Disasters and Emergency Management in Chemical and Industrial Plants: Drones Simulation for Education and Training

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Abstract. The use of simulation for training is proven to be extremely effective both in term of costs and in term of its flexibility for different uses and applications, such as building situation awareness and creating scenarios for training scopes. The aim of the project proposed is to demonstrate the powerful rule of simulation in UAV pilots' cooperative training; the project presented makes use of a 3D simulation environment in order to build a realistic condition of an emergency situation in a chemical plant for the first responders. The model proposed makes use of HLA (High Level Architecture) standards in order to be potentially federated with other existing simulators.

In the solution proposed, the pilot of the drone must accomplish the mission in a given time piloting a UAV; the scenario is based inside a chemical plant where a disaster is newly occurred. Then ability of the pilot is measured by the system and several constraints are reproduced to provide a realistic training scenario (such as small spaces and barriers to overcome, battery durations, risks of damages due to high temperatures zones, etc.); the system records and tracks all the actions of the pilot and gives a feedback to the user at the end of the simulation time.

Keywords: UAV · 3D simulation · Training and education · Augmented reality

1 Introduction

The use of Remotely Piloted Aircraft Systems (RPAS) is rapidly increasing as demonstrated by recent developments in regulations; in addition RPAS are now equated as aircraft and have to comply with aviation safety rules (EASA, 2014). Certificated programs for UAV (Unmanned Aerial Vehicles) pilot, including a

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mandatory number of hours of simulator have been instituted both in defense domain and in civil domain; in addition, civil domain is expected to overcome the military one in term of use of drones [1].

UAV can be controlled by a pilot or can have a pre-programmed mission/task to perform; thanks to their flexibility and the different mode of use there is a number of projects in a wide variety of sectors involving UAV's and their cooperation with human. Indeed UAV simulation for civil application can be found in context that are really different: helicopter-based UAV have been fruitfully used in precision agriculture for remote thermal signals and sensor for optimizing irrigation and water consumption [2] and multiple mini UAV have been used in forest monitoring [5].

It is clear that the wide spectrum of possible use for the UAVs imply a proper training for the pilot that must be tailored for each different context; for this reason, simulation can support at best the training and operations, in particular in critical environment [7]. Simulators have different advantages compared to live simulation; are more flexible for creating training scenarios, [8] they allow to reproduce "extreme conditions" like low gravity condition in space domain, or complex operations in a lunar base by making use of a federation of different entities [3, 6]. Autonomous Systems in general opens a door for a new training paradigm. The trainees and ASs must be trained in the same synthetic environment [9].

2 UAV for Disaster Assessment

Drones, and UAVs in general, can be used effectively for disaster assessment and they represent a useful resource for speeding up the operations and increase the information available for the emergency squad.

After the occurrence of a disaster, the first respondents needs to acquire information about the infrastructure that have been damaged and what is the current status of the disaster; furthermore, they have to coordinate the assistance and the emergency operations both in terms of actions to undertake and in term of allocation of the available resources [4]. For this reason UAV, can be fruitfully used in taking measurement, area mapping and visual inspection on a chemical plant scenario, where a disaster is newly occurred. Autonomous systems can increase the security for the first responders substituting their physical presence in dangerous situation with a remote control; finally, they can be used to support triage activities with the people involved.

In this context the capability of the UAV pilots to accomplish the task fast and effectively is a primary key; this imply an high attention on the quality of the training for the pilot on the ground.

The aim of this project is a 3D simulation of a virtual environment representing an emergency situation focused on an accident inside a chemical plant. The project proposed is able to reproduce the emergency conditions inside and outside the plant and it can support:

- training both for single and multiple users
- mission planning
- support to operations.

Indeed one of the primary objective of the simulator is to reproduce the situational awareness, and for doing that, it is important to note that the forces involved should be able to do the following actions:

– undertake intelligent evaluations
– take an overview of the current situation, considering the present condition and the risk correlated
– estimate the potential risk related to the evolution of the current condition
– reach the “optimum” training level
– operate easily and in a coordinate way with the other people involved.

The trainee must define the action to undertake considering also the procedural aspect in a dynamic scenario evolving in time. Such scenario matches different chemical accident, with other ancillary failures stochastically generated (i.e. communication interruption, electrical power interruption) and drone’s constraints (speed, autonomy of the batteries, wind interferences etc.) that the user need to face.

