

Earthquake Rescue Mission Modeling Based on Multi-Agent

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Abstract

In order to better research the role helicopter played in the earthquake rescue, a helicopter earthquake rescue mission modeling method based on multi-agent was proposed. The elements of the earthquake environment modeling were described. Typical helicopter rescue missions in earthquake relief were divided into three basic types, and the mission flow was carded. The division and function of agents in the helicopter earthquake rescue mission model was introduced, and the agent information layers structure was established. An approach of helicopter earthquake rescue mission effectiveness evaluation, including three types of assessment indicators, was proposed also. Finally, the architecture of a simulation system based on this modeling method was built.

Keywords: multi-agent, helicopter rescue, earthquake rescue, air transport, mission modeling

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1. Introduction

After an earthquake, due to the destruction of the roads or ground traffic congestion in disaster areas, ground transport is difficult to access the disaster areas quickly and not be able to effectively control the spread of the disaster, thus losing valuable opportunity and time. Finally, the situation and losses of the disaster will be exacerbated. Therefore, using aircraft, especially helicopters, to perform the rescue missions such as supplies transport and injured rescue has a very prominent value. China is a quake-prone country, but it's aviation emergency rescue experience is limited. How to make better use of helicopters for earthquake relief is a problem which is urgent need to study.

Agent-based modeling (ABM) has developed rapidly in recent years [1-2]. S Coradeschi researched the intelligent agents for aircraft combat simulation [3]. M Tambe researched towards flexible teamwork [4]. J Himoff proposed the multi-agent logistics i-scheduler for road transportation [5]. K Moizumi analyzed the travelling agent problem [6]. A Nowroozi poposed a general computational recognition primed decision model with multi-agent rescue simulation benchmark [7]. J Ma conducted the agent-based simulation for urban emergency response planning [8]. Jiashun Zhang presented a multi-agent competition model to simulate the integrated transportation system [9]. Mingzhu Zhang developed a cooperation mechanism of wide-area protection system based on multi-agents [10]. And there are lots of application in the field of air transport. Í Oliveira researched the multi-agent tools for air traffic management [11]. Vladimir Gorodetsky et al researched airport airspace Agent-based air traffic management and built a multi-agent simulation software prototype [12]. Minh Nguyen-Duc et al researched the application of multi-Agent technology in air traffic management, especially in real-time traffic synchronization [13]. Don Perugini et al researched the global military logistics transportation scheduling based on agent [14].

ABM is particularly suitable for complex system modeling and simulation, and in helicopter emergency rescue mission the environment is complex, involving a synergy between the different units, so the use of ABM technology for modeling can better achieve the helicopter emergency rescue mission simulation. This article will use ABM to achieve the helicopter earthquake rescue mission modeling for the research of helicopter's (or other aircraft) types, number demand and command scheduling mode in earthquake relief missions.

2. Mission Modeling

2.1. Environment Modeling

Mountains, forests, and other natural terrain will affect the rescue operations, however the earthquake will also affect the environment in disaster areas. Usually it is worth to notice that the destruction of buildings and roads, as well as the spread of fire. This disaster environment will make part of the region that people or vehicles can't close. The area which helicopter can be landing will also become limited, and in some regions helicopter even difficult to approach (such as a fire or a cluster of buildings). This environment will have a significant impact on the rescue mission. Therefore, the environment modeling not only reflects the visual effects in the simulation but also makes the simulation process more real through the physical effects in the scene.



Figure 1. Urban Disaster Area after the Earthquake

In order to reduce the difficulty of modeling, the game engine can be used for development. Its own physics engine can help the environment modeling with finite precision. Figure 1 shows the environment of an urban disaster area after the earthquake which is built by the game engine tool of Unity3D. Ground personnel action in this scene is limited that people need to avoid the collapse of the building and the fire area. However the helicopters need to land in open areas or keep hovering to implement the rescue.

2.2. Mission Description

In earthquake relief, helicopter's typical missions can be divided into three kinds such as the supplies transport, victims evacuation and wounded transport. Their contents are as follows:

- a) **Supplies transport:** Loaded with relief supplies from the heliport (airport), the helicopter unloads supplies after landing in the target area or airdrops without site for landing.
- b) **Victims evacuation:** After the helicopter lands in the disaster area, the victims go aboard and will be transported to the airport.
- c) **Wounded transport:** The wounded transport can be considered as a kind of personnel transport also like victims evacuation, but such a mission is unique therefore listed separately. Carrying stretchers or other medical and rescue equipment and a number of medical workers, the helicopter loads wounded on the ground which is a landing site or lowers the rescuer by ropes to fix and pull up wounded without landing site. Then the wounded will be transported to the airport.

