Instructions on How to Carry Out Simulations Described in the Manuscript Entitled: Cooperative Survival Principles for Underground Flooding: Vitae System Based Multi-Agent Simulation

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1. Introduction

This document is intended as a short and simple guide on how to use the two model files, "Base or Rope Strategy.model" and "Group Strategy.model," with the artisoc simulation software. The basic functions of the software are described in its English manual (Kozo Keikaku Engineering Inc., n.d.) while this guide explains two specific models used in our manuscript, primarily focusing on how to change key parameters and run a simulation. A detailed explanation of the model is reported in our manuscript, which is currently under review.

The two model files, "Base or Rope Strategy.model" and "Group Strategy.model," have been developed for simulating evacuation and rescue behaviors under life-threatening situations, termed "survivability-critical situations," during underground flooding. As an illustration, three strategies for the evacuation and rescue processes are simulated and compared in an underground inundation case study in which people must be evacuated towards the surface.

2. Simulation Setting

The two model files have the same settings except for the evacuation and rescue strategies that evacuee agents follow in the simulations. The simulation spaces, flooding data, and basic agent settings are the same, while the "Base or Rope Strategy.model" file is for the Base and Rope Strategies, and the "Group Strategy.model" file is for the Group Strategy.

2.1. Location and Structure of Oike Underground Space

As a case study, the models create simulation spaces that reflect the Oike underground space in the center of Kyoto city, Japan, located near the Kamo River. In this multi-story space there are features such as a subway platform (B3F), a subway station concourse (B1F), and staircases between them (B2F). The platform space is 100 m × 8 m in dimensions and 2.7 m in height. B1F is 650 m × 40 m in dimensions. The three exits from B3F are all staircases leading to B1F. All staircases have handrails, so when evacuee agents face survivability-critical states, they can stand and maintain their positions by gripping these handrails.

2.2. Flood Data

The inundation flow used in the models employs flood data from a 1/100 scaled hydraulic model experiment that assumes 100 m^3/s overflows from the Kamo River at the upstream site of the Oike Bridge (Toda, 2007). Because the structure of B3F and associated staircases form a small and closed space, evacuation is difficult, especially for people who are located in B3F, where water level increases rapidly between 15 and 20 minutes after inundation starts. Because rising water levels make evacuation by the staircases more and more difficult, all staircases are regarded as bottlenecks.

3. Brief Description of Agent Model

The Vitae System model, proposed by Okada (2006), provides a comprehensible concept for modeling human behavior and decision-making under survivability-critical states. First, when evacuees face these states, they try to find and reach transitory shelters that will allow their survival. Then, the evacuees need to sustain their survival status. Finally, they have to be rescued by other people who still have enough survivability to be able to walk. These evacuation and rescue processes under survivability-critical states are modeled with the three fundamental elements of the Vitae System model: survivability, vitality, and conviviality. In the models, these elements are translated as walkability, gripping power, and evacuation and rescue strategies.

3.1. Basic Functions of an Agent

Evacuee agents have height, weight, walking speed, and gripping power. Based on the average characteristics of adult males, which is set as 100%, any kind of agent can be created by changing the indices of normalized values. The average data for 40-year-old Japanese men obtained by the Ministry of Education, Culture, Sports, Science and Technology-Japan (2010) is set as the standards: the standard height of a person ($H = 170$ cm), standard weight ($W = 70$ kg), and maximal grip ($G_{MAX} = 50$ kg). Accordingly, the relationships among height, weight, and gripping power are defined by equations. Hence, the normalized evacuee height is the only parameter, r_H. The maximum flood level at which adult evacuees can still walk is the survivable water level, 70 cm, based on studies by Toda (2007).

3.2. Evacuation and Rescue Strategies

The simulations offer a choice of three possible evacuation and rescue strategies: non-cooperative evacuation (Base Strategy); evacuation involving the formation of a group (Group Strategy); evacuation and rescue using a tool, such as a rope (Rope Strategy). Agents with enough survivability to evacuate can choose to help other agents or not and which strategy to use. If using the Group Strategy, agents join with others along the evacuation route and nearby. For the Rope Strategy, agents who are in relatively safe areas can help others but stay safe themselves by using a rope.

4. Running a Simulation Model

After starting artisoc on your computer, click “File” and choose “Open.” You can also use a short-cut key, “Ctrl+o” instead. Then, choose the model file that you want to run. As shown in Fig. 1, on the main screen, you will see two small windows: “Tree” and “Control Panel.” The tree window displays the structure of the model as a multi-level tree. It starts from “Universe” and goes to lower layers such as “Space,” “Agent,” and “Parameters of an agent.” The Control Panel is for managing several key parameters in a simulation. By changing the values, you can easily simulate a variety of evacuation and rescue processes in different situations.

