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Agent-based Modeling of Crowd Dynamics on a Moving Platform

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Abstract
This paper proposes a mathematical model and a computational approach applied to the study of the interaction between a moving platform and pedestrians walking on it. A ship deck motion used as a basic scenario for simulation is realized in three modes reproducing heaving, pitching or rolling rotations of the vessel. Behavior of virtual passengers is emulated by the Social Force pedestrian model modified with additional forces. In this paper the mathematical definitions of both models and their software implementations are discussed. The results of the experiments reproducing various combinations of characteristics of the ship motion are presented and compared with a case where it remained stationary. The paper is concluded with an analysis of the simulation results and perspectives for further research.
Keywords: agent-based modeling, crowd simulation, moving platform

1 Introduction & Related works

The problems of moving and tilted environments and their interactions with human beings have been in focus of researchers and practitioners in various fields for quite a long time. However, it was not until recently that specialists received tools and access to robust data in order to quantify and model the observed effects. Today, several fields of research could be identified where these problems receive significant attention: marine engineering and safety studies; civil engineering (design of residential constructions and footbridges); aircraft design and evacuation studies; railroad evacuation and carriage design.

In the domain of sea craft engineering and safety, one of the key issues is to analyze the effects that normal and extreme accelerations of the craft have upon the crew of the vessel and passengers (in cases of the civil fleet research). The exposure of the crew to vessel motion is investigated from the perspective of member's ability to maintain postural stability, perform key activities without stopping (due to the so-called Motion Induced Interruptions [1]) and withstand associated factors such as

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motion-induced fatigue [2] that may result in an increased number of accidents onboard the ship. The analysis of the secondary data (namely, reports of the actual accidents that took place, for instance, as in [3]) that was, for a long time, a predominant technique, has been recently complimented by the introduction of advanced sensors [4], experiments [5] [6] and modelling [7]. Recent studies have as well incorporated the use of interviewing for studying long-term adaptation to the aforementioned effects and assessing the role of additional factors, such as vibrations and noise [8].

Investigation of the ship motion-related effects on the behavior of passengers predominantly focuses on the evacuation process. Up to date there has been a large number of works dedicated to experimental studies of the evacuation process from ships [9] [10] [11]. Existing research vary in scale and initial conditions, but as Kim et al [12] and [13] illustrates, they partially agree on the dynamics of change of the mean individual walking speed and other factors relevant to evacuation dynamics. However, only a modest proportion of such studies actually takes into account various factors associated with crowd behavior (particularly, they are addressed in [10]).

Building upon the experimental data and real-world observations, researchers in the field of marine engineering and safety develop evacuation simulators in order to conduct cost-effective full-scale tests to be run at the early stages of ship and evacuation strategies design. The algorithms for simulating the evacuation of passengers from ships are transferred from the relevant research dealing with the evacuation from the stationary constructions. To our knowledge, it was not until 1998 that computational models started to take into account ship motion and tilt angles when simulating human behavior on board sea and ocean crafts [14]. Nowadays quite a few models incorporate ship motion and inclination modules into the simulation of ship evacuation.

In Kostas et al [15] a similar differentiation-based ship motion model is used, but it has fewer components, compared to the one described in this paper: it lacks Coriolis Force and the vertical acceleration of the ship – heave both realized in the model described here. The pedestrian model described therein resembles the RVO model, which has not been stated directly in the paper – it does not distinguish between obstacles and other agents and it is found to be less realistic compared to the Social Force pedestrian model. At the same time, it is more complicated on the side of different types of group aligning behavior accounted for and contextual embeddedness of the behavioral rules that agents follow. Pennycot and Hifi [16] in their paper focus the attention on the evacuation procedures in extreme conditions – where critical inclination angles (with the resulting stabilization of agents posture being considered) of the ship and fire are simulated as potential threats to the passengers. It is designed specifically for risk evaluation in different scenarios: one of the components of the system is represented by the outline of the ship with a route graph connecting the initial locations of the passengers, cabins, doors, passages, exits etc. In this sense, the scope of application of the model described here is somewhat broader as simulation modules are context-independent thus can be easily extended with additional models of hazards like it has been illustrated in [17] [18]. The evacuation model coupled with ship motion dynamics described in [19] is based on cellular automata for reproducing the movements of passengers aboard the ship. Though the proposed approach is more effective from the performance point of view – it has significant limitations on the realism side [20], which shall be taken into account when plausibility of simulation results is of higher priority than processing speed.

It has been found that studies accounting for evacuation process from the angled passenger vehicles [21] in accidents are very similar to the ones conducted in the field of ship motion-induced effects on passengers and the crew. However, after a closer examination, it became obvious that in the field of railroad evacuation the characteristics of the moving carriage is of little interest – the accent is shifted towards the changes in navigation that angled and unfamiliar environment brings into the process of evacuation.

In the field of civil engineering, the interest towards the effects that the motions of the environment have upon human beings is concentrated on such issues as physical interaction between pedestrians and the man-made infrastructural objects they are walking across (and particularly, synchronization