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# RESEARCH FOR PEOPLE EVACUATION BEHAVIORS IN LARGE-SCALE BUILDING BY USING COMPUTER SIMULATION SOFTWARE

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**Abstract:**
The safety issue is always being popular topic for the building construction, especially with large-scale building. For example, how to lead the people accurately to reach the safe and appropriate emergency exit in time in the large-scale building, and to prevent the great injuries and deaths. Therefore, it has become an urgent subject to the government to design 2D computer simulation software of dynamical evacuation route with using the C# (C Sharp Program Language) for understanding the necessary time for people fleeing from a fire within the large-scale building. This study mainly applied two steps including 2D computer simulation software to build and construct 3D virtual reality; and then to carry on the 3D virtual reality testing and questionnaire investigation. The finding of this research can ensure all people reach the emergency exit in time in every floor safely, and meanwhile reduce the time and being out the building. The result of this study is intended to provide the appropriate management model in safety system.

*Keyword: Evacuation Behaviours, Large-Scale Building, Computer Simulation Software*

## 1. MOTIVATION AND PURPOSE

According to the statistics data [1] of National Fire Agency, Ministry of The Interior from 1997 to 2012, there are 385-1,069 people injured or died in the fire accident per year in Taiwan. The number of the fire disaster happened is larger than the nature disaster; from 1997 to 2012, the nature disaster is happened 143 times, the fire disaster is happened 129,663 times. Therefore, the rate of the number of the building fire happened is 32.7% - 76.1% to all kinds of fire happened in whole year. The number of building fire happened is the first place in all kinds of fire. Hence people should understand the seriousness of the fire, and how to save oneself, how to ensure personnel security within the building, those are important issues which people and government should face it.

Learned from the relevant research report or documents materials, when the fire happened, people would lose the judgement, discrimination and analysis abilities [2]. Even the electric system of building can function normally in the fire, people still feel panic and helpless. Because people could not familiar with the routes of escape, the direction of escape and emergency exits within the building. The worst situation is that the electric system break down suddenly, people must be looking for exits in the dark situation and could be attacked by the high temperature flame or dark smoke, it would make serious calamity.

Most of the public building are quite strange to people such as amusement park, theatre, shopping mall, restaurant and underground shopping street, where people could not visit every day. It is one reason to make people fatal harm when they try to evacuate [3] if the fire happened. The second reason is that the routes of escape in most of public building are complicated or the guide signboard of escape are too little to find or too small to read. In this research, using C Shape (C #) program to construct 3D virtual reality and inviting general people to participate in this experiment, it would try to understand and analyze the evacuation behavior of people in the building as a puzzle, would try to shorten the time people reach the emergency exit and would try to raise the success probability of fleeing and evacuating.

## 2. DOCUMENTS REVIEWING

The route map of emergency evacuation should be put up on all the public building according to the current regulations [4]. When the urgent accident happened, the map should have function to guide people reaching to the safe place (such as staircase, emergency staircase) or the ground story. In normal situation, perhaps the route map could have function for general people within the building non on fire. When people within the fire building, it is too difficult to require people memorizing or understanding the direction and content on the route map of emergency evacuation. Additionally, in a large-scale public building, the floor is large, the route is complicated, and the purpose of facilities using is complicated also. When fire happened, it cannot be accurately known which floor or room got fired. If the fire had spread on the route of emergency evacuation, it would be dangerous to require people following the instruction of the route map in fact.

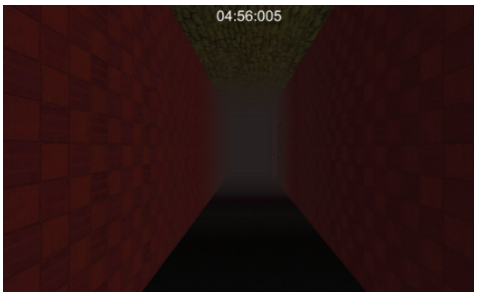
Learned from the relevant documents and materials, when the large-scale building got fire happened, people usually have those behaviors such as following behavior, looking for the known routes and exits [5~12]. Therefore large quantities of people gather to a few emergency exits in short time, then jammed, ran back, and stopped up situations happened. Finally it is no enough time to escape, people lie down at a few emergency exits [13, 14]. In fact, in order to evacuate a large number of people in short time, there are many exits set up in the large-scale building in each floor. Because of inappropriate and ineffective guidance and instruction, only a few people pass some emergency exits, some emergency exits no one pass [15, 16].

## 3. RESEARCH METHOD

There is no proper software which can fit the need to this research on market at present. So this research builds and constructs 3D virtual reality simulation software. Moreover, in order to imitate real fire situation and increase the sense of the tester, this research uses the first-person perspective to create different fire situation by virtual reality technology. There are three steps to build the simulation software: (1) using 3D graphic application to construct a model, (2) importing the model to interactive dynamic editing application to construct different fire situations, (3) testing, and then to upload and retrieve all the data materials after finishing tests.

