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School Auditorium Evacuation Simulation

Arwa A. Al Shamsi
arawee_a@yahoo.com

The British University in Dubai, Dubai, UAE

Abstract. Intelligent systems are the revolution of the future that increasingly utilized recently for anticipating events and planning for disasters. Human lives are priceless. Staying safe is a need for all humans. Around the world, disasters and the unfortunate incidents may result in negative effects on both governments and individuals especially if it results in injuries or loss of lives. The main concern of the owners of real estates, projects developers and safety inspectors of environments in which crowd of people are gathered is the safety of each individual at that place. It is difficult to model disasters and unfortunate incidents in real-life situations, as a result, Agent-Based models are implemented to efficiently simulate such incidents. Agent-Based models can be used to model individual evacuation as well as human behavior during emergency situations. In this paper, an Agent-Based modeling of pedestrians was investigated. In the literature survey section, a number of research papers about Agent-Based modeling of pedestrian during emergency evacuation have been surveyed with the main focus on the crowd evacuation and human behavior during evacuation. Then the author extended Lecture Hall Evacuation Model from the NetLogo User Community Models to model the school auditorium evacuation. The author modified the lecture hall environment to match the school auditorium environment. Several scenarios were implemented to test the developed model of the evacuation for school auditorium with one exit, then for school auditorium with two exits, after that for school auditorium with three exits and finally for school auditorium with four exits. The author investigated how far the number of exits and the number of people affect the evacuation time. At last simulation results presented that school auditorium evacuation in case of four exits provided the best evacuation time while the evacuation of the school auditorium that has three exits is the worst.

Keywords: *Simulation, Evacuation, Modeling, NetLogo software.*

1. Introduction

Emergency evacuation is the immediate and rapid movement to escape or exit a place where a situation of danger or disaster is, in order to maintain safety and life. Emergency evacuation may be due to some natural disasters such as floods, earthquakes and volcanoes and may be due to sudden accidents such as fires. Emergency evacuation should be planned in advance by building owners and construction engineers to ensure safe and effective evacuation in emergencies and disasters. Emergency evacuation should be well planned to, in order to ensure the safety of people as achieving safety and safety standards in buildings is a priority. In many countries, building permits are granted only after security and safety requirements are met in the construction plan. with the emerge of intelligent systems and simulation software, measuring the security standards as well as number of and the position of the exits become much easier. Software for evacuation simulation can strongly help to examine how the people will gather and flow during the evacuation (Alexia Zoumpoulaki, Nikos Avradinis, Spyros Vosinakis, 2010). Researchers as well stated that evacuation simulation software can be effectively used to simulate evacuation time and distribution among exits.

Agent-Based Modeling and Simulation ABMS is a sturdy technique for modeling real-world situations. (Chuanjun Ren, Chenghui Yang, and Shiyao Ji, 2009) stated that “In ABMS, a system is modeled as a collection of autonomous decision-making entities called agents”, Agents are able to interact with each other and make decisions based upon predefined rules. In ABMS field several platforms and toolkits developed for designing environments and developing agents. One of the most popular platforms is NetLogo software which is a multi-agent programmable modeling environment. (WILENSKY, U., 1999) presents in their research paper a Simulation of School Auditorium Evacuation. In this project, the author extends a Lecture Hall evacuation Model from the NetLogo User Community Models to model the school auditorium evacuation. The author models the School Auditorium Evacuation using NetLogo software. In this paper, the author investigated how far the number of exits as well as the number of people may affect the evacuation time. The author also investigated the best number of exits in order to achieve the best evacuation time. This paper organized as follows: Section 2 provides a literature survey of research papers about Agent-Based Simulation for modeling pedestrians, Section 3 defines the research objectives, Section 4 gives description of the hypothesis and research methodology, Section 5 describes the simulation environment, Section 6 shows the implementation and analysis, Section 7 provides the findings and the discussion, Section 8 presents the conclusion and the future work, Section 9 includes the references.

2. Review of Current Research

Researchers were interested in using the Agent-Based model for simulation. Noticeable number of researchers focused on the simulation of evacuation during fire disaster. Wagner, Neal, and Vikas Agrawal (2014) presented a prototype of an Agent-based Decision Support System (ABS) which simulate the evacuation of crowd during fire disaster. They focused on evacuation for a concert venue setting. The system modeled using both NetLogo and Java programming languages (Wagner, Neal, and Vikas Agrawal, 2014). The main goal of any person in the crowd in case of presence of fire disaster is to avoid fire. The person movement algorithm consists of exit selection, selection of the way to that selected exit and the movement along the selected way toward the selected exit and all these components governed by the fire avoidance component. The defined Agent-based System is powerful and highly customizable which allows for user definition of the layout and structure of the simulated concert venue. The defined Agent-based System can benefit fire disaster mitigation planner for concert venues to minimize fire disaster effects by selecting most suitable safety measures [1]. Another research paper interested as well in simulating evacuation in case of fire presence. Chuanjun Ren, Chenghui Yang, and Shiyao Jin (2009) published "Agent-Based Modeling and Simulation on Emergency Evacuation" research paper in which they developed an Agent-Based Modeling and Simulation (ABMS) on emergency evacuation using Repast Software. ABMS is considered a useful technique for modeling simulation. Researchers focus mainly on crowd evacuation management in the presence of fire using Repast Software. Repast (Recursive Porous Agent Simulation Toolkit) allows to design agent and environment that agent can interact with. Researchers concerns on whether the environment is convenient for evacuation in case of emergency situations, and how to effectively evacuate people of such environment. Researchers designed different types of agents and attributes and their interactions. During emergency evacuation, the agent's behavior has three dimensions: the environment and the evacuation configuration; controls utilized at evacuation; and "Social psychological and organizational characteristics impacting the response and collectivities that participate in the evacuation" and this dimension is considered by the researchers of this paper. Researchers investigated different types of people (e.g., men, women, children, leaders and security guards). Researchers as well as take into consideration different attributes. Researchers defined the environment as 4 meters wide by nine meters long basement. It has three exits. Researchers presents the following environmental characteristics which have notable consequences on the evacuation and the behavior of the individuals:

- "The total number of people in the area
- The number of exits
- The number of policemen in the area
- The number of security guard in the area
- The intensity of the fire
- The velocity of the spread of the fire
- The toxicity of the fire
- The distribution of policeman and

- The distribution of security guard" Chuanjun Ren, Chenghui Yang, and Shiyao Ji, 2009)

Researchers utilize Repast which uses program language to design multi-agent models. In this paper, researchers wrote many Java classes to specify the behavior of agents and the environment properties. Researchers first used a discrete cartesian grid to model the environment then they added the agents. Researchers conducted experiments several times and stated the following findings: (a) As the number of people increased, the evacuation time will increase as well, in the meantime, there will be an increase in the number of casualties; (b) The number of casualties will not affect by either the number of security guard or the number of exits; (c) The evacuation time is not affected by increasing the number of exits; (d) The number of casualties is mainly inspired by the panic scale and population scale; (e) "faster is slower", which means increasing the velocity may enlarge the casualties number which may be considered as obstacles that slow down crowd Chuanjun Ren, Chenghui Yang, and Shiyao Ji, 2009). A research paper that considers that evacuation of building in case of fire was surveyed. Jianyong Shi, Aizhu Ren, Chi Chen developed an Agent-Based model for large building evacuation in the presence of fire (2008). Researchers presented "Agent-based evacuation model of large public buildings under fire conditions" research paper to present an integrated model in which the interaction between the occupants and the fire field is considered in the model. Researchers first constructed a basic Agent-Based Evacuation model then an occupant evacuation simulation model is adopted. The basic model of evacuation depends on physics modeling principle that is used to show the evacuation progress while the mathematics model used to simulate the characters and individual behaviors. The AIEva model is introduced by researchers. AIEva is an Evacuation Simulation model that is based on the Dynamic Mathematical Model. AIEva includes Spatial Environment Model (SEM) which represents building environment in fire situations and the Agent Decision Model (ADM) to determine occupant evacuation behavior. In the evacuation model researchers specify the status and the rules of behavior for all occupants. During the evacuation, occupants affected by subjective factors like the environment understanding and Objective factors like obstacles and crowd density and both factors affected each other. In the evacuation model agent has three main problems: next routine decision, validation of speed and the conflict due to having more than one occupant entering the same grid. AIEva utilizes FDS (Fire Dynamics Simulator) to simulate the fire scenario and fumes level. Object Oriented Program (OOP) design is used to present the physical model and Mathematics model in computer.

