ClassEscape: The Conceptual Design of Crowd Modeling in Fire Evacuation Simulation

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***Abstract*— In the contemporary era, the proliferation of various applications, notably crowd modeling, has revolutionized problem-solving approaches across diverse sectors. However, the absence of organized fire drills poses a significant challenge to navigating hazardous zones to safety, particularly within densely populated lecture halls. To tackle these challenges, this paper presents the conceptual development of an evacuation simulation framework. The framework aims to propose a pseudo-code for path selection with a graphical interface tailored for simulating fire emergency evacuations, specifically within lecture halls or theaters. Utilizing 2D/3D model simulations, the framework seeks to replicate crowd evacuation scenarios with varying fire locations, providing valuable insights for enhancing fire safety measures and emergency response strategies. The significance of this project lies in its potential to educate and prepare students and staff in Faculty of Computer Science and Information Technology (FCSIT) teaching and learning facilities for making informed decisions during fire emergencies, thereby improving overall safety and preparedness. This conceptual design serves as a foundational step towards developing a comprehensive simulation tool for effective fire evacuation planning in educational institutions.**

Keywords—simulation application, 2D/3D crowd simulation model, fire evacuation, educational properties & safety

I. Introduction

In the years 2021 to 2023, there has been a decreasing trend in reported fire incidents, from 36014 cases to 17235 cases according to data from the Fire and Rescue Department of Malaysia [1]. However, despite this decline as shown in Fig. 1, fires continue to pose a significant risk to both individuals and their surroundings if not promptly addressed, particularly in densely populated buildings. A newspaper report from 2023 highlighted a fire incident at the Laboratory of Universiti Sains Malaysia (USM), resulting in 60% damage [3]. While it was fortunate that no individuals were present in the laboratory at the time, the incident raises important questions: What if students had been present? and what factors influence evacuation times in complex buildings, and how does the intricacy of building design impact evacuation efficiency?

Fire evacuation simulation may be one of the approaches that can be used to address these questions. Simulation is basically tools allow for the emulation of key behaviour within a system under study, fostering user interaction to deduce behaviour patterns. This expansive framework has proven highly effective for learning, problem solving, and design purposes [34]. Within the realm of fire engineering design, Fire evacuation simulation plays a vital role in fire safety design techniques in visualizing and assessing escape strategies. They serve as valuable guides for constructing systematic buildings that mitigate risks to life from hazards like fire, bomb threats, toxic gas releases, and crowd pressure.

Since the mid-1980s, researchers have employed computer simulations to model fire evacuation scenarios, leading to the development of over 20 safety evacuation models. These models can be categorized into optimization, simulation, and risk assessment types, several of which have practical applications [5]. Some scholars have advanced fire evacuation modeling by combining various techniques to enhance realism. For instance, in a study conducted by [45], simulation techniques using Fire Dynamics Simulator (FDS) were utilized to examine the impact of fire on evacuation density in a university teaching building during an epidemic.

Nonetheless, the fire evacuation simulation in lecture hall or theatre has represent elements such as fixed or pivoting seat rows, fixed or varying aisle widths, flat, stepped, or sloped floors (or combinations thereof), and single or multiple exits with differing sizes and placements and other architectural features commonly found in university teaching buildings [21]. These elements play a crucial role in determining evacuation dynamics, as they can impact movement speed, crowd flow patterns, and potential obstacles during emergencies. Incorporating these details into fire evacuation simulations is essential for developing more accurate and effective fire evacuation simulation strategies tailored to the specific challenges posed by university teaching environments

Fire evacuation in complex buildings presents a multifaceted challenge, as it depends on a myriad of factors including the building's characteristics, the specific emergency circumstances, and individual reactions during crises [17]. Despite the ongoing debate and scrutiny surrounding this issue, stakeholders must navigate a delicate balance between safety protocols, architectural intricacies, and human behavior. Within institutions like universities, diverse architectural styles are evident in lecture halls, auditoriums, sports facilities, cinemas, and more. These structures feature a plethora of design complexities, ranging from fixed or pivoting seat rows, variable aisle widths, to flat, stepped, or sloped floors. Additionally, the presence of single or multiple exits with varying sizes and placements further adds to the challenge. Furthermore, these buildings must accommodate diverse occupant loads and characteristics. As the complexity of these features increases, the analysis and design of evacuation simulations become more intricate, necessitating thorough consideration of numerous factors.

