Research on the practical application of unmanned aerial vehicles (UAV) for disaster management

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1. Introduction

UAV are useful tools for disaster response, recovery, and mitigation. It provides imagery and crucial information of the hit areas after a disaster. First responders may use these information to monitor the situation and conditions after a disaster. Some advantages of using UAV in disaster management are summarized in these concepts; (i) reach; (ii) speed; (iii) safety and (iv) cost. UAV gather information from remote, difficult-to-access and hazardous areas reaching farther in distance than ground-based teams might be able. In addition, the portability of most commercial products increases the speed of information acquisition, team deployment and decision-making. On the other hand, human teams do not need to enter contaminated or highly risk areas. In addition, the accuracy and scope of the inspection and survey is improved. Finally, the cost of using a UAV is comparatively lower than to use helicopters. Conversely, small UAV units may have its disadvantages such as the instability due to high wind, which may affect image quality; the variability on GPS signal that may incur on drop-outs and consequently fly-away accidents. In this study, we briefly describe some applications of UAV for disaster management and to lay the ground for its practical application, we developed a tool for the planning stage on UAV missions in disaster management. We use an agent-based model (ABM) to describe multiple UAV units fulfilling individual goals within the same environment.

(a) Field survey using UAV (b) 3D model of damage state

Figure 1: Surveying typhoons 17-18, Sep. 2015 - Miyagi, JP

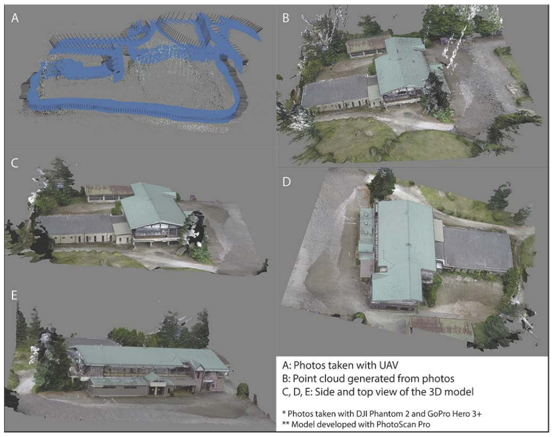

Figure 2: 3D model of a house using UAV imagery

2. Applications for disaster management

UAV are small, light-weight and quickly deployable, therefore, they offer the ability of rapidly respond to an emergency. When a disaster strikes a populated area, search and rescue teams are deployed to find survivors (Sato and Koshimura, 2013). In addition, an overall area survey is required to comprehend the extent of the impact of the disaster (Fig.1). Moreover, the situation and condition of an area impacted by a disaster is highly dynamic; therefore, frequent situational reports are requested for an effective use of resources and support logistics. Finally, on the way of recovery and reconstruction, details of damage, recovery and reconstruction processes can be archive on digital formats of video, photo and 3D models of cultural heritage or important structures (Fig.2).

These are some possible applications of UAV in disaster management, however, still several issues should be addressed. For instance, the law and prohibitions for using UAV in many countries is highly strict or none due to a stigma given to drones by its use in warfare. As Kim and Davidson (2015) suggest, questions on UAV users and responsibilities within disaster response are still unanswered; training, collaboration, permissions, air traffic control and coordination among multiple UAV based responders need to be addressed.

3. Objective

In this study, we explored the applications of UAV for disaster management, as detailed before. In addition, to lay the ground for the practical application of UAV in disaster management, we developed a tool for the planning stage on UAV missions in disaster management. We use an agent-based model (ABM) to describe multiple UAV units fulfilling individual goals within the same environment.

4. Methodology

The specific tasks we will address by modeling are: i) Mapping and situation monitoring of points of interest (POI); ii) Shelter monitoring; iii) Search and Rescue and iv) Relief Delivery. These applications and multiple goals can be simplified as the requirement of a unit to visit multiple POI in the minimum time, avoiding collision with other units or the environment (i.e. trees, mountains, buildings, etc.). Therefore, we conceptualized the model as a multiple searching

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path optimization problem. In this paper, to avoid units collision we used a layered mission (different heights during flight). Then, the following units will be involve in the development of the ABM for UAV swarm mission planning: (i) UAV-Mapper: Requires to visit POI set by the user; (ii) UAV-Shelter monitoring: Requires to visit pre-set or user-set shelter locations; (iii) UAV-Search and Rescue: Requires to visit highly populated structures (if data available) or user-set locations (high probability spots to find survivors); (iv) UAV-Relief Delivery: Requires to visit medical center locations.