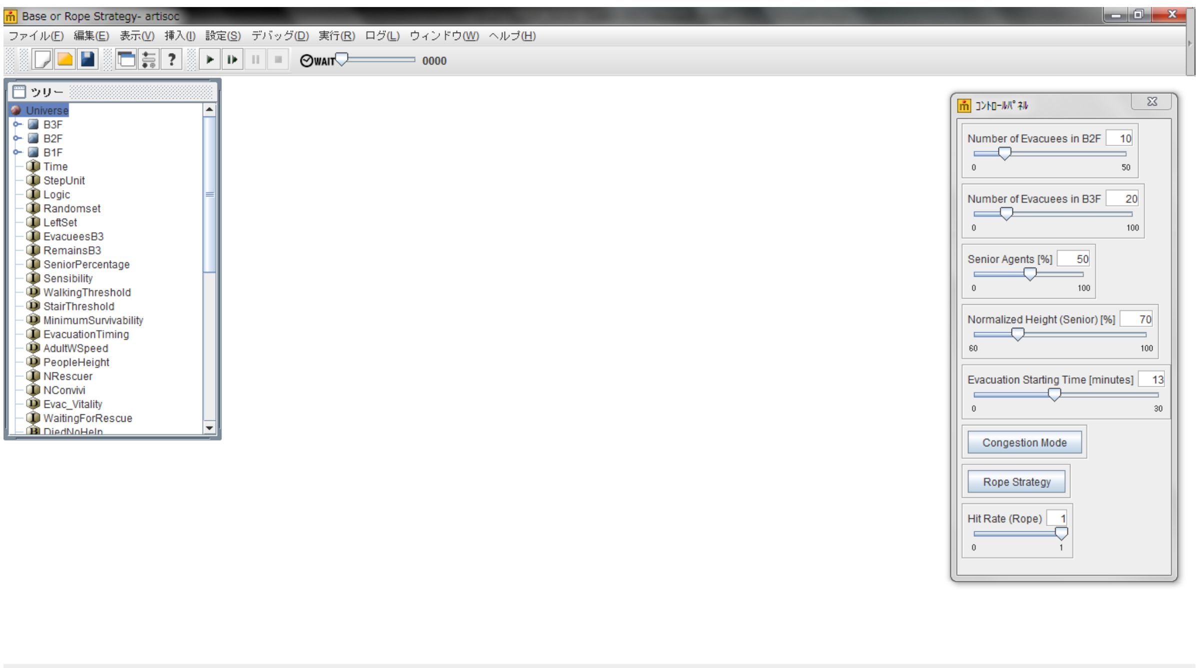


Fig. 1 Main screen with two windows: the Tree (left) and Control Panel (right)

4.1. Parameters on a control panel

4.1.1. Number of Evacuees in B2F or B3F

The slide bars at the first and second from the top are for controlling the number of evacuee agents initially located in B2F and B3F, respectively. The minimum numbers are zero and the maximum numbers are 50 and 100 evacuee agents in B2F and B3F, respectively. The evacuee agents are created for each floor, and randomly distributed throughout the floor.

4.1.2. Senior Agents [%]

These simulation models have two types of agents: senior and adult agents. The third slide bar represents the percentage of senior agents of all evacuee agents. If you choose "80," the number of senior agents is 80% of all the evacuee agents. Note that the number of senior agents is always rounded down if the theoretical number of senior agents is not an integer. For example, if you have 35 agents in B3F and the percentage of senior agent is 30%, the number of senior agents in the simulation will be 10 since the calculated number is 10.5.

4.1.3. Normalized Height (Senior) [%]

The fourth slide bar represents the normalized height of senior agents. As the name indicates, this value represents how tall an agent is if the height of 170 cm is set as 100%. However, this value also represents the normalized weight and normalized gripping power. Thus, this percentage indicates the senior agent's ability to evacuate compared with a normal (adult) agent.

4.1.4. Evacuation Starting Time [minutes]

With the fifth slide bar, you can change the starting time of the evacuation. For example, if you set it at 12, evacuee agents distributed along each floor start to evacuate after 12 minutes from the beginning of flood. Changing the evacuation starting time controls the severity of the evacuation.

4.1.5. Congestion Mode

The button at the sixth position from the top can control whether a simulation includes a congestion factor or not. When the congestion mode is selected in the simulation, walking speeds are modified based on the population density around an agent. As the density increases, the walking speed decreases.

4.1.6. Rope Strategy ("Base or Rope Strategy.model" only)

The "Base or Rope Strategy.model" has additional parameters on the control panel. The Rope Strategy button switches the strategies between Base and Rope Strategies. If the button is off, the simulation runs with the Base Strategy. If the button is on, all agents follow the Rope Strategy.

4.2. Running a Simulation

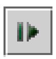
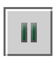
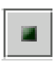
At the top of the main screen, you can see "Menu Bar" and "Run Panel." With this panel, you can start, run only one simulation step, pause, and stop the simulation. The command represented by each button is explained in Table 1. It consists of four buttons: Start, Single step, Pause, and Stop buttons. Click the Start button to start the simulation. By clicking the Single step button instead of the Start button, you can simulate only one simulation step, and the simulation is paused. The pause button allows you to temporally stop the simulation. You can restart the simulation from the paused point after pausing it. The Stop button is for ending the simulation; you cannot then restart the simulation.