The aim of this project is to create a sophisticated graphical interface tailored specifically for simulating fire emergency evacuations of agents within lecture halls or theatre. This objective encompasses the development of a simulation that incorporates various scenarios occurring within these spaces. The primary focus lies in analyzing how the location of the fire within the lecture hall affects the overall evacuation time of the agents. Through this endeavor, the aim is to provide a comprehensive tool for understanding and optimizing evacuation strategies in emergency situations within such environments. Moreover, the prediction tools and the model, background studies, methodology, problem statement, scope, significance, and the expected outcomes of this project will be defined in further detail.

The significance of this project lies in its role in educating and preparing UNIMAS students and staff for making crucial decisions during fire emergencies. This high-quality graphical interface simulation serves as an educational tool, enabling realistic scenarios within lecture halls/theatre. It allows individuals to visually engage with simulated fire evacuations, fostering a better understanding of the importance of prompt and informed decision-making during emergencies.

Furthermore, enhancing the effectiveness of simulations to mimic various fire emergency scenarios within lecture halls/theatre. By creating diverse scenarios, this project aims to provide a comprehensive learning experience. Through these simulations, individuals can explore multiple evacuation paths and strategies, fostering better preparedness for different emergency situations.

Moreover, focus on understanding how the location of a fire within a lecture hall influences evacuation dynamics. Analysing the impact of fire locations helps in determining the most efficient evacuation routes and strategies. By studying these impacts, this project contributes to improving fire safety protocols, aiding in quicker and more efficient evacuations during emergencies.

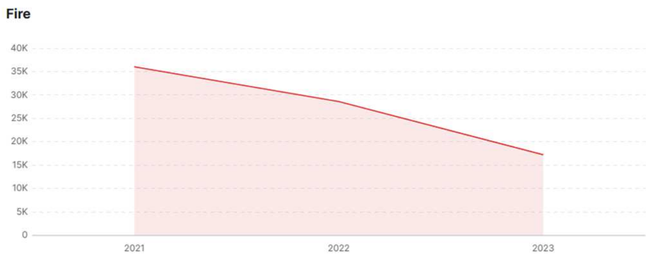

Fig. 1: Trends of Reported Fire Incidents in 2021 to 2023

II. PROBLEM STATEMENT

This project addresses critical issues at UNIMAS related to fire emergency evacuations, particularly the lack of comprehensive studies or dedicated research focusing on fire evacuation protocols specific to the institution. This gap in research directly affects UNIMAS's preparedness and hinders the development of accurate simulations for fire emergency evacuations in lecture halls or theatres using 3-dimensional simulation. While existing literature showcases models like those employed by [31] utilizing Fire Dynamics Simulator (FDS) data integrated into a Unity3D virtual environment for realistic fire scenario simulations in educational contexts, comprehensive, context-specific research in educational settings remains limited. Despite the emphasis on virtual reality (VR), which can incur significant costs, 3D simulations offer a cost-effective alternative, providing greater flexibility in customization and modification without the need for specialized hardware like VR headsets. This flexibility is particularly advantageous for iterative design and testing processes. Additionally, while the research involving real human decision-making may yield accurate results, it often lacks the scalability and computational flexibility that 3D simulations offer, enabling the handling of higher densities of simulated entities and more intricate decision-making processes. Moreover, this challenge extends beyond UNIMAS, highlighting a systemic issue across educational institutions worldwide. Fire evacuation protocols frequently lack the necessary adaptation for the diverse architectural layouts and crowd dynamics encountered in lecture halls and theaters, including the critical consideration of fire location within the lecture hall or theatre. This deficiency significantly hinders the development of realistic simulation scenarios essential for refining evacuation procedures. As a result, it undermines the goal of creating diverse and accurate simulations tailored to the specific requirements of UNIMAS.Additionally, the irregular conduction of fire drills at UNIMAS, especially within the Faculty of Computer Science and Information Technology (FCSIT), exacerbates these challenges. Infrequent fire drills negatively impact the familiarity and preparedness of students and staff of UNIMAS regarding evacuation procedures and optimal paths. Data from recent studies and incident reports can illustrate this point further. For instance, evacuation times to empty UNIMAS building is 7 to 10 minutes [1]. Additionally, according to a survey by Fu (2023), a substantial portion of the student body lacks basic fire safety training, with 38.83% of students having never participated in fire drills and about 10% incorrectly believing that elevators are safe for evacuation during a fire. This lack of routine practice contributes to a decline in knowledge retention, potentially causing delays and confusion during emergencies, as individuals may forget essential actions. The absence of regular drills increases the risk of panic, congestion at exit points, and potential injuries or stampedes during evacuations. Consequently, the combination of insufficient research on fire evacuation protocols and irregular fire drill practices directly hampers the institution's comprehensive preparedness for fire emergencies. These limitations obstruct the objectives of creating effective and tailored simulations and analyses for fire emergency evacuations in UNIMAS lecture halls or theatres, underscoring the urgent need to rectify these deficiencies to enhance safety and preparedness. Addressing this gap not only benefits UNIMAS but also sets a precedent for improving fire safety protocols in educational institutions globally**.**

