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Validation of advanced evacuation analysis on passenger ships using experimental scenario and data of full-scale evacuation

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ABSTRACT

Evacuation analysis, which calculates the total evacuation time should be fulfilled for all passenger ships. One of the ways to calculate evacuation time is to use the computer simulation, which models various effects of human behaviors in an emergency situation. In the previous research, SIMPEV (SIMulation system for Passenger EVacuation) was developed for the evacuation analysis based on the latest human behavior algorithms. It has already showed that SIMPEV basically satisfied the eleven test cases suggested in International Maritime Organization (IMO) Maritime Safety Committee (MSC)'s Circulation 1238. The main focus of this paper is the validation of SIMPEV by using "SAFEGUARD Validation Data Set 1 and 2", which performed real evacuation trials in two full-scale ships to compare simulation data with experimental data. Total evacuation time is computed by SIMPEV based on the validation data sets such as drawings, initial distributions and end locations. The results from 50 times simulation are analyzed to be compared with the experimental data in the statistical methods. From the results, it is found that SIMPEV satisfies the acceptance criteria for each of data sets. Furthermore, the results show a close similarity to those of the other simulation programs.

1. Introduction

There have been numerous efforts to improve the safety in passenger ships, especially in extremely emergency situations, such as fires and floods. Among such efforts is the evacuation analysis in accordance with the International Maritime Organization (IMO) Maritime Safety Committee (MSC)'s Circulation 1238, "Guidelines for Evacuation Analysis for New and Existing Passenger Ships" [1], which gives guidelines with regard to the total evacuation time. Evacuation analysis is classified into two methods: simplified evacuation analysis and advanced evacuation analysis. In the former, the total evacuation time is calculated using the empirical equations given by the rule, and in the latter, the time is estimated through computer simulation. Some research institutes recently developed computer programs for advanced evacuation analysis, and among such programs is the SIMPEV software developed by DSME and SNU (Seoul National University) [2,3].

Several algorithms and assumptions are necessary to reflect human behavior in computer simulation when the passengers are moving toward the designated assembly stations through the corridors. For example, each of the passengers has to find its way to an assembly station without being stuck in or penetrating any wall. The passengers should have their own speed according to their age and gender. Group behavior, which means that the passengers get together and follow the leader, should also be considered.

IMO MSC/Circ. 1238 suggests 11 test cases for the validation of advanced evacuation analysis software, but as these are mainly unit function tests in simple compartments, even though a program satisfies all the test cases, the total evacuation time estimated by the program could be different from the real evacuation situation. Therefore, to obtain real evacuation data, evacuation trials in two full-scale ships were carried out by the SAFEGUARD project [4]. From the trials, validation datasets were obtained for the validation and calibration of evacuation analysis software.

The rest of this paper is organized as follows. Chapter 2 provides a brief review of the algorithms and the simulation procedure implemented in SIMPEV. The purpose and main results of the SAFEGUARD project are summarized in chapter 3. The results of the simulation and validation of SIMPEV as applied to the datasets

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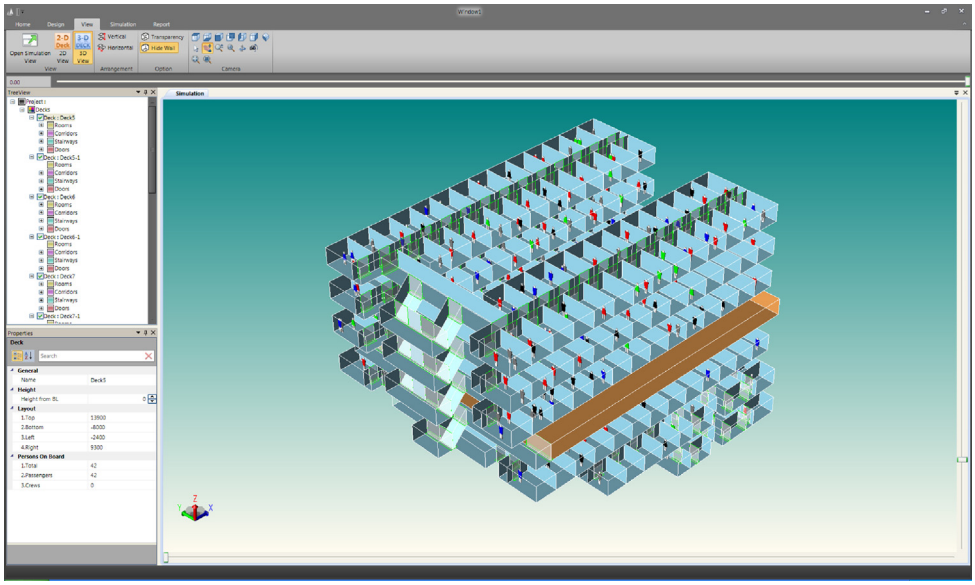

