

Simulation of Debris Flow Disaster Evacuation of Hillside Community Using the AnyLogic Software

Simulation of debris flow disaster evacuation

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Abstract—The more obvious global warming in past years has resulted in climate changes. Located in circum-Pacific earthquake zone, lots of earthquakes often result in landslides. Moreover, the island climate, greenhouse effect, and climate abnormality cause frequent heavy rainfall and rainstorm for disasters of debris flow, landslide, and earth slide on hillsides. In face of natural disasters and the introspection after disaster relief movement, the arrangement of evacuation programs, in consideration of safety and promptness, becomes one of important research issues. In this study, AnyLogic is applied to simulate pedestrian dynamics for assisting in the dynamic simulation of debris flow evacuation of hillside communities, and the simulation results are used for discussing the appropriateness of the evacuation plan. The result reveals that, as the example of Yuanquan Village, Ershui Town, Changhua County in Taiwan, it takes about 15min for protected targets evacuating from dangerous areas to the shelter, which is about the same as the actual debris flow prevention drill in the community.

Keywords—*debris flow disaster evacuation; hillside community; AnyLogic*

I. INTRODUCTION

Typhoon Morakot seriously attacked central and southern Taiwan in August, 2009 [1]. The weird route and long stay of Typhoon Morakot and the influence of southwesterly flow resulted in large amount of torrential rain and major disasters. According to the preliminary statistics of Water Resources Agency [2], the rainfall caused by Typhoon Morakot approached several world extreme records. Besides, the single-day rainfall of Typhoon Morakot was ranked on the top in past years. Due to the climate change resulted from global warming, similar events would possibly occur in the future. During Typhoon Morakot, the entire island was attacked by the rainstorm. Such long-delay, high-strength, and broad-area rainfall could result in various types of disasters, including flood, shallow landslide, debris flow, deep earth slide, and dammed lake [3]. When Geology Act was passed, areas with suspected geologic disasters would be announced as geology sensitive areas. The safety evaluation of hillsides communities would become the primary research direction in the future.

To cope with changes of climate and natural environment in the future, a lot of thinking models need to be adjusted. It is urgent to study the evacuation points or routes around areas with frequent disasters. Yuanquan Village, Ershui Town, Changhua County, is selected as the research object in this

study for collecting relevant community evacuation plans [4]. Besides, aiming at evacuation routes for protected parties, the AnyLogic software is utilized for the dynamic simulation of pedestrian dynamics to evaluate the existing evacuation points and routes. In the future, the evacuation mechanism and disaster prevention model could be further studied for providing actual assistance for relevant units.

II. RESEARCH METHODS

The AnyLogic software, mainly used in this study, presents four famous modeling methods of (1) system dynamics, (2) discrete event simulation, (3) agent-based modeling, and (4) pedestrian dynamics [5-7]. Being one of the commonest simulation tools, the unique flexibility of modeling language of AnyLogic allows users capture complex dynamic systems. The graph interface, tool, and object library allow users rapidly modeling in various fields, e.g. manufacturing and logistics, business process, human resource, and consumer or patient behaviors. AnyLogic supported model design samples are large models with modular, hierarchical, and digital structure.

AnyLogic, the unique simulation software, is based on the latest complex system design methodology, the first tool introducing UML language into model simulation, and the only commercial software supporting mixed-state machine, which could effectively describe evacuation and continuous behavioral language. Meanwhile, it presents broad application on evacuation, continuity, mixed system modeling, and simulation tool, including control system, transportation, dynamic system, manufacturing, supply line, logistic department, telecommunication, network, computer system, machinery, chemical industry, sewage treatment, military, education, evacuation, and disaster prevention [8,9].

III. RESULTS AND DISCUSSIONS

A. Study Area

Ershui Town is located in the south part of Changhua County, with Baguashan as the boundary with Mingjian Town and Chushan Township in Nantou County on the northeast, Zhuoshui River as the boundary with Linnei Town in Yunlin County on the south, Xizhou Town on the west, and Tienzhong Township on the north. It is on the southwest end of Baguashan that there is Baguashan on the north and Zhuoshui River on the south, with narrow plain (Figure 1). There are 6 potential debris

flow torrents in Ershui Town, distributing in Dayuan Village, Yuanquan Village, and Changhe Village. It is easily resulted in natural disasters of erosion, landslide, earth slide, and debris

flow, when there is torrential rain with typhoons, to cause traffic disruption and serious damage on residents' life, property, and public facilities.