In actual earthquake relief, these three basic missions might co-exist. Figure 2 shows a typical rescue mission process. After received the information about the disaster, the commander releases task orders. Then after fueling, maintenance and other ground services at the airport, the helicopter flies to the disaster area with relief supplies. At last, unloaded supplies, the helicopter carries the wounded and returns to the airport.

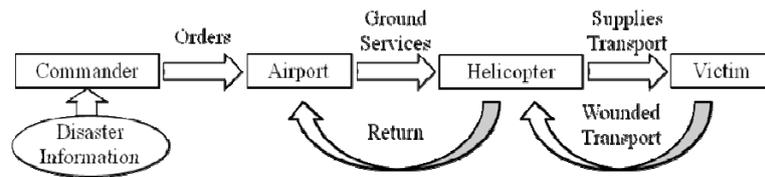


Figure 2. A Typical Rescue Mission Process

2.3. Agent-based Modeling

In this paper, based on the function of each unit in the rescue mission, the helicopter earthquake rescue mission model contains the following types of agent:

- Commander Agent:** Responsible for the allocation of the rescue mission (including mission type and destination), command and scheduling helicopter agents in the mission. The commander as the leader of the entire rescue mission needs to analyze the global resource information to make timely decisions.
- Helicopter Agent:** As the core of the implementation of the rescue mission, its basic duty is reciprocating transport between the airport and the disaster areas. It is the connecting link between the victims and the airport.
- Human Agent:** Including rescuer agent and victim agent. Rescuer agent needs to help wounded victim agent to aboard the helicopter; victim agent need to approach to the helicopter agent to receive relief supplies or be evacuated by helicopter. Human agents can only act on the ground and their moving ability is restricted by the terrain environment.
- Airport Agent:** Airport Agent's duty is to maintain the normal operation of its own and trying to meet the needs of the helicopters involved in the rescue mission. It needs to conduct its own resource allocation (airport facilities and ground personnel, etc.), arrange for the helicopter taking off and landing, and keep the airspace management in airport area.

The above four categories of agent constitute the information layers structure which is shown in Figure 3. The ground layer is divided into two regions, disaster areas and airport areas, which are respectively airport agents

3. Evaluation of Mission Effectiveness

Mission Modeling is used to evaluate the effectiveness of the mission through the simulation. Helicopter earthquake rescue mission effectiveness indexes can be divided into mission completion, mission consumption and mission occupancy.

3.1. Mission Completion

The degree of mission completion need to be calculated based on the type of mission. The degree of completion of a single basic mission (supplies transport, victims evacuation and wounded transport) is as follows:

$$E_s = \frac{\sum M_f}{M_{all}} \quad (1)$$

In the equation, E_s is the completion degree of a single basic mission, M_f is the amount of a single flight's transport (weight of supplies or number of people), M_{all} is the amount of the supplies or people need to be transported in the mission.

If the rescue mission includes one or more basic missions, the degree of completion of the entire mission need to combine the degree of completion of each basic mission:

$$E_{cm} = \frac{\sum (k_s \cdot E_s)}{\sum k_s} \quad (2)$$

In the equation, E_{cm} is the completion degree of the entire mission, E_s is the completion degree of a single basic mission, k_s is the coefficient of each single basic mission.

3.2. Mission Consumption

The main consumption in rescue mission is time and fuel:

$$E_{cn} = \frac{k_T \cdot T}{t} + \frac{k_f \cdot \sum W_{fh}}{w} \quad (3)$$

In the equation, E_{cn} is the consumption degree of the entire mission, k_T is the coefficient of the mission duration, T is the mission duration, t is unit time, k_f is the coefficient of the mission fuel consumption, W_{fh} is the fuel consumption of a single helicopter, w is unit weight.

3.3. Mission Occupancy

The mission occupancy refers to various resources occupancy. The degree of the mission occupancy is the time duration for the individual's use of various resources in the mission process. The resources of mission include helicopters, pilots, ground crews and airport facilities, etc.

$$E_{oc} = \sum (k_r \cdot \sum T_{ir}) \quad (4)$$

In the equation, E_{oc} is the occupancy degree of the entire mission, k_r is the coefficient the occupancy for a single kind of resource, T_{ir} is the occupancy of each unit of a single kind of resource.

