Drones to the Rescue: A Support Solution for Emergency Response

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ABSTRACT

Emergency is a threatening condition that requires urgent action, an effective response and within an emergency scenario there may be risks for responders, as well as for those affected. Response time is crucial for affected individuals and environments to be addressed on their needs. In this context, the goal of this work is to support the agents involved in the emergency response, through an application-supported collaborative solution using drones. This solution aims to collect information from the worked emergency scenario, so that, through the collaboration of specialists, there is a greater support for the decision-making made by the responsible agents within this scenario, causing it to occur in a shorter time, thus speeding up the response to the emergency. In this work, the aim was to validate with experts from the Rio de Janeiro Firefighters, who already work with drones, by evaluating the utility of the solution in real scenarios.

Keywords

Emergency, Information System, Collaborative Systems, Decision-making Drones.

INTRODUCTION

The society can undoubtedly be considered as a living complex system and from an organizational perspective are born in a certain place and have their own structural dynamics, where is possible to distinguish two independent structures: the organization itself and its environment (Maturana and Varela, 1987). The authors emphasize that the modifications are triggered by the disturbing agent but determined by the structure of the disturbed system. Consequently, the environment and the organization in observation act as mutual sources of disturbances and trigger mutual changes of state. However, the routine of human life may lead us to believe that nothing other than usual will happen. Surprisingly, this apparent normality may suddenly change with one or more traumatic events. These events give rise to dramatic situations capable of transforming the previous state of harmony into a troubled environment, where scenarios of disorder and chaos are presented. This dramatic and potentially traumatic environmental transformation introduces the concept of emergency. An emergency or crisis is a threat condition that requires urgent action[1].

According to França et al. (2017), in a world where information is completely spread by the world wide web, we can know very fast, in a general way, about emergency situations that happen on the other side of the world. Every situation like this has a great impact on society, so there is a need to interpret the signals that are generated and happen imperceptibly. In this way, the response teams, in emergency situations, should be able to act immediately and effectively immediately after being called. Response time, therefore, is critical for controlling the adverse situation (Klein et al., 1993). However, response actions can become confusing due to the lack of reliable and integrated information about the emergency scenario. Thus, the coordination of actions loses efficiency as the lack of information and its fragmentation contribute to the inefficient allocation of the resources involved. Complementarily, Vivacqua and Borges (2012) state that there is often a lack of information regarding the region around an emergency; The lack of aerial vision of the site and its surroundings brings limitations to the agents responsible for the response.

Often the scenario encountered in these situations presents several risk factors, both for the team responsible for the response and for people who need some support in this environment. In addition, response times associated with effective actions are vitally important in reducing or even eliminating existing risks.

In this scenario, the opportunity to apply a solution involving drones was envisioned, aiming to support decision making in emergency environments by obtaining and communicating useful information to the response teams. Drones, also known as unmanned aerial vehicles (UAVs), are machines that are gaining popularity and are currently widely used. They can be standalone, remotely controlled or equipped with cameras; allowing real-time recording and viewing.

Until recent years, UAVs use was directly associated with military use, particularly armed attacks (Klein et al., 1993). However, researchers, enthusiasts and other users has contributed to the use of this equipment exceeding military employment and that's why a regulatory need to be discuss (Gilman, 2014; Kerasidou et al., 2015).

This research aims to support the decision-making process. The focus is on assisting emergency response teams through a collaborative solution supported by an application and a drone. This solution aims to collect information from a given emergency scenario, so that, through the collaboration of specialists, decision-making is optimized, leading to faster decision making, thus speeding up emergency response. Therefore, the main objective of this paper is to propose a collaborative technological solution that supports decision making in response to emergency situations, by obtaining and providing more information about the scenario.

This paper is structured into five sections. Section two presents the backgrounds related to emergency, disasters and crisis, besides emergency management and drones. Section three provides information about research design and methodology. Section four presents and discusses the results achieved and to finish this paper the authors discourse about the conclusions.