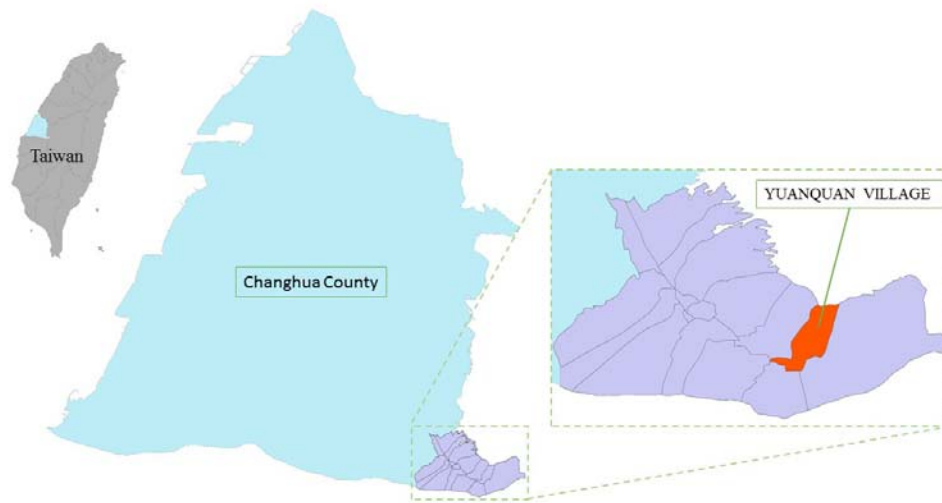


FIGURE I. GEOGRAPHIC POSITION OF YUANQUAN VILLAGE.

B. Simulated Results

1) Modeling

a) Importing the satellite aerial photograph of Yuanquan Village, as the base map, into AnyLogic and zooming to the correct proportion, the base map is used for drawing the simulation area for modeling.

b) The simulation area is selected with the “wall line” function, and pedestrian activity areas are restricted according to current conditions.

c) The house exists of protected parties are established “pedestrian exit”, and the shelter (Yuanquan Elementary School) is established “end of pedestrian” (Figure 2).

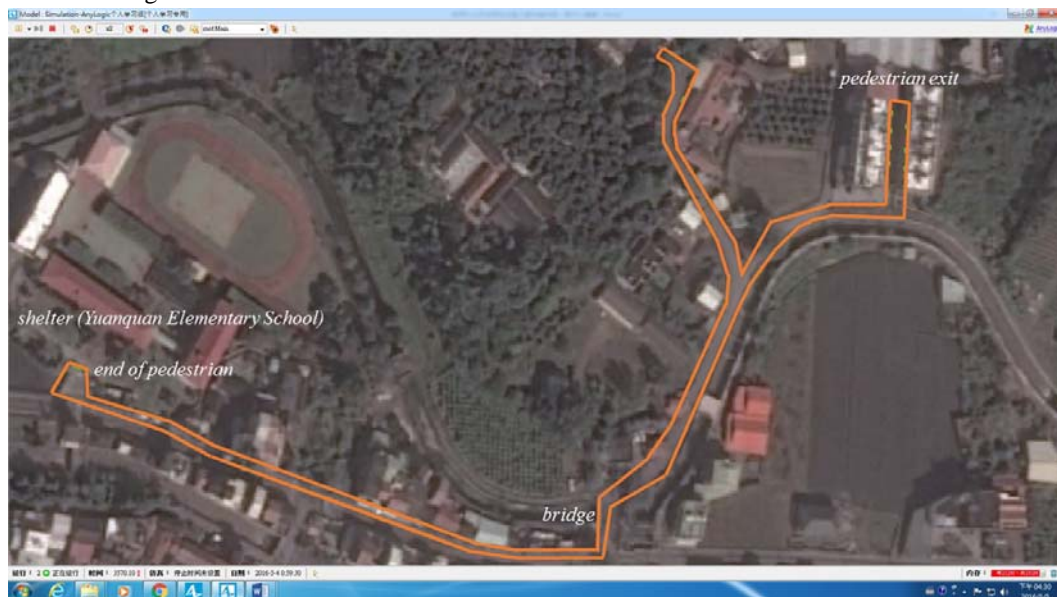


FIGURE II. SHELTER MAP.

d) The time for pedestrians and the number of people are set with “time table” of the program.

e) The house locations of protected parties are established connection with “time table.”

2) *Simulation condition:* Basic data of addresses and households of protected parties in Yuanquan Village are investigated as the parameters of pedestrian dynamics simulation. It is set that protected parties would evacuate to

Yuanquan Elementary School when there is a disaster. The survey results reveal that there are total 26 people in 7 households, as the protected parties, in Yuanquan Village.