AIEva basically consists of:

1) Fire information database used as a tool for data mapping.

2) Core analysis module which is responsible for calculating the next destination of the agent.

3) Rule reasoning mechanism.

4) Graphics platform.

The researchers specified the finding as: (i) AIEva is useful for the calculation of the fire safety measures. (ii) When apply using the system for simulation, the fire and the fumes can be effectively modeled. On the other hand, (iii) It is complicated to simulate the behavior of the occupant in emergency situations. Moreover, (iv) It is difficult to verify the model because it is impossible to conduct repeatable experiments (Jianyong Shi, Aizhu Ren, Chi Chen, 2008).

A large number of researchers interested in investigating the human behavior during evacuation. Xiaoshan Pan, Charles S. Han, and Kincho H. Law (2005) aim to investigate the social behavior of human in case of emergency evacuation of a building. Researchers presented "A Multi-Agent Based Simulation Framework for the Study of Human and Social Behavior in Egress Analysis" research paper. Researchers developed a prototype system to model some behaviors during emergency situations. Researchers believed that in order to improve crowd safety during emergency situations; It is important to understand human behavior in such situations. Researchers developed multi-agent computational system that is able to model some human behaviors during emergencies. In the developed system; "each occupant is simulated as an independent agent equipped with sensors for perceiving environment, mind for decision-making, and actuators for taking actions" (Xiaoshan Pan, Charles S. Han, and Kincho H. Law, 2005). Autonomous agent represents human individual and it is capable to interact with other agents as well as the environment according to Individual Behavior Model and global rules on crowd dynamics. In the system, the researchers adopted Perception-Interpretation- Action Model in which the agent is continuously makes decisions in accordance to the surrounding environment. Researchers presented the architecture of the system as the following:

- Geometric Engine: utilizes AutoCAD/ADT to represent the physical environment.
- Population Generator: generate the occupants.
- Global Database: store the information of the agents and the environment during the simulation.
- Events Recorder: capture simulated events.
- The Visualizer: represents results of the simulation.
- The Crown Simulation Engine: considered as the core module of the multi-agent system.

It is critical to effectively represent the physical environment in the simulation system. Researchers utilizes Geometric Engine to extract the model of the environment that is built by using ADT (Architectural Desktop). Human individual is represented as autonomous agent. Researchers divided the human behavior into locomotion, steering and social. The modeled system successfully represents locomotion as the motion and steering behavior as environment navigation. The System capable to represent the Social behavior such as competitive behavior, queuing behavior and herding behavior (Xiaoshan Pan, Charles S. Han, and Kincho H. Law, 2005). Another research paper investigated the human behavior of crowd. Linbo Luo, Suiping Zhou, Wentong Cai, Malcolm Yoke Hean Low,Feng Tian, Yongwei Wang, Xian Xiao and Dan Chen (2008) aim to develop Agent-Based behavior model for crowd simulation. Researchers presented "Agent-based human behavior modeling for crowd simulation" research paper to investigate the possibility to mimic decision making process for real life. Researchers developed layered system for modeling behavior. The developed system is designed to be able to model cognitive process that reflects human-like decision making process, "which involves person's awareness of the situation and consequent changes on the internal attributes" (Linbo Luo*, Suiping Zhou, Wentong Cai, Malcolm Yoke Hean Low,Feng Tian, Yongwei Wang, Xian Xiao and Dan Chen, 2008). In the developed model, researchers identified different attributes, each of them influences Agent's decision making, these attributes are divided into static attributes such as the agent's characteristics and dynamic attributes such as Physiological, Emotional and Social Group attributes. (a) The physiological attributes determine the physiological ability of the agent to deal with sensed information. (b) Emotional Attributes: two attributes are considered in the developed system; attraction and panic. (c) Social Group attributes in which different social groups represents different types of Agent. The model is developed as layered model to effectively produce real behavior in case of emergency situations. Implementing layered system on modeling human behavior is more realistic since it reflects the natural human decision-making process. The layered framework allows to implement different scenarios due to its flexibility. The framework consists of individual module and crowd module both are in the upper layer and physical module in the lower layer. The upper layer responsible of choosing most suitable behavior based on current situation investigation. While in the lower layer, basic actions are generated based upon sensed information. In the developed simulation system, the population of the crowd is generated first, then the agent collects information about the environment. After that, the events are generated, and as a result, the situations will be changed. These changes to the current situations will affect the internal attributes of the agent and cause the agent to select behavior from the retrieved behavior list. Researchers tested the developed system and conducted a case study then they stated the findings as: (a) When testing the developed system, each individual agent is capable of responding separately. (b) Based on physiological, emotional and social group attributes, agents can make decisions that are imitating real human decisions (Linbo Luo*, Suiping Zhou, Wentong Cai, Malcolm Yoke Hean Low,Feng Tian, Yongwei Wang, Xian Xiao and Dan Chen, 2008). Another interesting research paper about crowd evacuation behavior was surveyed. Mihai Horia Zaharia, Florin Leon, Cristea Pal and Gabriel Pagu (2009) presented an "Agent-Based Simulation of Crowd Evacuation Behavior" research paper in which they introduced an agent-based simulation system for modeling crowd evacuation that can be used to provide more accurate results in modeling the evacuation route during emergency situations. Researchers extended Boids Simulation model that was developed by Reynolds to simulate crowd behavior. In Boid, simple rules are used to control each agent. "Separation rules maintain a certain separation distance between nearby agents. Cohesion rules are causing a group formation effect. Alignment rules give the agent the ability to head in the same direction as other nearby agents" (Mihai Horia Zaharia, Florin Leon, Cristea Pal, Gabriel Pagu, 2009). Researchers extended Boid model by adding rules in order to simulate real-time behavior in case of crowd evacuation. Boid algorithm implemented through three classes. Flocking2D is the main class and it includes one obstacle and list of Boid. FlockBehavior class responsible for obtaining separation, Cohesion and alignment rules. This class is extended by the researchers. Researchers added new rule that limits the maximum velocity of the agent. In order to create agents, Researchers utilizes Abstract Factory design pattern in which agents are created along with appropriate behavior. Researchers extended the FlockBehavior class of Boid with HumanBehavior class and as a result new behavior was achieved which allows the agent to respect the role of separation, cohesion and alignment. Furthermore, agent become able to move toward and away from specific place. Agents also can avoid obstacles and follow specific points. Researchers apply using counters to measure the time needed by group of agents from start point to the end point. Researchers tested the developed system by conducting series of tests and they proof that the developed system which is extension to Boid can properly simulate human behavior in case of emergency. The presented software is flexible and allows for further enhancement. It allows as well as to add more rules and modify the input parameters (Mihai Horia Zaharia, Florin Leon, Cristea Pal, Gabriel Pagu, 2009). Personality and emotion during evacuation is a big concern for researchers in Agent-based model field. Alexia Zoumpoulaki, Nikos Avradinis, Spyros Vosinakis (2010) aim to design evacuation simulation model based on multi-agent BDI architecture. Researchers presented "A Multi-Agent Simulation Framework for Emergency Evacuations Incorporating Personality and Emotions" research paper in which they utilize OCEAN model and OCC model to enhance their developed model. To effectively model realistic behaviors during the evacuation, it is essential to investigate cognitive science and surveys real situations. Researchers developed EP-BDI (Emotion Personality Beliefs Desires Intentions) in which (OCEAN) model of personality and (OCC) emotion model are incorporated. The emotion module considers the evaluation of the obtained information to make decisions and execute actions. "The personality module influences emotional reactions, indicates tendencies to behaviors and help address issues of diversity" Alexia Zoumpoulaki, Nikos Avradinis, Spyros Vosinakis, 2010). In the developed system, researchers adopted OCEAN model that defines five basic traits which are: Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism. Researchers utilize a mechanism to model social organization in which the groups of crowds will dynamically formed, and based on the knowledge, personality and emotions, the roles will arise. The developed system architecture begins with Perception phase in which the agent obtains information from the environment. The agent's beliefs will be updated according the obtained information. Next in the Decision-Making phase, this information will be used to generate a Desire in order to reach an Intention. In the developed system, Researchers modeled five positive/negative emotions which are: "Joy/Distress, Hope/Fear, Pride/Shame, Admiration/Reproach and SorryFor/HappyFor. The first three emotions concern the agent itself, while the last two focus on other agents" Alexia Zoumpoulaki, Nikos Avradinis, Spyros Vosinakis, 2010). A vector that shows the status of agent's emotion is assigned for each agent. Agents attached with sensors in order to perceive information and update agent's beliefs as well as Agent's emotion state. These updates can be used to assign the desires an importance value that helps agents to choose the desire to be accomplished first and the possible intension that can be achieved. Researchers developed simulation system for fire evacuation. In the developed system, the environment is 2D space in which the static objects modeled as obstacles and expanding regions represents fire. The user of the system can define the initial population and the position of the fire. Agents attached with sensors to acquire information from the environment. Agents capable of exploring the environment, moving individually and performing coordinated motion behaviors. Researchers tested the developed system and found that it is capable to generate variety of behaviors that are matching the real evacuation. "These include emergent group formation, bi-directional motion, altruistic behaviors and emotion propagation" Alexia Zoumpoulaki, Nikos Avradinis, Spyros Vosinakis, 2010).