BACKGROUND

Emergency, Disaster and Crisis

Lindell et al. (2007) report that the concept of emergency concerns harmful events of low intensity; those that cause a limited amount of damage to property or individuals. The response to these events, given their small scale, is the responsibility of the fire department, police department or medical institution. The term emergence may also refer to the imminence of the occurrence of a particular harmful event; such as the forecast of a hurricane in the next 48 hours. The urgency of this situation calls for swift and timely action. Generally, an emergency is an unexpected event that threatens people, communities, property or business continuity. Emergency therefore requires immediate action, efforts and resources to minimize or even nullify adverse consequences.

The concept of disaster is associated with sudden and severe natural disasters such as droughts, forest fires, earthquakes, hurricanes, windstorms or volcanic eruptions that end up causing damage and harm to the environment, individuals and property. But the definition of disaster involves much more than the mere

[1] https://www.unisdr.org/we/inform/terminology

occurrence of these events and is the result of a phenomenon, which may be natural, caused by man or arising from the relationship between them. The phenomenon itself is called an adverse event, and this is the cause of the disaster. Disaster can also be understood as a sudden or progressive natural or man-made event that severely affects the community, manifesting the total or partial disruption or destruction of the social system or livelihoods. As a result, the disaster imposes an allocation of resources beyond the normal scope of a jurisdiction or segment of government to address it through exceptional measures or to restore normality of that community (Lindell et al., 2007).

Responding to a disaster or emergency is enhanced by the actions envisaged in the preparation phase. Relief actions are performed during the response and, finally, the reconstruction phase begins. During the reconstruction, lessons learned feedback the prevention actions envisaged in the preparation phase with the aim of refining these preventive measures. Figure 1 presents the life cycle of an emergency or disaster (Gilman, 2014).

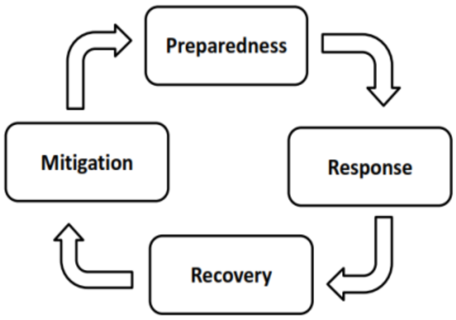

Figure 1. Life Cycle of an Emergency / Disaster - Source: Adaptation of (Gilman, 2014)

Prevention is the first phase and covers actions aimed at preventing disasters or reducing the impact of the consequences. Preparedness is the second phase of disaster management, that includes actions to increase the responsiveness of individuals and organizations so that they can act more effectively. The answer is the third phase in emergency and disaster management. It covers the set of actions taken to help and assist the affected parts (people, animals, environment, properties, etc.), reducing damage and losses, to ensure the functioning of the main systems that make up the community infrastructure. Vivacqua and Borges (2012) state that this is the most complex and the most studied phase of all. These authors also report that this phase presents as characteristics unpredictability, high speed of events, high number of people involved, little time for decision making, unavailability of resources, uncertainty about the situation and stress on those involved. Reconstruction is the fourth and final phase and encompasses actions for the recovery of the affected parts; such as rebuilding a community, allowing the restoration of the normal state.

Emergency Management

Over time, individuals and communities have always tried to find a way to deal with disasters. However, organized and systematic attempts at disaster management are relatively recent. As such, the range of situations that could involve emergency management or the emergency management system is extensive. This reinforces the premise that emergency management is a complex and fundamental process for the safety of everyone's daily life and should make up daily decisions and not just critical moments (Haddow et al., 2017).

Emergency management encompasses the entire planning and intervention process aimed at minimizing the impact caused by extreme events, as well as the implementation of response and recovery actions to mitigate the social, economic and environmental consequences that impact the community. It is a multidisciplinary, progressive process, both reactive and preventive in nature. It covers several areas of knowledge such as risk management, leadership and collaboration (Haddow et al., 2017; Gilman, 2014).