3) Simulation results

a) Simulation I: Under normal situation, the changes of evacuation at various time points are simulated. In the first 1 minute, all protected parties leave the houses. The community exit becomes crowded 1'35" after the simulation. The residents gradually move to the crossroads 2'36" after the simulation when pedestrians appear different walking speed in the evacuation process; those moving out latter appear slight push. The crowded residents gradually show their own speed 5' after the simulation; the front-end people reach a half way, while the backend people are still around Yuanquan Village activity center 5'45" after the simulation. The backend people gradually cross the 6'43" after the simulation. The front-end people reaches the shelter (Yuanquan Elementary School) 7'42" after the simulation, while some people arrive at the shelter (Yuanquan Elementary School) 8'18" after the simulation, the last part of people arrives the shelter (Yuanquan Elementary School) entrance 13'33", and the last person enters the shelter (Yuanquan Elementary School) 14'17" after the simulation. In this simulation, no special crowding appears, and all people enter the shelter 14'17" after the simulation.

b) Simulation II: The changes at various time points are simulated under the same situation, but events, e.g. tree collapse next to the bridge to narrow the road, are included to compare the difference. It is observed in this simulation that slight push appears on the narrowed road, but the evacuation speed do not show large changes. All protected parties complete the evacuation for 14'23", about 6" slower.

c) Simulation III: Since there is no significant difference in simulation II, tree collapse next to the bridge and serious flood on the road to reduce large area of the road are simulated under the same situation for the change comparison. The simulation results reveal some push on the narrowed road. Although a large area of the road is reduced, people do not slow down. The last resident is merely 12" latter than the one in simulation I, and the evacuation of all residents is completed at 14'29". Apparently, people would self-adjust the

team when encountering obstacles. There is no significant effect on entering the evacuation road sequentially.

d) Simulation IV: As the previous simulations do not appear large differences, the number of evacuation people is increased 10 times for the simulation with large difference in the number of people. It is to observe whether the number of people is the factor. The evacuation residents obvious appear push behaviors 1'31" after the simulation. The front-end residents rapidly leave 3'03" after the simulation, while the back still show push situation. The first resident arrives at the shelter (Yuanquan Elementary School) 7'45" after the simulation, and the last resident arrives 18'07" after the simulation. This simulation shows 10 times difference in the number of people, but merely 3'50" is taken more than it in simulation I.

e) Simulation V: Based on simulation IV and with the same conditions as in simulation III, it aims to discuss whether obstacles would result in obvious time difference when there are more people. Similar to simulation IV, the front-end people does not change much of the speed, while the backend residents appear obvious differences. It increases 3 minutes, in comparison with it in simulation IV.

C. Discussions

In this simulation, it is observed that slight push would appear in the movement, when the number of people is not many, but the overall movement is rather smooth. When obstacles are added, human behaviors would be influenced, but would not show serious delay. Instead, people would sequentially enter the road entrance when there are obstacles. It is different from vehicles that people would not be immediately affected by narrowed road. In this case, narrow roads would not appear large influence when the number of people is not many.

Meanwhile, in order to observe the effect of the number of people, all units are adjusted 10 times number of people. The time for simulation I (normal number of people without obstacles) and simulation IV (10 times number of people without obstacles) appears 3'50" difference. In simulation IV (10 times number of people without obstacles) and simulation V (10 times number of people with obstacles), merely 2'31" in increased. Apparently, obstacles would not appear too much influence on the evacuation time when the number of people does not reach certain degree (Table 1).

TABLE I. ARRIVAL TIME FOR VARIOUS SIMULATIONS

Description	Simulation I	Simulation II	Simulation III	Simulation IV	Simulation V
First arrival	7'42"	7'45"	7'45"	7'45"	7'45"
Final arrival	14'17"	14'23"	14'29"	18'07"	20'38"
Simulation condition	26 residents	26 residents, tree collapse	26 residents, tree collapse, road flooding	260 residents	260 residents, tree collapse, road flooding

The simulation result in Yuanquan Village is about consistent to the actual debris flow disaster prevention evacuation drill in Yuanquan Village. The future disaster plan could refer to the simulation to reduce the mobilization of large manpower and objects [10].

IV. CONCLUSIONS

This study attempts to apply the pedestrian dynamics model in the AnyLogic software to simulate the evacuation routes for protected parties around potential debris flow

torrents. According to the simulation, both indoor space and outdoor large space could be operated with the software. Besides, the settings of “time table” and “target line” in the software could simulate whether evacuation units and rescue units could have different circulation on the same road; even the time could be arranged to avoid conflict on the single road. Under the complete function of AnyLogic, the CAD and GIS layers could be imported for the simulation. Meanwhile, large scale evacuation or multi-variables could be simulated for more simulation conditions and more changes. The simulation with the software could assist actual evacuation drills in planning. Virtual Reality (VR) could be further integrated for people experiencing the disaster prevention drill effect.

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