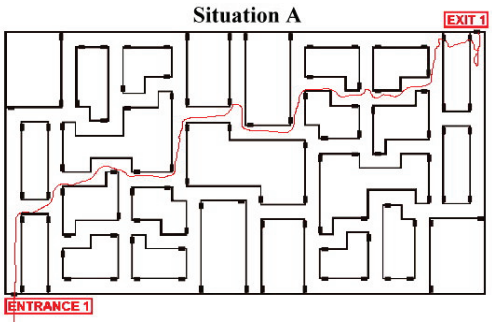
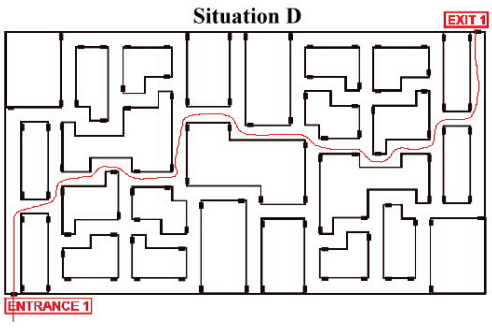
This research selects 3ds Max to build a 3D model. For convenience of constructing software, for applying to other hardware, for crossing different platform smoothly, and for integrating with other system, this research selects Unity3D as interactive dynamic editing engine. There are four smog situations set up in this research. Situation A and B are initial fire (or floors not on fire), smog is less within building. Situation C and D are dim situations, simulate smoke spreading within building after fire happened. Shown in Picture 1.

**Picture 1:** Different smog situation set up in virtual reality of simulation software

| | |
|---|---|
|   |   |
| Bright | Dim |

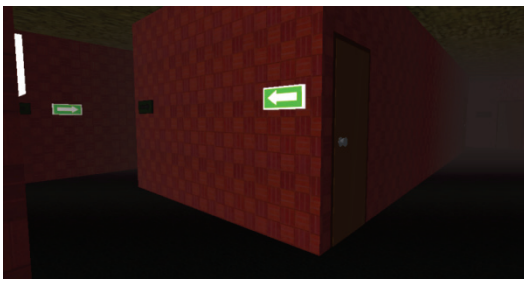
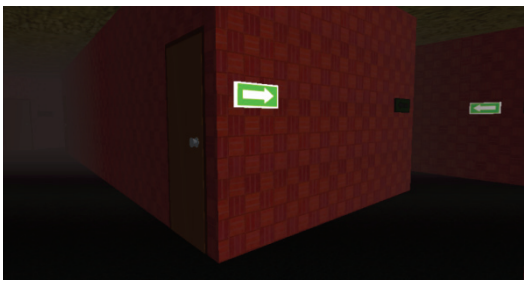
While tester is moving in the virtual reality, the computer would automatically record coordinates and mark the position of tester, and temporarily store the value in the storing device. After finishing the test, the computer system would connect all the points and completely show the picture of moving trace of tester. Shown in Picture 2.

**Picture 2:** Moving trace of tester in situation

| | |
|---|---|
|   |   |
| Moving trace of tester in situation A | Moving trace of tester in situation D |

In the situation B and D, there are continuously flashing direction lights installed in the shortest evacuation route from “entrance” to “exit”. The purpose of installing the direction lights is to guide tester entering the shortest evacuation route. The height and the indicated direction of lights is shown in Picture 3.

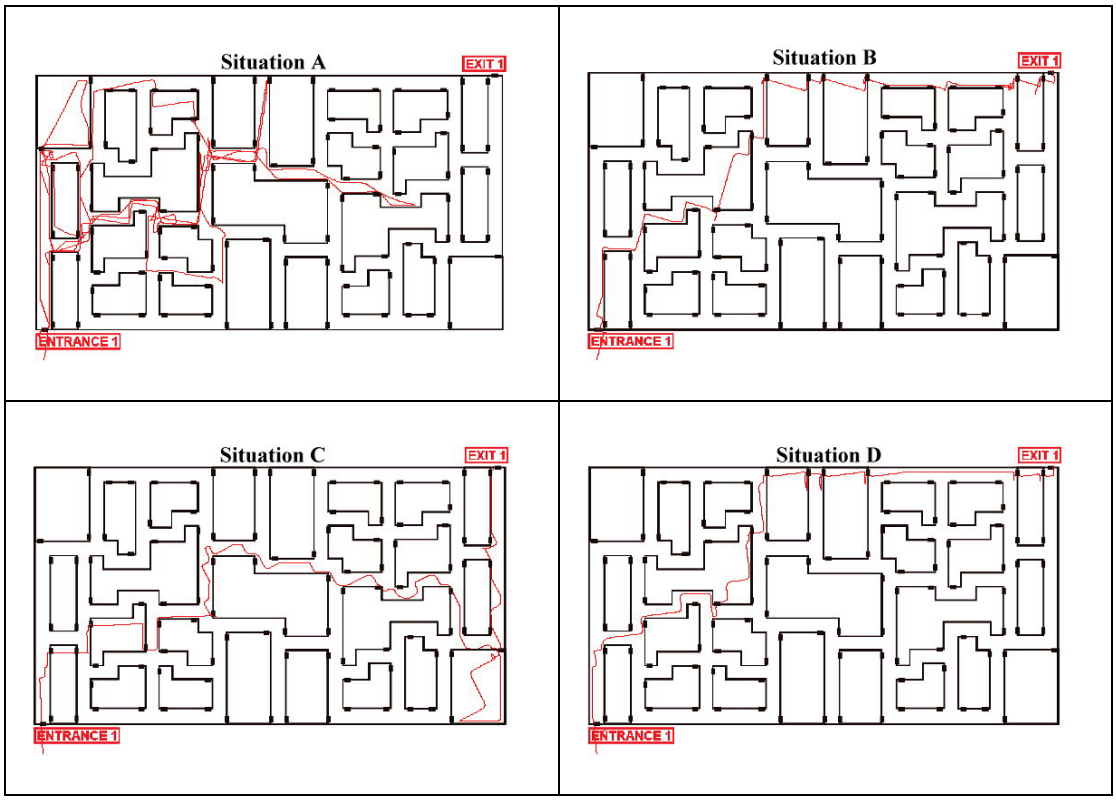
**Picture 3:** Direction lights install in the situation