Vivacqua and Borges (2012) affirm the existence of four factors that underline the importance of emergency management: (i) public awareness of risks, emergencies and disasters has increased as the cost of disasters has increased dramatically in recent years; (ii) companies understand that disasters can disrupt their operations and even cause bankruptcy; (iii) there is rapid population growth in high risk areas. This increases the potential for damage caused by a potential disaster; (iv) emergency management is increasingly requiring specialized training. In fact, to respond quickly to complex incidents, managers must make coordination decisions in a short time; which leads to restrictions on the ability to analyze issues related to the coordination (Chen et al., 2008).

Drones

Drone, also called UAV - Unmanned Aerial Vehicle, is a globally recognized English term for a remotely controlled unmanned aircraft. It can be used, for example, for surveillance, delivery or for leisure. This generic term may refer to various vehicles, such as airplanes, helicopters, multi-rotors or any other type of vehicle capable of flying and meeting the above characteristics. The drone may be of various sizes and its ability to fly autonomously may vary, as it can be completely autonomous or may it depend on human interaction during a flight (Gilman, 2014).

Indeed, aerial imaging technology associated with coordinated autonomous flight can quickly reshape disaster response capabilities. Drones are already used around the world in disaster response, such as earthquakes, hurricanes, landslides, floods and are involved in other stages of the emergency life cycle. This equipment is much more used in the trauma response phase than in other emergency phases; however, it is observed that they are still underused. There are many possibilities of applications, among them, in the emergency context, it is relevant to mention: (i) recognition and mapping; (ii) structural integrity analysis; (iii) temporary delivery of groceries and parts of infrastructure; (iv) detection and fire extinguishing; (v) fire response in high-rise buildings; (vi) chemical, biological, radiological, nuclear or explosive events; (vii) search and rescue operations and (viii) risk assessments and logistic support (Chen et al., 2008).

In fact, this equipment is very versatile and offers benefits yet to be explored, among them it is worth mentioning: (i) reduction of exposure of risk response agents; (ii) increased effectiveness of response agents; (iii) clear vision at low altitudes difficult to achieve by manned aircraft; (iv) portability and few requirements to put them into action and (v) great value for money (Chowdhury et al., 2017; Lee et al., 2016; Amukele et al., 2015; Lally et al., 2019).

RESEARCH DESIGN AND METHODOLOGY

Time is a precious variable in emergency management. However, decision makers need reliable information about the current event to direct efforts. Eventually, in order to support the emergency response, it is necessary to call in specialists from specific areas, such as those who have knowledge of fire, liquid or gas leaks, radioactive leaks, among others. In this context, when there is the possibility of aerial visualization of the scenario, as in some cases of fires, landslides or floods, it is possible to be much more assertive in decision making.

Generally, it is recommended that data captured at the emergency scene go through an analysis process. In the event of aerial image capture, these should be forwarded to specialists; which may, in the course of the analysis, make relevant observations and notes about the situation, and then be directed to the decision makers. Currently, several computational technologies have been used to support the decision making process, such as: (i) capture tools; (ii) image processing tools (2D / 3D mapping for example) and (iii) collaborative tools that can handle photos, text and files, instant messengers, email applications and cloud file storage services (remote server).

The present work presents a solution implemented by an application that, when fed with aerial images of the emergency scene, allows: (i) to make the content available on the web; (ii) share the content; (iii) display the images in an organized manner; (iv) insert graphic markings on images; (v) view and edit comments; (vi) display map content and (vii) has responsive design (desktop and mobile). This solution seeks to support agents involved in emergency response as well as decision makers through the availability of images, analyzed by experts.

The Solution

The proposed solution involves three modules, one responsible for capturing images via drone, another that allows images to be made available in the cloud, both available on the market, and a third module that has been developed. This latter is a web system, the central theme of this work, which makes it possible to view and collaboratively edit the captured images through a browser. Considering an emergency scenario, this paper proposes that agents involved can act according to the following steps and illustrated by Figure 2.