III. LITERATURE REVIEW

In the context of education fire safety and evacuation protocols, understanding the pathfinding behaviour of individuals towards the nearest exit is crucial. Educational buildings, with their dense population, diverse facilities, and potential fire hazards, necessitate efficient evacuation strategies. [22] contributes to this understanding by delving into the fire safety of educational buildings and analysing various fire types and hazard sources. Employing simulations through PyroSim and Pathfinder, the study identifies critical factors like smoke height and evacuation times for different exit routes, emphasizing the importance of knowing the location of the nearest exit in fire emergencies to minimize overall evacuation time.

Aligned with UNIMAS's Occupational Safety & Health Guidelines: Emergency Preparedness [1], individuals are directed to prioritize safety measures, including immediate evacuation and utilizing the nearest stairwell. However, if stairwells are obstructed by fire, the protocol recommends seeking refuge in designated areas equipped with communication capabilities. This underscores the significance of identifying the nearest exit as outlined in UNIMAS's evacuation protocol, which aims to reduce overall fire evacuation time. Integrating such research findings into evacuation protocols ensures a comprehensive understanding of pathfinding behaviours and their impact on evacuation efficiency, thereby enhancing preparedness for fire emergencies in educational settings. By aligning evacuation procedures with empirical evidence and UNIMAS's protocol, educational institutions can optimize safety measures and effectively mitigate risks, ensuring swift and safe egress to the nearest exit and minimizing overall fire evacuation time.

Crowd simulation, widely recognized for mimicking virtual individuals' movements, has gained significant traction across diverse research domains [43]. Its fusion with exploring how fire locations affect evacuation dynamics in Faculty of Science Computer and Information Technology (FSKTM), Universiti Sarawak Malaysia's has sparked substantial interest. This exploration investigates whether fire placement in a lecture hall influences evacuation speed, including the choice of exit doors designated as safe zones in simulated scenarios. The goal is to validate the accuracy of simulated fire evacuation scenarios in lecture halls compared to real-life events. Moreover, it aims to assess how the application of crowd simulation through 2D/3D model-based approaches could enrich insights and advancements in this domain.

Despite being extensively studied, crowd simulation resources, specifically regarding crowd modeling and the impact of fire locations in UNIMAS lecture halls and theaters on the total duration of fire evacuations, remain relatively scarce. This scarcity poses elevated risks in fire evacuation incidents due to the unpredictable and fluctuating nature of hazard positions and severities. Such unpredictability can significantly complicate evacuating from disaster zones, particularly when individuals act erratically, exacerbating safety concerns, especially within a crowd [16]. For instance, during the Iroquois Theatre Fire in 1903, 602 individuals tragically perished as they became trapped and crushed while attempting to escape the flames [32].

To comprehensively explore this topic, constructing and examining crowd simulation dynamics in fire evacuations from lecture halls and theaters becomes imperative. The Theater Multimedia (TMM) facilities at FCSIT, UNIMAS, serve as primary references for this endeavor. Building on the assessments by [23] regarding room type characteristics, specific attributes of these spaces are identified, encompassing fixed seating, aisle dimensions, stepped and flat flooring, along with sloped areas for student seating. These areas feature multiple exits, including one at the front corner and two at the rear of the room. In [10] study, classrooms with central pathways proved most effective for evacuation, but longer delays increased reaction times. This underscores the importance of layout and quick decision-making in designing evacuation plans for schools.

