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RESEARCH ARTICLE

# Agent-based simulation of alternative classroom evacuation scenarios

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**Abstract**
Due to the growing number of emergency accidents occurring around students, evacuation issues have become significantly important for both school officials and architects. Simply following construction codes cannot ensure that a building's layout is suitable for evacuation behaviors; therefore, to discover the suitable planning schemes, we have introduced an agent-based simulation model via Netlogo to investigate the interrelationships between evacuation efficiency and classroom layouts. Before conducting modeling experiments, both the simulation structure and the sensitivity to its parameter settings are examined by validation research and sensitivity analysis. Furthermore, to demonstrate the importance of conducting fire drills with students, two different types of behavior rules are designed to reflect the distinctive characteristics of students evacuating without instructions and students evacuating in good order. The general comparison results show us that the classroom layout with two exits shortens students' evacuation time, and the premeditated behavior rules, meaning that students who follow preset instructions to arrange their activities, not only escape faster but also have some advantages in ensuring their safety during the evacuation process. Moreover, at the end of this paper, several methods of improving this simulation model are proposed for more complex research in the future.


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## 1. Introduction

Effectively organizing evacuation routes inside buildings, especially densely populated buildings such as theaters or schools, is always one of the most important aspects architects take into consideration during the design process. However, due to limited knowledge of human's behavior, architects usually create these evacuation designs from pure statistics instead of their practical usage. Therefore, as long as the critical statistics of the planning layout meet the demand of the construction codes, the planning scheme will be automatically identified as a qualified design by law. This type of static evaluation method can hardly tell the difference among all of the alternative designs in terms of safety, so it is unable to help us to select the most appropriate planning schemes for the building. Although some researchers would let people actually participate in evacuation tests and compare their results to determine which layouts could best facilitate building evacuation, this method cannot be considered good for evaluating performance. After all, exposing people to real emergency situations can be both time-consuming and dangerous; and applying such a complex research method in a small-scale design project is not very cost effective (Almeida et al., 2012; Camillen et al., 2009).

Therefore, to quickly assess their safety performance, other controllable alternatives should be taken into consideration, among which simulation models are the most commonly used. As previous research shows, the main operational mechanisms in traditional simulation models describe people's evacuation behaviors through a set of differential equations, assuming that they are completely homogeneous to reduce the calculation difficulty. One of the obvious drawbacks for this approach is that the idealized environment settings cannot fully reflect the dynamic characteristics of people's evacuation behaviors in the real world, which may cause some deviations in the analysis results. Fortunately, with the improving theory of complex system and computer technology, we are able to show these heterogeneous and dynamic characteristics through agent-based modeling (ABM) techniques (Steven and Volker, 2011). The basic principle of this research method is to establish a series of behavior rules for the agents based on real world experiences and to let them interact freely with each other and the virtual environment. As a result, unlike traditional models, the evacuating behaviors in this model are mainly driven by the dynamic interactions between agents and their environment, not just some pre-arranged rules.

Our particular interest in this paper is the case of a middle school teaming with young students. Because these juveniles have limited capacities to escape and that the classroom is the most densely populated place in the school, designing an appropriate education space should be the initial task for the architects. Therefore, the main focus of this paper is to use Netlogo, a popular ABM (Agent-Based Modeling) tool, to create simulation models for two different types of classroom layouts and to compare their evacuation performances from various angles. In addition, to demonstrate the importance of fire drills, we design the premeditated behavior rules based on the reaction patterns in the real world after people have received fire drill training, and compare its performances to the non-trained (self-organized) scenario to see whether it can help students escape from the classroom more quickly and more safely.

## 2. Related works

Integrating evacuation research with ABM techniques requires us to have a detailed understanding of people's decision-making mechanisms and transform them into computer programming languages. It is not easy to transform people's highly abstract psychological activities into logical relationships that can be recognized by computers. Therefore, many research efforts have been devoted to combining sociology and computer science to set up the simulation models.

According to the research of Craig, (1987), those collective patterns of motion that we have seen in evacuation processes, such as clogging or arching, are mainly driven by the "social force" and they are closely connected to individualistic and herding behaviors. Similarly, Colin and Tony (2005) have established a crowded evacuation model to investigate the interrelationships between the power of pushing forward and population density (Ansgar and Andreas, 2002). Su et al. (2008) used the simulation model as an evaluation tool to assess the performance of different evacuation plans for a hospital in the event of a terrorist attack. Unlike others, Xiaohui et al. (2012) adopted cellular automata theory as their simulation basis and created a new set of evaluation standards, including "escape income" to help agents decide on the most suitable place for evacuation. For convenience, Ganting Xia did not code the model by herself. Instead, she chose to use a well-developed modeling software to set up the simulation research and design a series of comparison experiments to explore the differences between two different types of evacuation behaviors (Tinxia, 2015).

Some scholars have already obtained good results on modeling people's evacuation processes by combining the ABM techniques with evacuation research. For example, Almeida et al. (2012) used Netlogo to test agent's evacuation performances in various scenarios and validate their simulation results through the Van Bogaer and Predetchenky formulae before applying any detailed analysis. Tariq et al. (2010) set up a bomb explosion scenario in Netlogo and changed the location of the rescue area randomly for each run to determine how different components of the layout would affect the final evacuation results. Vani and Sumam (2013) focused their attention on analyzing the impacts of different evacuation behaviors and measuring their efficiency in terms of the evacuation rate. In addition, Camillen et al. (2009) conducted a similar comparison research in his paper to test various evacuation strategies in a museum and demonstrated that due to its ever-changing environment, evacuation behaviors are difficult to predict using traditional simulation methods and that only ABM can successfully capture their dynamic characteristics. In conclusion, traditional equation-based modeling techniques and statistical analysis methods are not qualified for these types of non-stationary scenes; only ABM, where virtual individuals can freely move and interact with each other, could successfully capture these