3 Model Description

This project in Fig. 1 have been developed following the following steps:

– Chemical plant 3D models (interior and exterior);
– UAV 3D model-quadcopter;
– Set of humans inside the plant;
– UAVs physics implementation;
– UAV’s sensors implementation;

Fig. 1. User piloting the UAV over the simulated plant

The total number of polygons have been optimized in order to assure a sustainable workload for the graphic card for reproducing a real time simulation.

The initial scenario proposed is a chemical plant that have been damaged by a big earthquake causing an increase of the pressure in the production systems and uncontrolled chemical reactions that evolve with fire generation in different part of the plant.

Some toxic substances have been released in the atmosphere, and the toxic cloud is propagating with a certain speed and moving to the village close to the plant. The structure of the plant is damaged and the production systems and control system are out of order.

In the Fig. 2 is possible to see the diffusion of the toxic cloud: its propagation depends on different parameters that can vary during the simulation (such as wind speed, external and internal temperature, fire propagation inside the plant etc.).

The first responders can't direct access physically inside the plant due to the dangerous condition and they need to understand the situation by making use of the available drones in term of:

- what type of chemical material have been released
- what are the risks and what is the propagation speed of such kind of substances
- how many person have been involved in the disaster, what is their health condition.

The UAV is equipped with different sensors and have a predetermined autonomy of batter that is stochastically generated. Such constraint make the simulation closer to reality because the trainee should consider the total time available for his mission.

A further constraint is the wind speed limit, and the meteorological condition that are stochastically generated by the computer and that can vary during the simulated time.

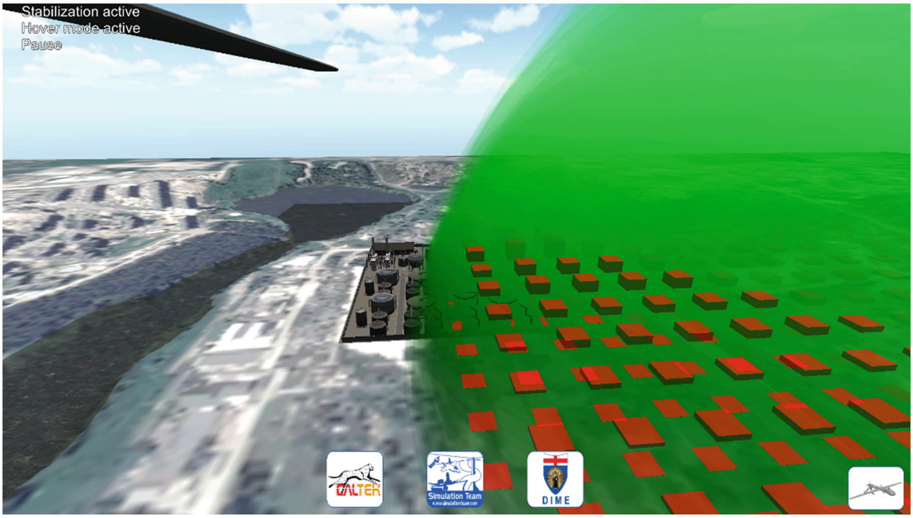

Fig. 2. Toxic cloud diffusion

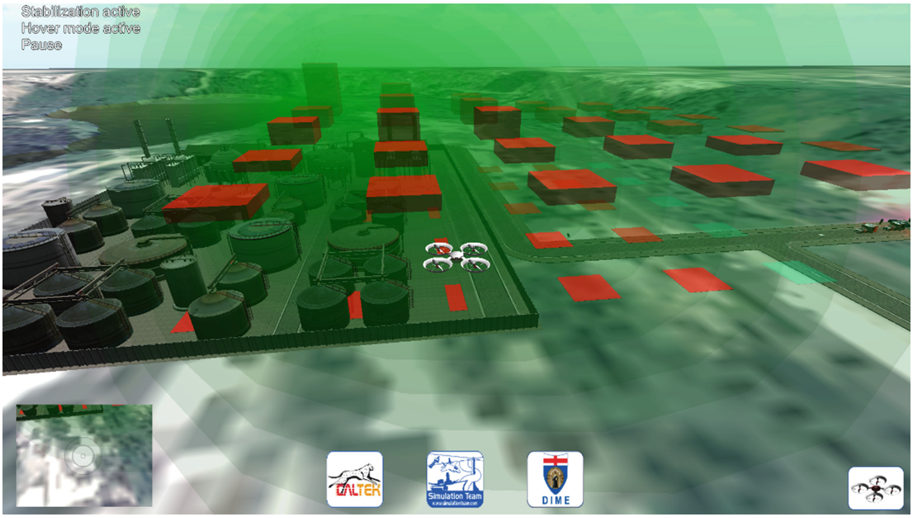

Fig. 3. User piloting the UAV over the plant

The simulated drone (Fig. 3) recreates the true real motion with the 6 degree of freedom (DOFz). The motion of the drone is given by the second law of Newton applied to the 6 DOFs.