Xiaoshan Pan, Charles S. Han, Ken Dauber, Kincho H. Law (2007) simulated human as well as social behavior in case of emergency evacuation by using Multi-Agent based framework. The researchers introduced "A Multiagent Based Framework for the Simulation of Human and Social Behaviors during Emergency Evacuations" research paper in which they focused mainly on safe egress. The knowledge of human and social behavior in case of emergency evacuation is critical to ensure crowd safety. "A multi-agent simulation framework is a computational methodology that allows building an artificial environment populated with autonomous agents which are capable of interacting with each other" (Xiaoshan Pan, Charles S. Han, Ken Dauber, Kincho H. Law, 2007). In such a framework, the individual of human is modeled as autonomous agents and the behavior is modeled as emergent phenomena. Researchers identified the nonadaptive crowd behaviors from individual level, interactions among individual level and groups level. Researchers believed that Multi-Agent simulation framework is suitable for simulating human and social behaviors and these believes led them to represent Multi-Agent Simulation System for Egress analysis (MASSEgress). By using MASSEgress framework the autonomous agent represents individual of human, this agent will interact with virtual environments as well as other agents according to crowd dynamics rules. MASSEgress system architecture consists of:

(1) Geometric Engine to produce geometries that represents the physical environment and considered to be used for crowd behaviors simulation.

(2) Population Generator to generate residents.

(3) Global Database to preserve the physical environment's information as well as the agent's information during simulation.

(4) Events Recorder to capture simulated events for evaluation.

(5) The Visualizer tool to show the results of simulation.

(6) The Crowd Simulation Engine which considered as the core module of the system.

Research findings are stated as: (a) The computational framework of the Multi-agent system able to model emergent human social behavior. (b) When designing simulation system for emergency evacuation, it is critical to understand the disruptive human behavior (Xiaoshan Pan, Charles S. Han, Ken Dauber, Kincho H. Law, 2007). An Interested research presented by Bandini, Stefania, Matteo Mondini, and Giuseppe Vizzari (2014) focused on negative interactions of high density pedestrians. Researchers introduced "Modelling negative interactions among pedestrians in high density situations" research paper in which they developed an extended model based on the floor-field approach. Researchers goal is to extend the floor-field CA pedestrian model that is used to simulate situations of high density pedestrians that involve negative interactions. Researchers considered the floor-field approach as the basic model to investigate high density situations. In the basic model the environment is represented as grid of square cells and it is used to indicate the position. Neighborhood function is used for connecting cells. Every cell can be free, occupied by obstacle or by pedestrian. Virtual grids used to show pedestrians behavior and interactions. In the basic model, the simulated time divided into steps of equal duration. The pedestrians characterized by their identifier, current position, last action and the destination. Researchers extensions claimed to overcome some basic model limitations. The first extension is a model that allows transient pedestrians overlapping in high density situations. The overlapping extension allows two pedestrians to stay in one cell. The modifications on the basic model involves changing the cell state to add one more state that indicates two pedestrians in the same cell. The admissible actions as well as modified to allow movement to cells occupied by one other pedestrian. The second extension is a model characterized by finger-discretization of the environment. This model useful because it allows for presenting pedestrians with smoother movement and has slight different velocities on the other hand this model is more complicated, and the computational cost is higher. For modeling finger-discretization extension, slight changes have been applied. At the environment level the size of the cell is reduced into one third of the original cell size in the basic model. The perception of the pedestrians is slightly modified. The extended models tested in experimental and real-life situations and the researchers stated the following findings: The overlapping extension is useful to present results with minimal computational while the finger-grained extension cannot provide improvements and its computational cost is high Bandini, Stefania, Matteo Mondini, and Giuseppe Vizzari, 2014).

Alessandro Pluchino, Cesare Garofalo, Giuseppe Inturri, Andrea Rapisarda, Matteo Ignaccolo (2014) presented an "Agent-based simulation of pedestrian behavior in closed spaces: a museum case study" research paper in which they modeled moving people in closed environment. Researchers developed an Agent-Based simulation system. Researchers conducted a case study on Castello Ursino museum in Italy. Researchers utilized NetLogo software to develop the simulation system. Researchers aim to test the carrying capacity of the museum. Researchers focused on the ground floor of the museum and considered it as the environment. In order to ensure the safety of the crowd as well as the visitors of the museum, it is essential that the environment meets the standards of safety. Researchers investigated the maximum number of people in the environment that will not affect the crowd safety in case of evacuation and emergency situations. Researchers utilized the developed system to evaluate Castello Ursino museum and found that around 200 visitors is the best carrying capacity of Castello Ursino museum in Italy. Researchers stated that the developed system is flexible, and it can be further extended (Alessandro Pluchino, Cesare Garofalo, Giuseppe Inturri, Andrea Rapisarda, Matteo Ignaccolo, 2014).

An interesting research paper presented by Soraia R. Musse, Cl´audio R. Jung, Julio C. S. Jacques Jr. and Adriana Braun (2007) in which they investigated the behavior of virtual humans in "Using Computer Vision to Simulate the Motion of virtual agents" research paper. They proposed a model in which the movement of virtual humans simulated based on examples. A camera with top down view setup was used to record real video sequences of human trajectories then using computer vision algorithms; the desired velocity of the tracked humans is fed into a virtual human simulator to reproduce the motion of real people in a virtual environment. This proposed technique is fully automatic without user intervention. The simulation of real life situation allows virtual agent to mimic the behavior of tracked people (Soraia R. Musse, Cl´audio R. Jung, Julio C. S. Jacques Jr. and Adriana Braun, 2007).