| | |
|---|---|
|  |  |
| The light guide to turn left then right | The light guide to turn right then left |

## 4. RESULTS

All testers will take four kinds of simulation situations, the serial number is A, B, C and D. The bright and flashing direction lights are only set up in situation B and situation D, which guide tester to take the shortest route and to arrive “exit” quickly. The moving trace of tester would be recorded completely on “picture of moving trace”. The picture of moving trace of the tester’s number “0ANLP5” is shown in Picture 4.

**Picture 4:** The picture of moving trace of the tester’s number “0ANLP5”




There are totally 296 testers finishing this experiment. All testers start from situation A to B, C and D orderly (means A→B→C→D). The tester start timing from “entrance” until arriving “exit” in each situation. If the moving time of tester ≧ 300 sec, the evacuation situation is judged failure. In contrast, if the moving time of tester < 300 sec, the evacuation situation is judged success. Before taking test in each situation, the tester is required to read the virtual reality plan map of emergency evacuation. After starting test in each situation, no plan map of evacuation is offered.

All test materials of testers are recorded according to each situation. The percentage is the number of testers in each situation to all testers. The percentage of success and failure of testers in each situation is shown in Table 1.

**Table 1:** The percentage (%) of success or failure of testers in each situation

| Conditions | Situation | A | B | C | D |
|---|---|---|---|---|---|
| | Light | Bright and no direction light | Bright and have direction light | Dim and no direction light | Dim and have direction light |
| Success | yes | 86% | 98% | 96% | 100% |
| | no | 14% | 2% | 4% | 0% |

A. The influence of strange environments on people escaping

All testers are the first time to take 3D virtual reality simulation test and to read the virtual reality plan map of evacuation. Under the condition of counting time, after reading the plan map, testers with temporary memory have to take the test immediately. The map is not offered when tester starts testing. There are no direction lights in situation A and situation C, therefore 14% testers in situation A cannot escape from the fire situation during the limited time.

B. The influence of cumulative experience on people escaping

The percentage of success of testers in situation C can be up to 96%, because testers read plan map of building many times and cumulative experience (testers had tested situation A and B), even there is no direction lights in situation C. Therefore, tester can escape from the fire building if they memorize the “entrance” and “exit” two relative positions and the evacuation route plan map of building.

C. The influence of direction lights on people escaping

The percentage of success in situation D is up to 100%, perhaps the direction lights play an important role in the fire situation. Learned from data of picture of moving trace, the situations with direction lights (situation B and situation D) are better than the situation A and situation C. Taking situation D as an example, more testers realize the direction lights can help themselves to arrive “exit” rapidly, so most of testers follow the direction lights reaching to “exit”.

D. The influence of familiarizing with the evacuation route within building on people escaping

Besides the direction lights, to be familiar with the evacuation route map of building could also help people escaping. Known from data in Table1, situation C and situation D (under the dim condition) are better than situation A and situation B (under the bright condition). Therefore, even testers are in the dim situation, because they are familiar with the route map of emergency evacuation, it can improve the probability of success of evacuation.

## 5. CONCLUSION AND SUGGESTION

People have to contest with the speed of high temperature flam spreading and thick smog dropping, when the building got fire. No matter which floor on or not on fire, people need to arrive “exit” right away. Learned from the results of this research, the current existing route map of emergency evacuation cannot effectively guide people arriving “exit”, when people are in strange environment. In order to decrease the casualties of fire, government should educate people the correct concepts and methods of evacuation. Through training and educating, it can improve people evacuation security by making people familiar with the compartment, facilities and evacuation route of building.

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