Each drone is equipped by:

- a main camera installed under the drone body and the user is free to switch the different views.
- a camera following the drone.
- air contamination sensor (e.g. oxygen level, toxics substances detection such as nitrogen, etc.).
- biomedical sensor measuring the health status of injured people (life signs such as breath, voice messages, etc.).

Further additional sensors may be present or not inside the drone, or can be out of order for example:

- capability to manipulate object
- capability to activate devices
- sensor measuring distances
- capability to record video and images.

The Fig. 4 shows the drone flying within the chemical plant when the air contamination sensor is active. When contaminants are found (e.g., Methane, Ammonia, etc.), the concentration of contaminants is shown by using red parallelepipeds whose height is proportional to the contamination level (the higher the height is, the higher is the contaminant concentration).

The biomedical sensor is used to check life signs; in order to work properly the drone must be close enough (e.g., less than 1 m) from the human body. Indeed the

Fig. 4. Drone flying inside the chemical plant, in the disaster zone

drone need to approach at the right distance for a sufficient time to the man on the ground for checking his life signs in a proper way.

It is worth mentioning that the disaster scenario changes every time the simulator is started, therefore, the user can always play a different scenario. In particular, contaminant concentrations as well as the position of the injured people and their life signs change every time the simulator is restarted.

Here is described an example of the mission for the trainee:

(1) Scenario Generation:

The system generate a scenario with a partial description of the event, an estimation on the number of people involved in the accident and the type of chemical substances that have been released. It is important to note that all the information will be partial and incomplete in order to make the scenario closer to the reality.

(2) Mission Planning:

The user have a set of available UAV available, with a predetermined autonomy of battery and each one equipped with certain sensor. Based on the configuration of the plant, the sensors and the information provided by the system (i.e. number of people involved, meteorological condition, chemical substances released, distance of the village near the plant) he have to decide the most suitable UAV to use considering also the drone dimension and its capability to enter and move in small space.

(3) Mission Execution:

The user should plan his mission and his flight plan considering all the constraints and the current condition, the layout of the plant and the possibility of interruption of the communication due to the layout of the plant or other events that can occur.

The user should perform the triage operation of the people involved during the accident in the right way. Each person involved in the accident has a different health status that change and get worse during time. The ability of the operator is to understand the situation and to decide the "best sequence" for the triage by processing the information given by the drone's camera and by considering the obstacles such as fire, smoke and high temperature that can damage the drone or make extremely challenging the drive of the drone itself.

(4) Simulation Results:

When the mission is accomplished, the system provides a feedback to the trainee (Fig. 5) with:

- Total time for the mission
- Damages for the drone
- Health condition of the people involved in the disaster
- Time elapsed
- Battery level
- Triage efficiency
- Area coverage
- Sampling effectiveness

As shown in the Figure, the time elapsed is the time from the beginning of the flight. The battery level shows the percentage of remaining charge. The triage efficiency is the percentage of people identified as injured. The area coverage shows the percentage of area covered by the flight of the drone, while the sampling effectiveness shows the percentage level of contaminants found through the air contamination sensor.

Fig. 5. Simulation results

4 Conclusions

The paper has presented a simulator developed by the University of Calabria – MSC-LES Team and University of Genova.

The simulator provides a 3D virtual environment, that involve the user reproducing the real condition in emergency situation; it is important to note that such situation are really difficult to be reproduced in reality, since the process can be time consuming, really costly, and dangerous.

The main objective is to propose an innovative instrument for training drone pilots in emergency condition in disaster relief context.

The simulation is based on discrete event; the stochastic nature of the simulator allow to test different scenarios with different conditions that change during the simulation time and that are different for every game.

Finally, the system can be federated by using an HLA-based bridge with other UAVs simulator or M&S Autonomous Systems' experimental frameworks [10] in order to support multiple training and experimentation; further development and researches are ongoing for Augmented Reality applications. Such simulator have been tested among a group of students and the results before and after the training have been compared. For brevity reasons the learning curve profile of the different users have not been reported. In average, the users have demonstrated a good improvement in the performance in particular in term of: speed in accomplishing the task, reduction of the number of mistakes and collisions, total time for the mission and area coverage.

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