The above research papers are surveyed and "Agent-Based Modeling and Simulation on Emergency Evacuation" Chuanjun Ren, Chenghui Yang, and Shiyao Ji, 2009) research paper that was presented by Chuanjun Ren, Chenghui Yang, and Shiyao Jin (2009) considered as interesting research paper. Repast (Recursive Porous Agent Simulation Toolkit) software is useful in developing agent-based model and it allows to design agent and environment that agent can interact with.

3. Research Objective

Agent-Based systems are widely used recently to simulate real-world incidents. In this paper number of research papers about Agent-Based modeling of pedestrian during emergency evacuation have been surveyed with main focus on the crowd evacuation and human behavior during evacuation. The main goal of the project is to develop an Agent-Based model to simulate the evacuation of attendees in school auditorium. In this research paper, the author utilizes an existing model from the NetLogo User Community Models that is used to simulate the evacuation of lecture hall to simulate the evacuation of school auditorium.

4. Problem and Proposed Solution

4.1. Hypothesis

The author aims to model the evacuation of school auditorium with different number of exits. The author will use NetLogo software to extend a model of lecture hall evacuation from the NetLogo User Community Models to model the school auditorium evacuation. The author aims to model the school auditorium evacuation for auditorium with different number of exits and different number of people inside the auditorium then investigate the differences in the evacuation time. The author specifies the research questions to be:

- How far the number of exits affect the evacuation time?
- How far the number of people to evacuate affects the evacuation time?
- What is the best number of exits in order to achieve best evacuation time?

There are two things to focus in the research paper, one is to model school auditorium evacuation, and the second is to investigate how far the number of exits and people to evacuate may affect the evacuation time.

4.2. Research Methodology

The author in this paper will model an evacuation of school auditorium. The author will extend an existed evacuation model of lecture hall from the NetLogo User Community Models open source that was programmed by Alex and Tobi (2010) using NetLogo software. The author will modify the lecture hall open source model to match school auditorium then the author will investigate the evacuation time to the model of the evacuation for school auditorium with one exit, then for school auditorium with two exits, after that for school auditorium with three exits and finally for school auditorium with four exits. The author will investigate how far the number of exits and the number of people in school auditorium will affect the evacuation time.

5. Simulation Environment

The author extended Lecture Hall evacuation model from the NetLogo User Community Models to simulate the evacuation of school auditorium (WILENSKY, U., 1999). In the Lecture Hall evacuation model, the environment represented as rectangular area that has two exits from where the students evacuated, board, projector space in which students cannot go over it or sit on it, walls and benches in which students are allocated. In the Lecture Hall model, the professor location is static while the students allocated randomly and the maximum number of students in the evacuation model is 147 students. In the model, the evacuation time depends on the number of students in the hall, whether there are obstacles and the student's chance of hanging behind. In the Lecture Hall evacuation model, there are four sliders that allow the user to apply different scenarios. The number-of-students slider allows the user to specify the number of students in the lecture hall, the section slider allows the user to specify whether to show the current state of the student, the breaks slider is used to define whether there are obstacles during the evacuation and the chance-of-hanging-behind slider that is used to specify the student's chance of hanging behind. The developer of the Lecture Hall evacuation model applied different scenarios and stated their findings that the greater the number of students, the greater the evacuation time and vice versa.

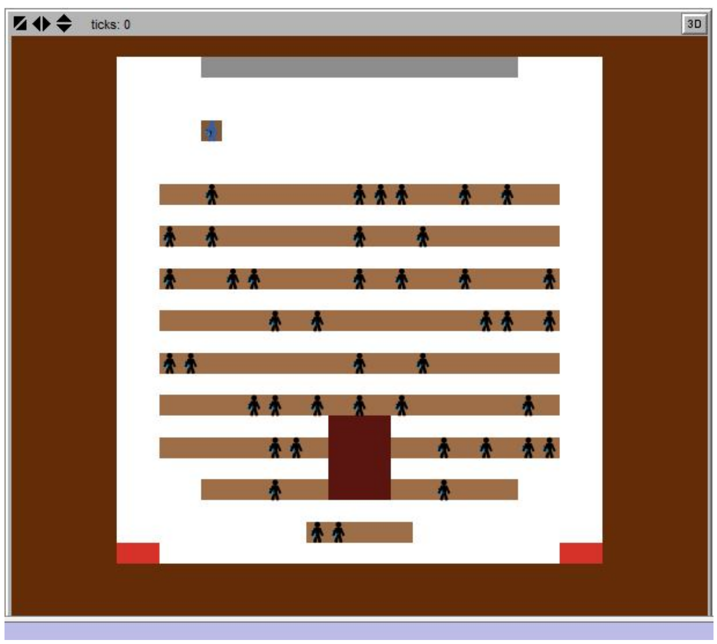

Figure 1: Environment setup in Lecture Hall Evacuation Model (WILENSKY, U., 1999)

The author of this research paper applied slight modification to the environment of the Lecture Hall Evacuation model in order to match the school auditorium environment. The board replaced with stage and the projector space in which students cannot go over it or sit on it was removed.

The School Auditorium Evacuation Model Environment has:

- Walls
- Benches
- Stage
- The Speaker location

- Randomly allocated Attendees

The maximum number of attendees is 147 and one speaker, the total number of people to be evacuated is 148. In the School Auditorium evacuation model, there are four sliders that allow the user to apply different scenarios. The number-of-attendees slider allows the user to specify the number of attendees in the school auditorium, the section slider allows the user to specify whether to show the current state of the attendees, the breaks slider is used to define whether there are obstacles during the evacuation and the chance-of-hanging-behind slider. The school auditorium evacuation simulation was applied to an auditorium that has one exit, then to an auditorium that has two exits, after that to an auditorium that has three exits and finally to an auditorium that has four exits then the results were recorded.

Figure 2: Environment setup in the Evacuation Model of School Auditorium that has one exit

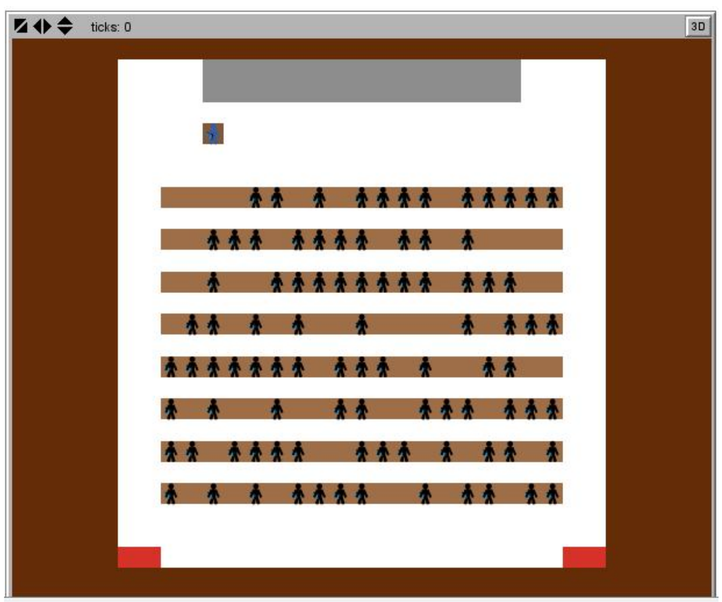

Figure 3: Environment setup in the Evacuation Model of School Auditorium that has two exits

