAV intended for intervention in post-disaster conditions is an important challenge. The gain in autonomy of mini drones, coupled with the use of non-conventional sensors such as Lidar, IR camera, etc. will strongly increase response capabilities – e.g. people detection, rapid mapping, damage estimation, etc. - of the rescue teams on the ground. To be effective, these customized sensor systems must perform their duties in an independent manner and transmit their data. This information will then be inserted in the decision making cycle. It is also imperative that the manipulation of these systems does not require special skills. This condition is *a sine qua non* condition which explains the rationale of our focus on autonomous flight and mission. Without that capacity, it would be not possible to correctly integrate these new tools within the rescue teams.

7. References

[1]. D. Guha-Sapir D, Ph. Hoyois, R. Below, “Annual Disaster Statistical Review 2012: The number and trends”, Brussels: CRED, 2013.

[2]. R.S. Chatterjee, B. Fruneau, J.P. Rudant,, P.S. Roy, P.L. Frison, R.C. Lakhera, V.K. Dadhwal, and R. Saha, “Subsidence of Kolkata (Calcutta) City, India during the 1990s as observed from space by Differential Synthetic Aperture Radar Interferometry (D-InSAR) technique”, Remote Sensing of Environment, 102 (1-2), 176-185, 2006.

[3]. T.J. Tanzi and P. Perrot, « Télécoms pour l’ingénierie du risque ». Collection Technique et Scientifique des Télécoms. Editions Hermès, Paris, 2009.

[4]. T.J. Tanzi and F. Lefeuvre, “Radio sciences and disaster management”, C.R. Physique 11, 114-224, 2010.

[5]. P.J. Wilkinson and D.G. Cole, “The Role of the Radio Sciences in the Disaster management”. Radio Science Bulletin, 3358, 45-51, 2010.

[6]. F. Lefeuvre and T.J. Tanzi, International Union of Radio Science, International Council for Science (ICSU), Joint Board of Geospatial Information Societies (jBGIS), United Nations office for outer Space Affairs (OOSA), 2013

[7]. T.J. Tanzi and F. Lefeuvre, “The contribution of Radio sciences to disaster management”, in International Symposium on Geo-information for disaster management – Gi4DM 2011, Antalya, Turkey, 2011.

[8]. Pampaloni, P. and Saranboni, K., 2004. Microwave Remote Sensing of Land. Radio Science Bulletin, 308 (March), 30-46.

[9]. Barlier, F., ed., 2008. Galileo a strategic, scientific and technical challenge. Fondation pour la Recherche Scientifique, l'Harmattan.

[10]. W. Schafer, J. Carroll, S. Haynes, Emergency Management as Collaborative Community Work. in ECSCW 2005: Ninth European Conference on Computer-Supported Cooperative Work, 2005.

[11]. E. Gomez, M. Turoff, Community Crisis Response Teams: Leveraging Local Resources through ICT E- Readiness. in Proceedings of the 40th Annual Hawaii International Conference on System Sciences, 2007.

[12] H. Lategahn, M. Schreiber, J. Ziegler, and C. Stiller, “Urban localization with camera and inertial measurement unit,” in *IEEE Intelligent Vehicles Symposium,* 2013, pp. 719–724

[13] Drone4u Project, Ludovic Apvrille, Jean-Luc Dugelay, http://drone4u.eurecom.fr/