5. Agent-based model

5.1. Model environment

To develop the ABM we used the NetLogo platform (Wilensky, 1999). NetLogo is a multi-agent programmable modeling environment designed as a "low thresholds and no ceiling" platform. NetLogo is a highly user-friendly platform with a Graphic User Interface (GUI) (Fig.3). To the left is the control panel where inputs, buttons and instructions are detailed. These are mainly to set and run the mission. In the middle is what NetLogo calls *the world*, in here, an image of the target area can be imported and georeferenced. On the right hand is the output screen, other optional features for mission test and graphic plots to evaluate the solution.

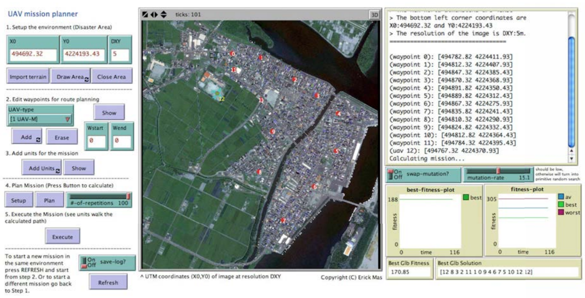

Figure 3: Interface of the model

5.2. Model algorithm

The flow of the model is shown in Fig.4. As shown, first it is necessary to set the environment, an image of the target area is imported with special care on the low left corner coordinate and the resolution. Next, the type of UAV is chosen and its waypoints are selected. At the same time, a log file is being created on the right output screen, this can be finally exported to save records of the planned mission. Once all units and their respective start point and waypoints are loaded in the model, the setup button will commence the calculation of initial possible paths for each UAV. In this study we will use the genetic algorithm approach to calculate the optimum paths.

5.3. Genetic algorithm

Genetic Algorithm (GA) is a search technique which generates solutions to an optimization problem using methods inspired by natural evolution characteristics. In GA, the initial population with candidate solutions (paths) evolves toward better solutions through mutation of its chromosomes (combination of waypoints). The initial population or paths is generated randomly and through the iterative process, new generations are created. Each generation is evaluated for

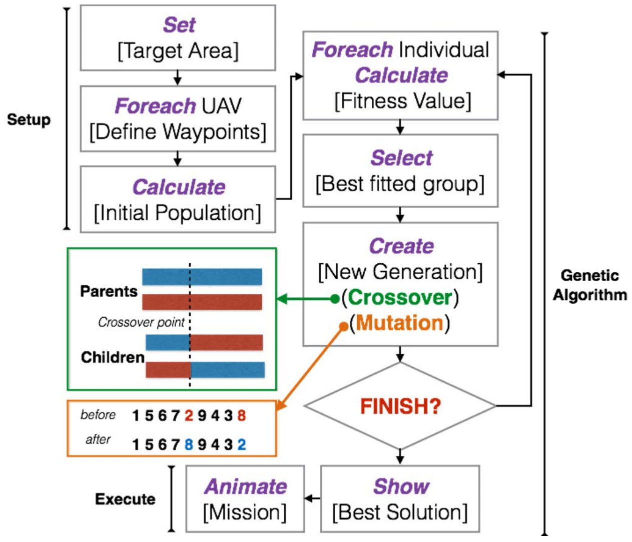

Figure 4: Model flow

its fitness and global contribution to the problem solution. The fitness refers, in this case, to the path length. Paths with higher fit value (minimum distance value) are selected to breed a new generation through crossover and mutation combinations. Crossover is the genetic operator used to produce a new generation by taking two solutions as parents and producing children by taking part of each parent's chromosome to create the child's chromosome. Mutation is used to maintain the genetic diversity from one generation to the next. GA can come to a better solution by mutation due to the alteration of gene (waypoint list) values. Through mutation, the algorithm prevents populations to have too similar chromosomes (solutions), avoiding local minima. The simulation finishes when a pre-defined number of generations have passed or the fitness value is accepted.

6. Conclusions

In this paper, we have briefly described some applications of UAV and developed a tool for planning UAV missions in disaster response situations. Genetic Algorithm was used to solve the path planning problem and a user-friendly environment was presented to facilitate and accelerate the planning task. At this stage, optimum paths are found, however, battery life or hovering time has not being assessed within the model. These improvements remain as our future task to fulfill our expectations in the model. As a preliminary report on the development of this tool, we acknowledge the advantages of UAV and the necessity to prepare for its active use in the future of disaster management.

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