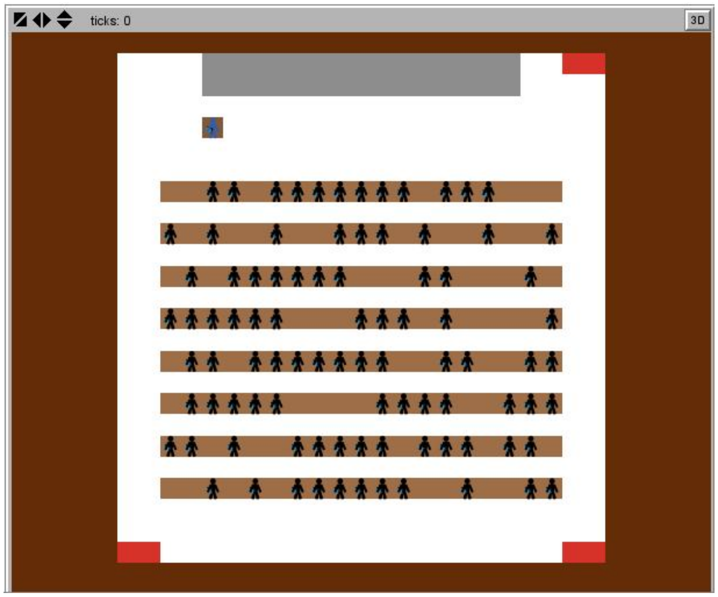

Figure 4: Environment setup in the Evacuation Model of School Auditorium that has three exits

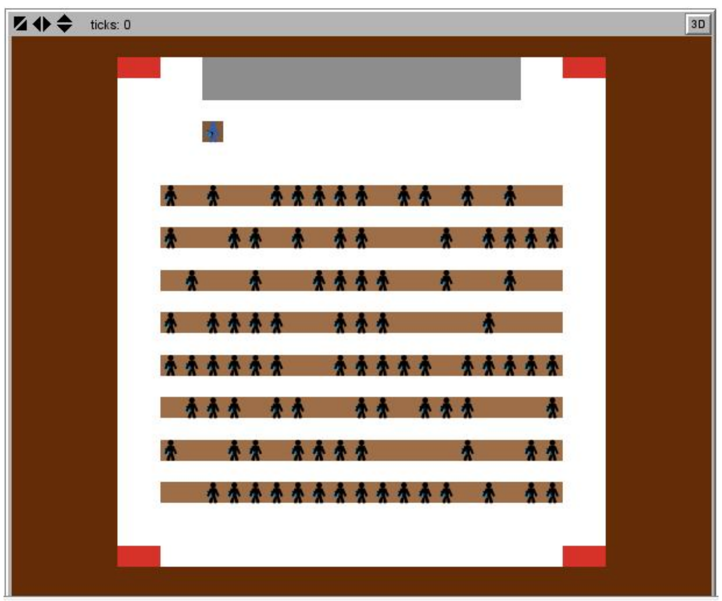

Figure 5: Environment setup in the Evacuation Model of School Auditorium that has four exits

6. Implementation and Analysis

The School Auditorium Evacuation model is implemented for different number of attendees. The following captures show the evacuation time for different scenarios and different number of attendees.