After several seconds for compiling the code, the simulation starts. During the simulation, several new windows appear on the main screen as shown in Fig. 2. They are classified into three groups: simulation spaces, statistics at that point, and console. In the windows showing simulation spaces, you can see each agent's behavior in the simulation in real time. In statistics windows, some selected values for the simulation are plotted as time-series graphs. The meanings of the values are explained in Section

4.3. The console window displays verbal explanations of results and/or values which are requested to be printed in the code.

Table 1

Buttons in the Run Panel and their commands

Button	Name	Command
	Start button	Starts the simulation
	Single step button	Runs one simulation step and pauses the simulation
	Pause button	Pauses the simulation (You CAN restart the simulation from the point)
	Stop button	Stops the simulation (You CANNOT restart the simulation)

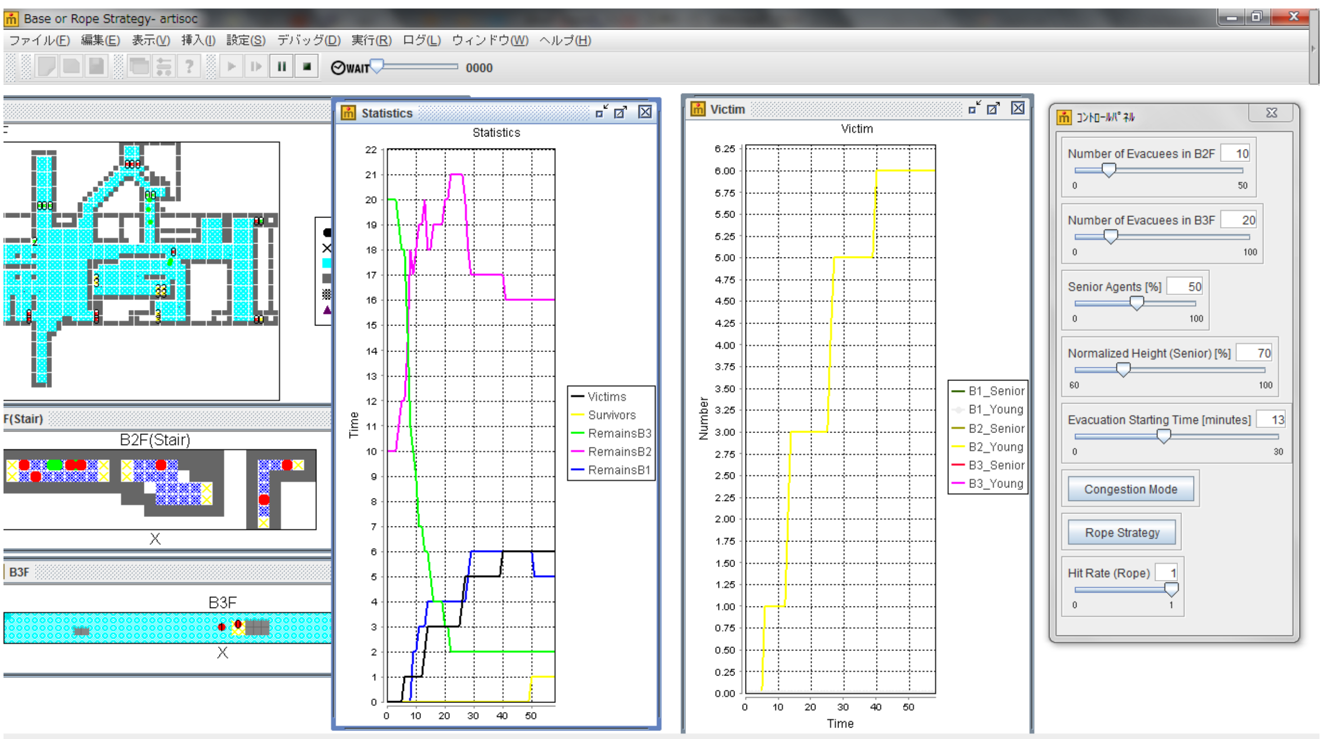


Fig. 2 Main screen with result windows and simulation spaces when a simulation is running

4.3. Outputs

During and after the simulation run, two windows for showing the findings appear. With the plots in the figures, you can view the overall results.

4.3.1. Values in "Statistics"

The graph entitled "Statistics" plots the numbers of survivors, total victims, and agents remaining on each floor. The vertical axis shows these numbers, while the horizontal axis the simulation steps. In the modeled simulation, each simulation step equals two seconds, so the horizontal axis represents time having the unit of "two seconds." For example, "30" in the horizontal axis means "60 seconds."

4.3.2. Values in "Victim"

The graph entitled "Victim" depicts the numbers of victims on each floor and the agent type. The values in the graph have names such as "Bi_Senior" or "Bi_Adult" for $i = 1,2,3$. The first part indicates the floor while the second part identifies the agent type. For example, "B2_Senior" represents the number of senior agents who fail to evacuate and are trapped in B2F (staircases).

ACKNOWLEDGMENT

The authors are thankful to Kozo-Keikaku Engineering Inc. for its permission to use the program artisoc academic 4.0. The authors also grateful for the assistance and flood data provided by Professor Keiichi Toda of Kyoto University.

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