1) A qualified agent takes off a drone near the emergency location;

2) The agent commands the drone to flight over the emergency location;

3) After finding scenes of interest, the agent remotely triggers the capture of photos by the drone's camera;

4) The agent downloads the captured images to his mobile phone through the application;

5) The downloaded images are recognized by a second application present on the pilot's phone. This app

starts the process of uploading images to a folder located on the cloud;

6) The images are available on a cloud storage service;

7) Experts and other contributors will be users of a third application, available on the web, which displays the content previously captured that are located on the cloud;

8) Users view the images obtained and their locations; use the app's features to edit images (inserting and / or changing comments) to aggregate information to support decision making;

9) Users view changes made by other collaborating agents and can make new considerations and edits to images;

10) Decision makers access the platform and refer to the original and edited content to support decision making regarding subsequent actions.

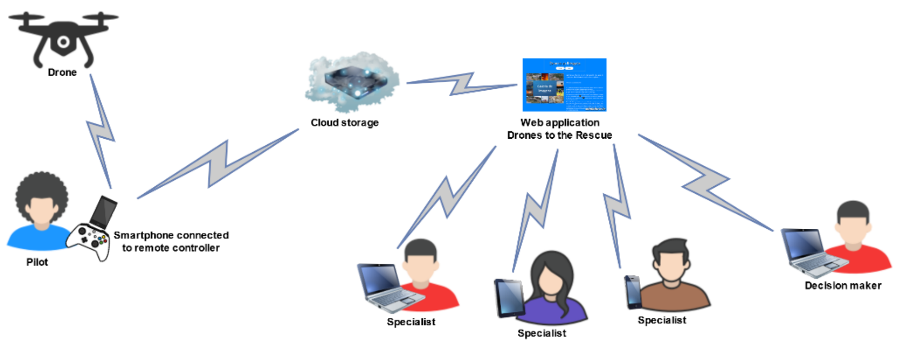

Figure 2. Solution Overview

In this solution, the camera attached to the drone is the source of the images, which serve as the central element in the solution. The Figure 3 represents the flow made by an image. The application allows visualization, collaborative interaction and also provides full support for images taken by other means such as smartphone cameras, satellite images, drawings, among others. However, in this paper we emphasize only drone images.

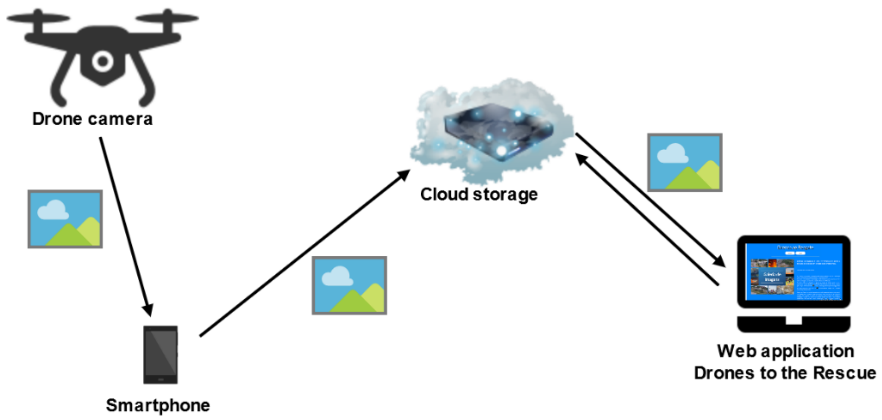

Figure 3. Image capture and treatment flow

Using this solution in an emergency scenario requires a drone, a drone-compatible smartphone with internet access and web-connected devices to use the third module.