Fig. 1. Main view of SIMPEV.

from the SAFEGUARD project are presented in chapters 4 and 5. Finally, the conclusions of this paper, which are based on the validation results presented in chapter 6, are given in chapter 7.

2. SIMPEV – integrated system for advanced evacuation analysis on passenger ships

SIMPEV contains many convenient functionalities and user-friendly GUIs (graphic user interfaces). The main view of SIMPEV is shown in Fig. 1.

2.1. Algorithm

To describe the human movement around and inside the compartments of a passenger ship, several behavior models for each passenger or group are implemented in SIMPEV. The main algorithms used in SIMPEV are listed in Table 1. More detailed information about the algorithms could be found in Roh et al. [3] and Cho [5].

It is assumed that a human model will choose the shortest-distance route from its start location to its destination as its escape route. As the basic walking direction is assigned in the grids, the human model can find its escape route easily. Then, due to the nearby passengers, the basic walking direction is modified by crowd behavior algorithms such as the flocking, leader-following, and counterflow algorithms. The flocking and counterflow algorithms are affected by the other human models around a particular human model, regardless of such models' destinations. On the other hand, the leader-following algorithm is affected only by the other human models moving toward the same destination.

Table 1
Algorithms implemented in SIMPEV.

	Algorithm
Behavior model	Velocity-based model
Geometry representation	Basic walking direction grid by visibility graph
Movement model	Inter-person distance (flocking algorithm)
Leader-following behavior	Leader-following algorithm
Counterflow-avoiding behavior	Counterflow algorithm

2.2. Simulation procedure of evacuation analysis

The simulation procedure of the evacuation analysis with SIMPEV is shown in Fig. 2.

- Modeling (Fig. 2-(1)): the compartments of a passenger ship generally consist of public spaces, service spaces, and cabins. All the passengers and crew members are made to stay in these spaces when the simulation is initiated. These spaces are modeled as rooms. The passages, such as the corridors and stairways, are defined as among the spaces that the passengers and crew members can use to find their way to the destination space called *assembly station*. If there are CAD files of the decks, these can be used as background images.
- Initial distribution (Fig. 2-(2)): according to the day or night evacuation scenario, which is assigned before the simulation, the passengers and crew members are distributed to the public spaces, service spaces, and cabins. Each of the rooms has its designated assembly station, toward which the passengers and crew members distributed in the room are supported to move when they evacuate.
- Running simulation (Fig. 2-(3)): according to IMO MSC/Circ. 1238, a minimum of 50 different cases should be simulated for each case. These cases should be made up of 10 different randomly generated populations, and there should be five repetitions for each population distribution.
- Result (Fig. 2-(4)): from the 50 simulations, the total evacuation time and the longest pass are obtained.

2.3. Modeling of passenger and crew

The walking speed of each passenger is defined in IMO MSC/Circ. 1238 [1] according to its age and gender. Different body colors and shapes are assigned to the passengers and crews, as shown in Fig. 3 and Table 2.

2.4. Verification of SIMPEV through IMO tests

To verify the algorithms, the tests are provided in IMO MSC/Circ. 1238 [1] Annex 3. The tests include that for checking if the various components of the program perform as intended. This