6.1. Evacuation Simulation of School Auditorium that has one exit

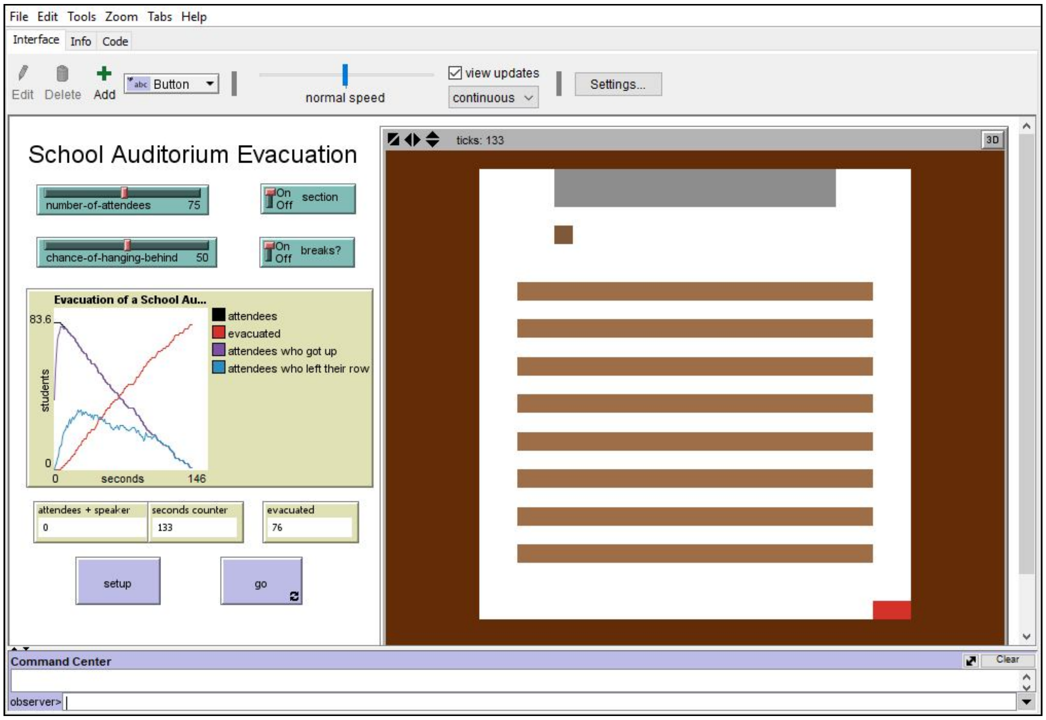

Figure 6: results of evacuating 75 attendees from auditorium with one exit

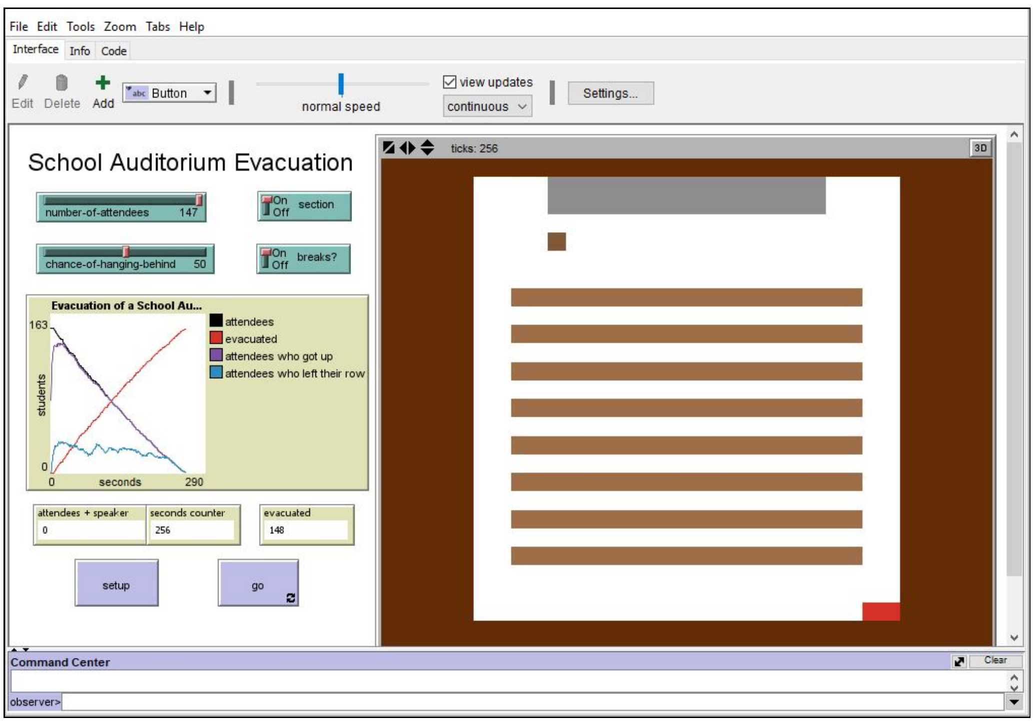

Figure 7: results of evacuating 147 attendees from auditorium with one exit

6.2. Evacuation Simulation of School Auditorium that has two exits

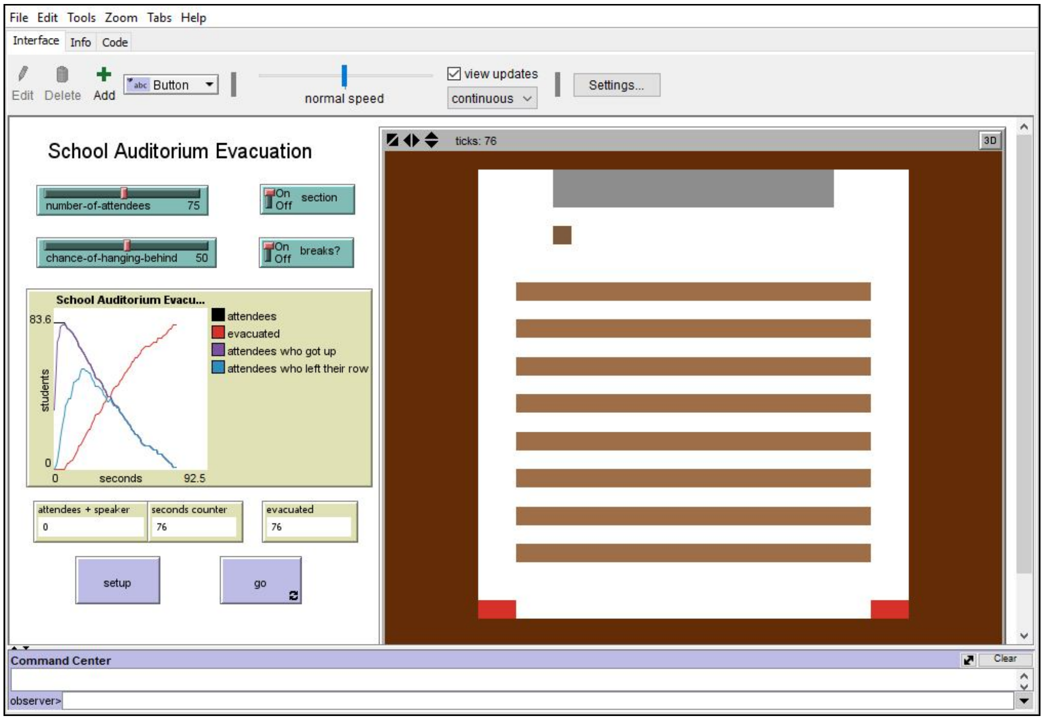

Figure 8: results of evacuating 75 attendees from auditorium with two exits

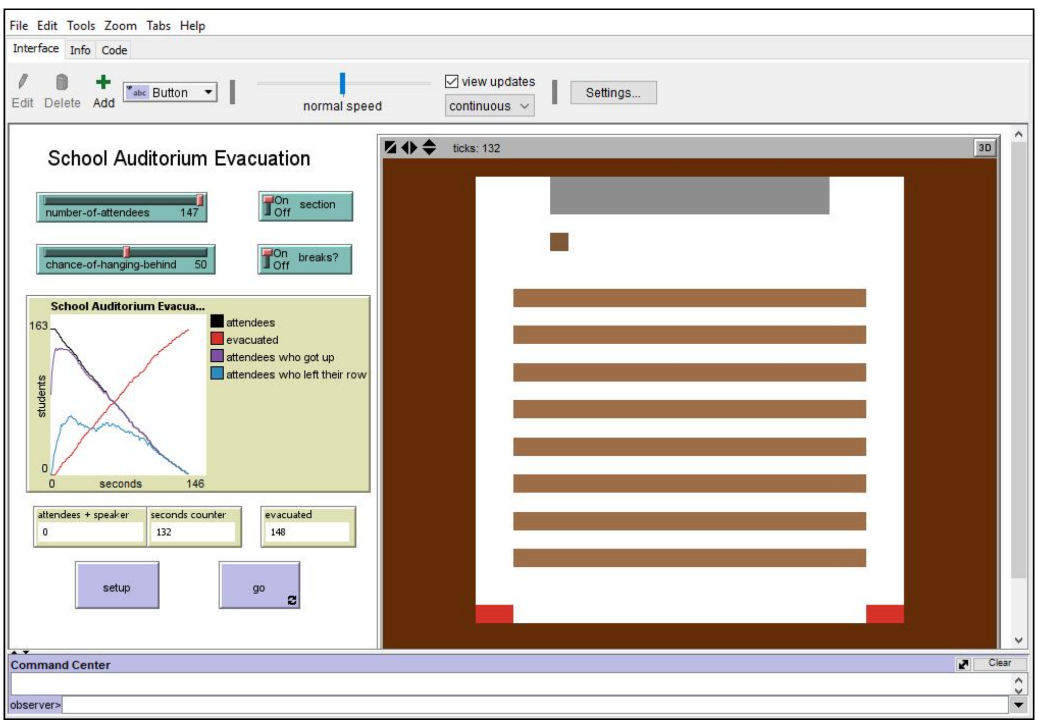

Figure 9: results of evacuating 147 attendees from auditorium with two exits

6.3. Evacuation Simulation of School Auditorium that has three exits

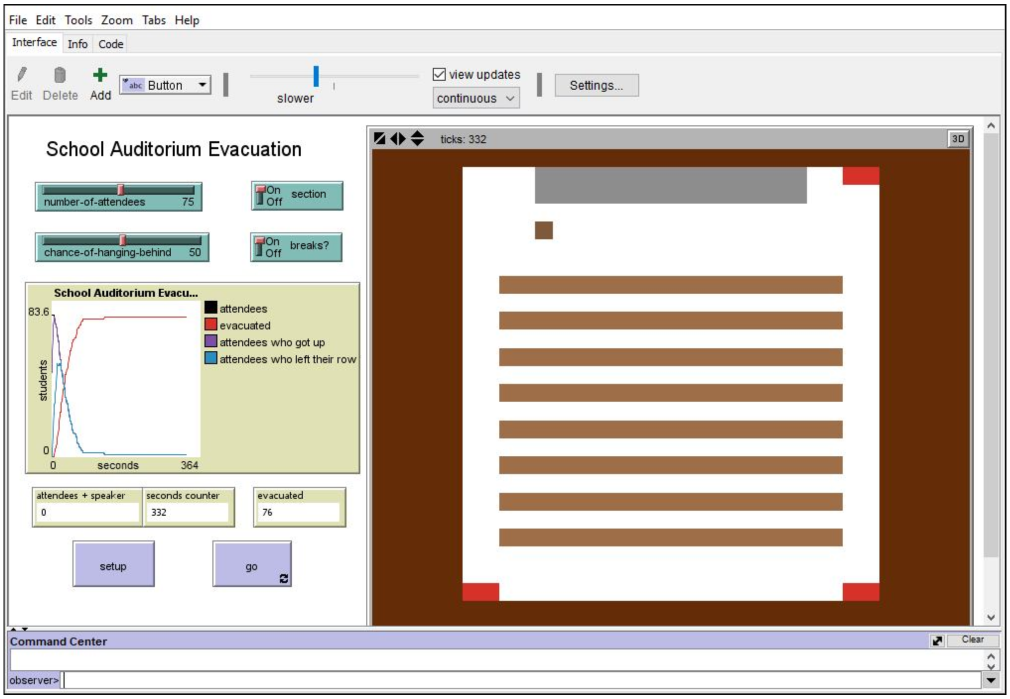

Figure 10: results of evacuating 75 attendees from auditorium with three exits

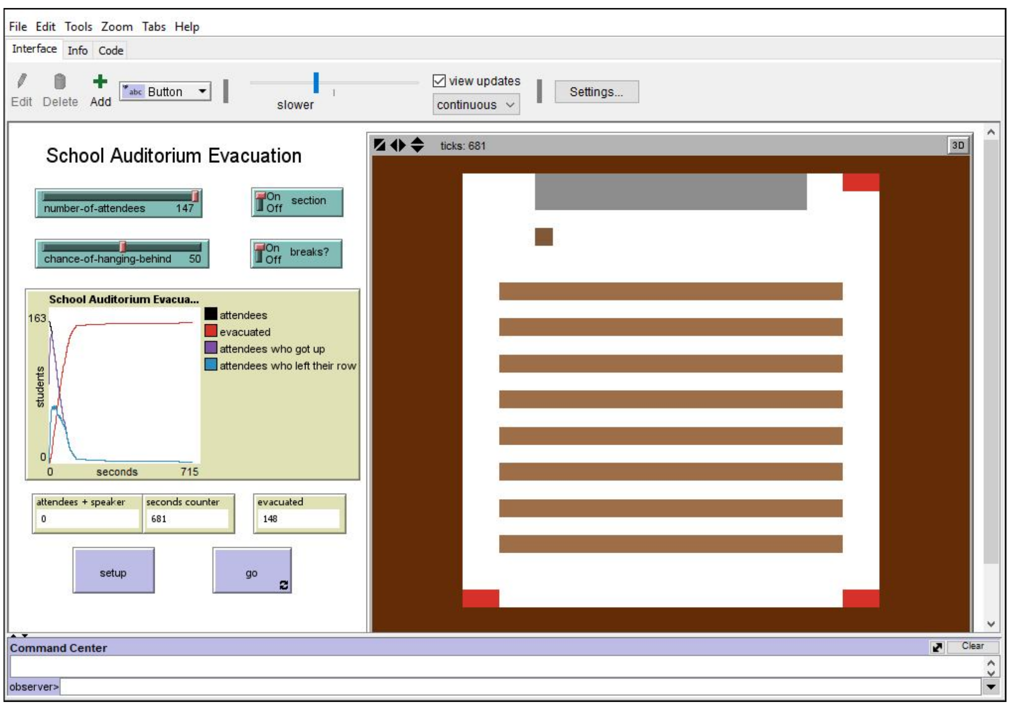

Figure 11: results of evacuating 147 attendees from auditorium with three exits

6.4. Evacuation Simulation of School Auditorium that has four exits

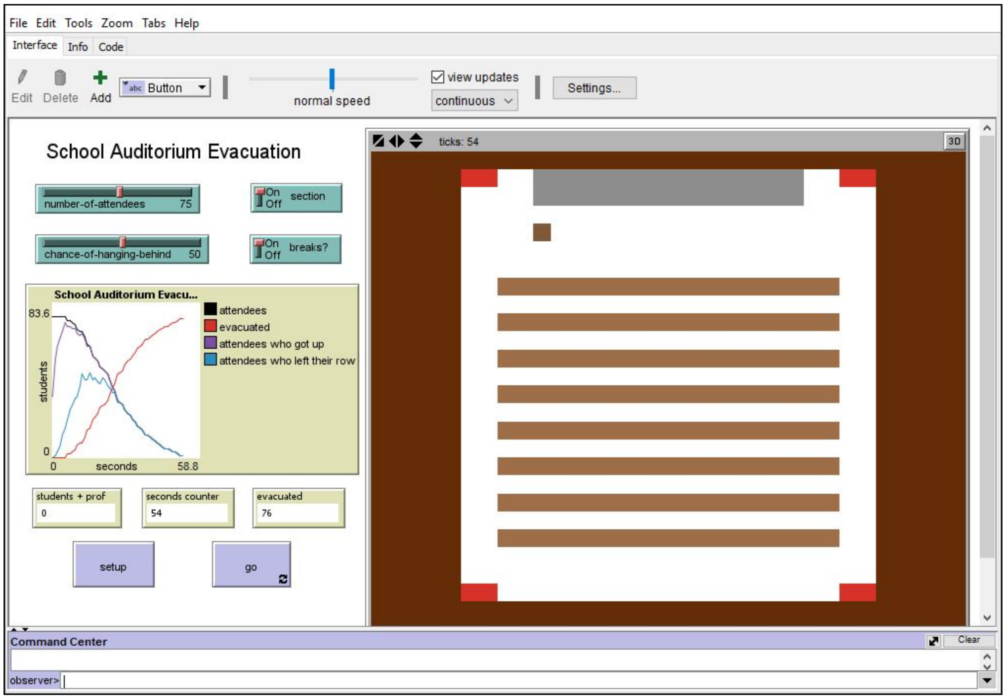

Figure 12: results of evacuating 75 attendees from auditorium with four exits

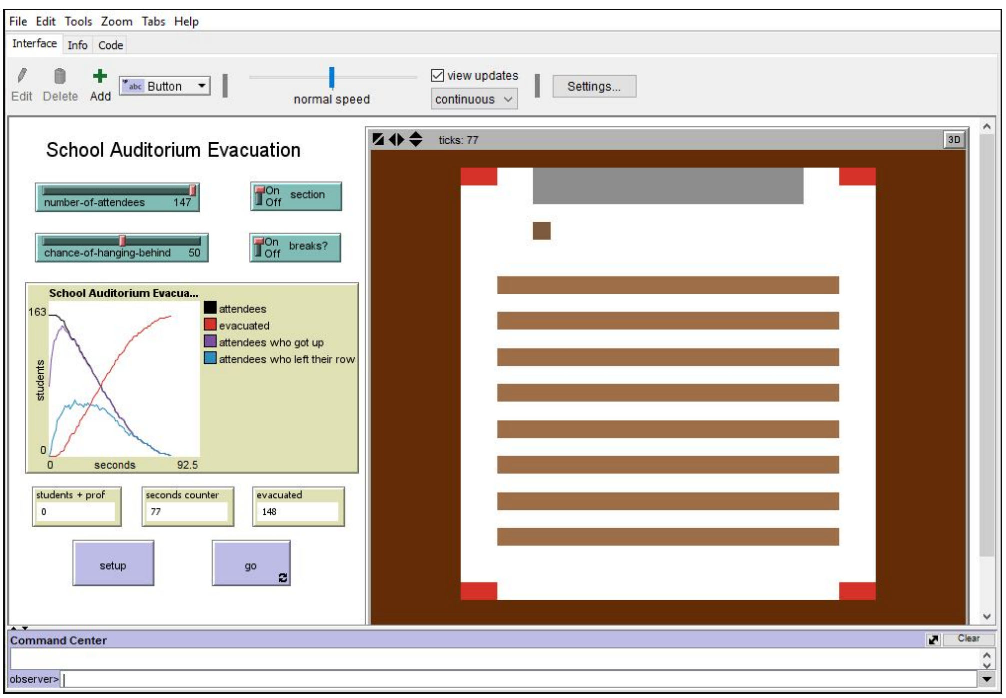

Figure 13: results of evacuating 147 attendees from auditorium with four exits

7. Findings and Discussion

Different Scenarios were implemented, then data were analyzed, and findings were presented satisfying the major research questions in this work, as follows:

- The greater the number of people to be evacuated, the greater the evacuation time and vice versa.

- The number of exits strongly affects the evacuation time.

- The best evacuation result is for an auditorium that has four exits then for an auditorium that has two exits then for an auditorium that has one exit and the worst result was for an auditorium that has three exits.

- Evacuation from an auditorium that has three exits cause the attendees to get confused and as a result the evacuation time increased.

- The best setup for school auditorium to achieve the best security measures during emergency situations is to have four emergency exits.

- The worst setup for school auditorium that may lead to disaster during emergency situations is to have three emergency exits.

- The NetLogo software is an effective software to simulate the evacuation of a school auditorium and it was able to produce interesting results for different evacuation scenarios.