The solution is designed to be captured by a DJI drone, along with an Android smartphone, although it is easy to find ways to use an iOS device and other drones with similar functionalities. The cloud service of choosing is Google Drive, along with the consumption of Google APIs by the web application so it will be possible to upload or download from the cloud. The original pictures were uploaded as they were taken, with geographic coordinates and no comments, and were consumed by the web application. The latter has three main components: Image Gallery, Image and comment Editor, and the Map. Through the application, which was coded mainly in Javascript, PHP, HTML and CSS, it is possible to make visual editions to images with an open-source improved editor. The users can insert icons, shapes, texts, make drawings and do other basic editing functionalities. It is also possible to insert and edit a separated comment which will be associated with the image as it is saved on the description field available on Google Drive. Another important functionality, present on the Map component, is the capacity to view images displayed on a map of the region, positioned by the correspondent coordinates.

Methodology

In order to achieve the proposed objective, we initially performed a bibliographic survey to identify systematic and technical characteristics related to the use of drones. This survey was extended to also cover emergency management.

Next, the team defined the functional requirements for the application and carried out a survey to identify an appropriate set of software to the defined requirements.

As a way to validate the usability of the application, after its development, the team designed a questionnaire to capture the views of potential users regarding the usability of the application in emergency situations. At this moment we detail an experiment to be carried out with professionals responsible for handling emergencies, preferably belonging to the air operations group (AOG) belonging to the Rio de Janeiro State Military Fire Department, more specifically at the Unmanned Aerial Vehicles Coordination.

As mentioned above, the validation was divided into two phases: (i) the controlled experiment and (ii) evaluation through a questionnaire whose answers were treated qualitatively, because of the low number of participants as they are an active Firefighting unit, where occurrences happen at any time.

All experts had continuous access to the web application to observe and collaborate by editing images of a set of buildings simulating a fire. One of the captured images can be seen in Figure 4.

Figure 4. Aerial photograph captured for experiment

To carry out the experiment we proposed an emergency scenario, in which a hypothetical fire and building collapse situation was created. Five specialists participated into this evaluation. They are firefighters, men and around thirty years old, and fifty years old. They analyzed and edited the captured images while new scenery information arrived via other means. In the proposed scenario, a response team (composed of 2 specialists in this study) would initiate their action and transmit new information during the experiment. We used this new information to generate new analysis and editions.

RESULTS AND DISCUSSION

The Expert firefighters, who participated in the experiment, considered it very successful. All features available by the solution were verified and it was noticed that the experiment generated an environment similar to a real scenario. The Figure 5 shows two participants analyzing and editing received images.

Figure 5. The Experiment

We performed a qualitative analysis through the applied questionnaire and we received five responses. It is worth mentioning the experience these participants have in the emergency response process; most of them with 20 or more years of experience in this area of knowledge. The software resources chosen to implement the solution performed satisfactorily and the participants highlighted the importance of compatibility of software resources used in solution with drones already used by the group. Another positive point was that good image capture depends heavily on the pilot's technical knowledge, as well as the presence of suitable cameras for such operations.

We received a very positive feedback from the Image Gallery component. It should be noted that the participants reported difficulties in current operations; as they consume valuable time transmitting drone images for viewing and analysis and the proposed solution met that need. The participants reported that the solution streamlines the team's performance in the field and helps direct response actions. The Figure 6 shows an edited image being presented in the gallery.

The following improvements have been suggested: (i) multiple drone support; (ii) organizing content in folders and (iii) the implementation of an access control to the images.

Figure 6. Edited image visualization in gallery

The Image and comment editing component satisfactorily met the proposed objective. It was evidenced because this component allows the scenario creation quite adequately. In addition, the set composed by the image and comments facilitates and improves substantially the understanding of what is happening in the scene of the event; as well as the actions intended to be performed in this scenario. The Figure 7 presents the view of this component.