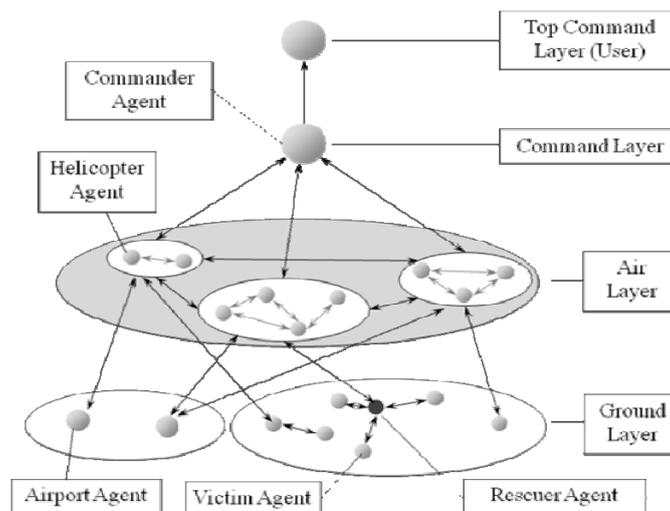


Figure 3. Information Layers Structure of Agents

4. System Architecture

It is necessary to build a simulation system for the helicopter earthquake rescue mission simulation and analysis after the mission modeling. Figure 4 shows the overall architecture of the simulation system. The system is comprised of four main modules which are resource module, calculation module, display interface module and result module.

a) Resource Module: It provides the resources for calculation module and display interface module. Resource module includes two parts which are database and file manager. The database stores the parameter information of helicopter, airport and terrain etc which the simulation required. File manager is responsible for the management of 3D models, audio files and animation etc entity files.

- b) **Calculation Module:** It is the core of the simulation system and includes environment model and agent model. The simulation process is driven through the calculation module's operation.
- c) **Display Interface Module:** Its main function is to display the process and result of the simulation to the user.
- d) **Result Module:** It summarizes the simulation data and calculated based on effectiveness evaluation algorithm. Finally, the result report is generated by result module for the user.

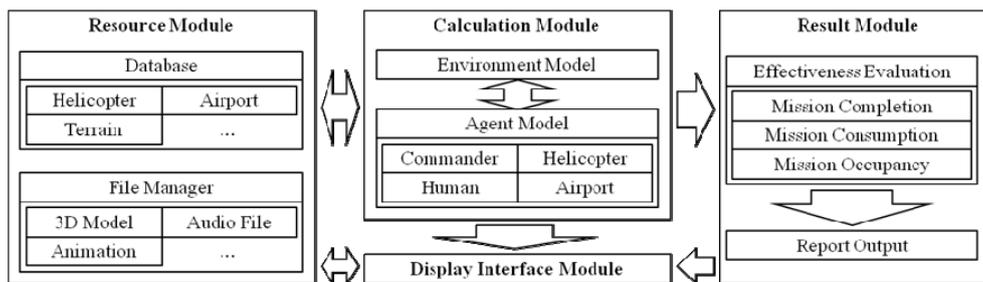


Figure 3. Overall Architecture of the Simulation System

5. Conclusion

With a lot of applications in the field of aviation, ABM is very suitable for the modeling of complex systems, and earthquake rescue mission can be seen as a complex system.

In this paper, the content and process of the helicopter rescue mission in the earthquake relief are researched, and the ABM technology is used for the mission modeling. In earthquake rescue, helicopter's main job is to transport which can be divided into supplies transport, victims evacuation and wounded transport. According to the work of the units in the rescue mission, four categories of agent, commander, helicopter, human and airport, are proposed. They are in different positions of the information layers structure and interaction with others. An approach of helicopter earthquake rescue mission performance effectiveness evaluation, including three types of effectiveness indexes which are mission completion, mission consumption and mission occupancy, is proposed also. Finally, the architecture of a simulation system based on this modeling method is built. The helicopter earthquake rescue mission can be seen as a complex system, the modeling method researched in this paper will be an efficient approach to establish the simulation system and research the role helicopter played in earthquake relief. Better grasp of the usage of helicopters, the earthquake rescue will be more efficient and more people will be saved.

In sudden large-scale disaster relief (such as the earthquake in Wenchuan, Sichuan province, China, 2008), more aviation resources will be mobilization for emergency rescue missions. The scale and complexity of the simulation of these missions will have a large increase, which will contain more the types and number of aircraft, and will be a corresponding increase in the level of the command system. Therefore the work in this paper will lay the foundation for further research.

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