- The Table below represents results for different evacuation scenarios of school auditorium:

No. of people / No. of exits	25	50	75	100	147
One Exit	58	89	133	173	256
Two Exits	39	53	76	104	132
Three Exits	179	250	332	365	681
Four Exits	31	38	54	62	77

Table 1: Evacuation time in seconds for different evacuation scenarios of school auditorium

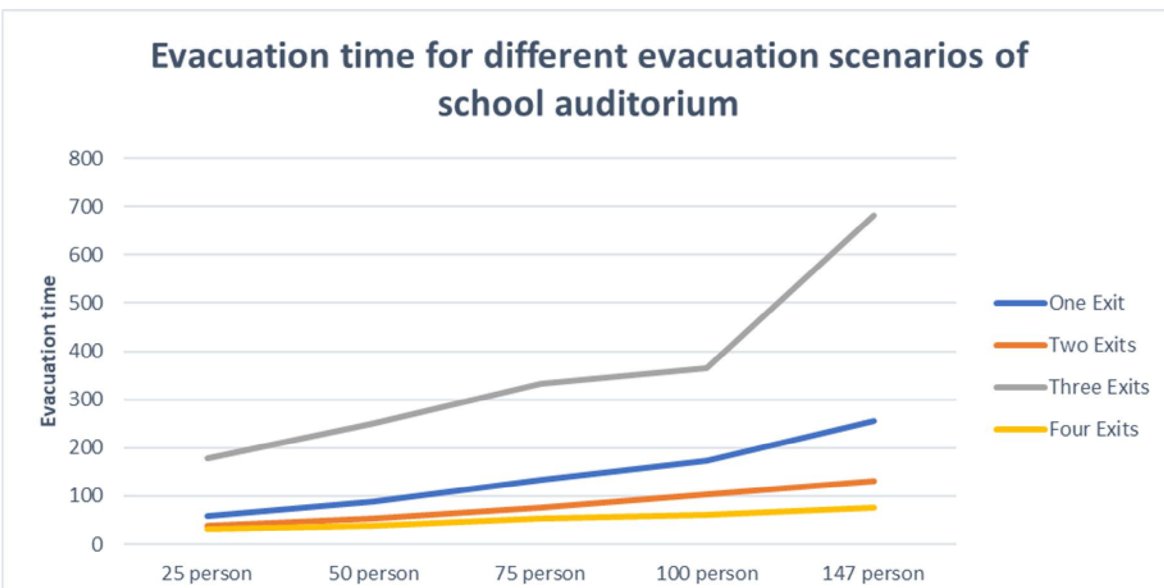

Figure 14: Evacuation time for different evacuation scenarios of school auditorium

8. Conclusion and Future Work

Intelligent systems are increasingly utilized recently for different purposes, one of the main usages of intelligent systems is for anticipating events and planning for disasters. The human lives and safety are precious. The safety of people is the main concern of governments, institutions, and decision-makers. In this regard, great care has been taken to achieve the best safety standards in different places such as commercial complexes, schools, theaters and many others. With the emergence of intelligent systems and programs that enable the user to simulate the reality and plan for disasters, many real estate owners and project managers tend to use such systems to simulate emergency situations in order to achieve the best security measures to ensure the safety of individuals. In this research paper, the author extended an open-source Lecture Hall Evacuation Model from the NetLogo User Community Models to model the school auditorium evacuation. The author modified the lecture hall environment to match school auditorium environment. Several scenarios were implemented to test the developed model of the evacuation for school auditorium that has one exit, then for evacuation of school auditorium that has two exits, after that for evacuation of school auditorium with three exits and finally for evacuation of school auditorium that has four exits. The author investigated how far the number of exits and the number of people affects the evacuation time. Data were analyzed, and findings were stated as the best evacuation time of school auditorium achieved in the case of evacuation of school auditorium that has four exits or two exits, while the evacuation of school auditorium that has three exits is the worst due to many reasons such as individual confusion. The author recommend the use of four and two exits in case of evacuation of square and rectangular shape places such as rooms, halls, auditorium, etc.. Moreover, the Author recommend the use of NetLogo software due to its effectiveness in the simulation of emergency situations. The author recommends for future work to investigate the best position to place exits in order to achieve best evacuation time.

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References

Alessandro Pluchino, Cesare Garofalo, Giuseppe Inturri, Andrea Rapisarda, Matteo Ignaccolo, (2014). Agent-based simulation of pedestrian behavior in closed spaces: a museum case study. Journal of Artificial Societies and Social Simulation (JASSS) 17 (1) 16, 2014. arXiv:1302.7153

Alexia Zoumpoulaki, Nikos Avradinis, Spyros Vosinakis. (2010). A Multi-Agent Simulation Framework for Emergency Evacuations Incorporating Personality and Emotions. In: Konstantopoulos S., Perantonis S., Karkaletsis V., Spyropoulos C.D., Vouros G. (eds) Artificial Intelligence: Theories, Models and Applications. SETN 2010. Lecture Notes in Computer Science, vol 6040. Springer, Berlin, Heidelberg

Bandini, Stefania, Matteo Mondini, and Giuseppe Vizzari, (2014). Modelling negative interactions among pedestrians in high density situations. Transportation research part C: emerging technologies 40 (2014): 251-270.

Chuanjun Ren, Chenghui Yang, and Shiyao Ji, (2009). Agent-Based Modeling and Simulation on Emergency Evacuation. Complex Sciences. Complex 2009. Lecture Notes of the Institute for Computer Sciences, Social Informatics and Telecommunications Engineering, vol 5. Springer, Berlin, Heidelberg.

Jianyong Shi, Aizhu Ren, Chi Chen, (2008). Agent-based evacuation model of large public buildings under fire conditions. ScienceDirect. Automation in Construction 18 (2009) 338–347. © 2008 Elsevier B.V.

Linbo Luo*, Suiping Zhou, Wentong Cai, Malcolm Yoke Hean Low,Feng Tian, Yongwei Wang, Xian Xiao and Dan Chen, (2008). Agent-based human behavior modeling for crowd simulation. COMPUTER ANIMATION AND VIRTUAL WORLDS. 2008; 19: 271–281.

Mihai Horia Zaharia, Florin Leon, Cristea Pal, Gabriel Pagu, (2009). Agent-Based Simulation of Crowd Evacuation Behavior. Conference: 11th WSEAS International Conference on Automatic Control, Modelling and Simulation. 2009. ISSN: 1790-5117.

Soraia R. Musse, Cl´audio R. Jung, Julio C. S. Jacques Jr. and Adriana Braun, (2007). Using Computer Vision to Simulate the Motion of Virtual Agents. Graduate Program on Applied Computing. Universidade do Vale do Rio dos Sinos. In Wiley Online Library2007 ..

Wagner, Neal, and Vikas Agrawal, (2014). An agent-based simulation system for concert venue crowd evacuation modeling in the presence of a fire disaster. Expert Systems with Applications 41.6 (2014): 2807-2815.

WILENSKY, U., (1999), NetLogo, Center for Connected Learning and Computer Based Modeling. Northwestern University, Evanston, IL, http://ccl.northwestern.edu/netlogo

Xiaoshan Pan, Charles S. Han, and Kincho H. Law, (2005). A MULTI-AGENT BASED SIMULATION FRAMEWORK FOR THE STUDY OF HUMAN AND SOCIAL BEHAVIOR IN EGRESS ANALYSIS. International Conference on Computing in Civil Engineering. 2005.

Xiaoshan Pan, Charles S. Han, Ken Dauber, Kincho H. Law, (2007). A Multiagent Based Framework for the Simulation of Human and Social Behaviors during Emergency Evacuations. Published on AI & SOCIETY; Journal of Knowledge, Culture and Communication. ISSN 1435-5655. 2007.