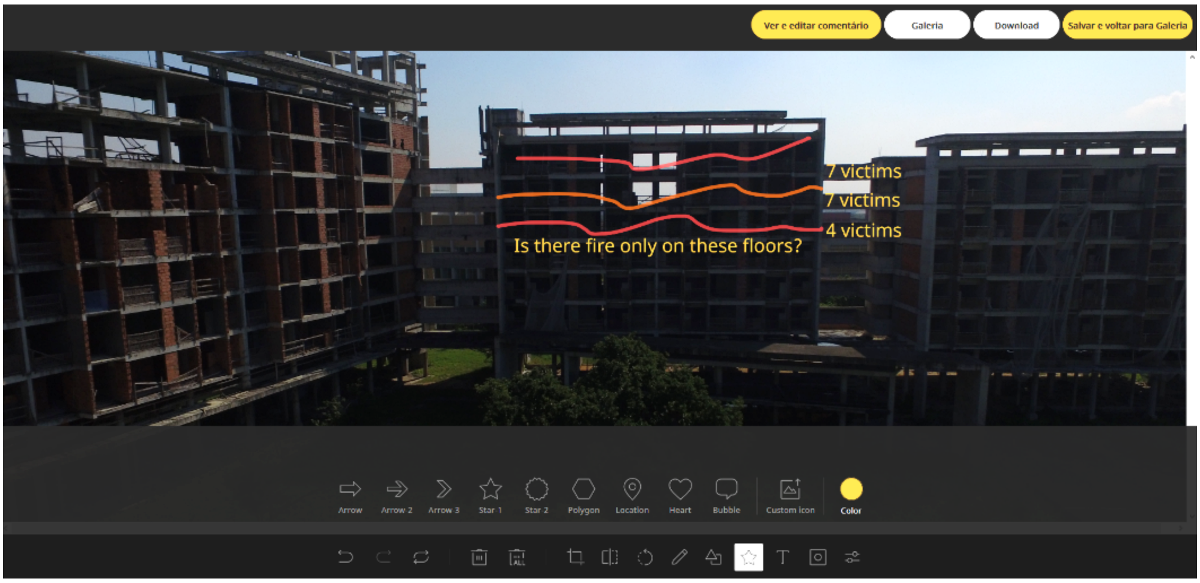

Figure 7. Image and comment editor

The images seen on the Map, as shown in Figure 8, were also approved as field orientation and knowledge of geographical coordinates are important data. This feature provides both a broader view of the emergency scene and the resources view (such as the presence of water), near the region.

Figure 8. Map showing captured images

The application integrates several important features, present today in other tools separately. This solution has advantages over features currently used by the institution for similar purposes. In fact, the application facilitates knowledge and management of resources available at the emergency region.

Overall, this solution presented a very satisfactory result and the experiment carried out proved its efficiency in supporting decision making. In addition, an optimization in response time to emergencies would be possible, according to the experts.

CONCLUSION AND FUTURE WORK

This paper presents a solution aimed at assisting both emergency management and emergency response. Despite the possible usefulness of this solution in prevention, preparation and even reconstruction activities, this work focused on the emergency response stage.

It is appropriate to highlight that this solution emphasizes collaborative work throughout the decision-making process in an emergency scenario. The images obtained via drone are accessed by a team of experts; which can edit them collaboratively by inserting useful information to the team responders at the scene of the emergency.

The participants of the experiment are firefighters with extensive experience in emergency response and the questionnaire answered by these participants allowed a qualitative analysis. This analysis concluded that the objective of the work was successfully achieved, the hypothesis was validated and there was a very satisfactory return.

In summary, there is a great demand for tools that support the decision-making process in the emergency scene, especially within the unit responsible for the use of drones. The results were very satisfactory and aroused the interest of this unit in the continuity of the project; as well as making the solution available for immediate use.

Future work

As future work, the following suggestions were made:

- Access control for captured and edited data, thus preventing leaks of content restricted to those involved in the operation. Therefore, it will be necessary to develop a specific module for this purpose.
- Optimize the organization of captured images by grouping them in function of its origin and versioning of images allowing their tracking.
- Treatment not only of images, but also of videos captured by the drone.

- Live streaming, where it will be important to have low latency and transmission delay, so a good internet connection is essential.
- Display of the geographic coordinates of the drone on the map.
- Report new captured data via email or SMS using an active message trigger system for interested parties.
- Standalone flight support for 3D mapping, in conjunction with an application connected to the drone, so that drone operation takes place autonomously, such that it is possible to form a 3D map after processing the images.

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