In addition to the noted advancements in crowd simulation, it is pertinent to highlight relevant research conducted in the context of fire safety and evacuation simulations in college buildings. For instance, [22] conducted a comprehensive analysis of fire dynamics and evacuation simulations in college buildings, emphasizing the unique challenges posed by dense populations, experimental instruments, and flammable materials on campuses. Using advanced simulation tools such as PyroSim and Pathfinder, the study investigated the impact of fire on evacuation processes, including critical factors such as smoke height and evacuation time for different exit routes. While, in this paper focuses on the impact of fire within lecture hall or theatre on the total fire evacuation time and it also differ in term of software tool such as Unity that leverages to create realistic simulation tailored to lecture hall or theatre.

Furthermore, while [48] demonstrated the effectiveness of agent-based models (ABMs) in fire evacuation simulations, their application in museum settings may constrain the generalizability of their findings to educational environments. In contrast, the research was specifically tailored to educational buildings, acknowledging the distinct challenges and dynamics inherent in such settings. By customizing the simulations to educational contexts, it sought to offer more relevant and actionable insights to enhance fire safety measures and emergency response strategies in educational institutions.

By tackling these limitations head-on and leveraging the capabilities of 3D Unity simulations, the project aimed to make a significant contribution to the field of fire safety research in educational environments. Through rigorous analysis and validation of the simulations, the endeavour was to provide invaluable insights that could inform policymaking, infrastructure planning, and emergency preparedness efforts in educational institutions.

Crowd modeling has its roots before the year 2000 and has since undergone extensive evolution. It functions as a tool to visually represent the dynamic behavior of humans and predict future outcomes based on different scenarios. Following the turn of the millennium, crowd-related papers underwent continuous dynamic evolution from 2000 to 2023. The chronological progression of these papers' evolution is depicted in Fig. 2.

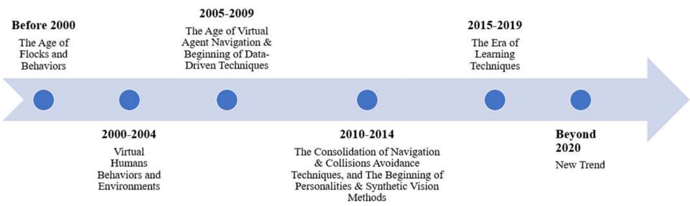

Fig. 2: Evolution of Crowd Simulation Paper [35]

This chapter explores previous crowd simulation studies, making comparisons with this project regarding models, tools, and other aspects. It also clarifies essential theories, concepts, definitions, and terminology within crowd simulation, aiming to enhance the comprehension of the project's direction. This effort aims to provide substantiating evidence for the practical issues targeted by this project.

According to [6] significant figures in the advancement of crowd simulation literature, a crowd can be defined as the gathering of numerous agents in a confined area simultaneously, with its density presumed to be high enough to facilitate ongoing interactions or reactions with others. Through the conceptualization of crowds, a crowd model is constructed, emphasizing the simulation of agents' behaviors and movement patterns within a collective. This model considers factors such as density, speed, and direction, employing simulation principles.

The notion of crowd simulation can be categorized into three distinct types: visualization, simulations, and real-time simulations. It's crucial to distinguish between these three concepts to prevent any confusion. Table 1 presented below outlines the disparities between visualization, simulations, and real-time simulations.

TABLE 1: COMPARISON OF CROWD SIMULATION CONCEPT

Visualization	Simulation	Real-Time Simulation
It is the data's representation.	A simulation replicates the functioning of real-world processes or systems by employing models.	Performing the simulation in sync with real world time [46].
It takes complicated data and converts it into an easy-to-understand 2D graphic, graph, graphic image, or even 3D animation.	It produces precise data on their performance, use, and total impact on output over time.	Produces real-time data that syncs with the real-world event in real time [46].
Example graph, bar chart, pie chart,etc.	Example evacuation simulation, aviation, manufacturing, etc.	Example flight control system, traffic control system, industrial automation system, etc. [46].

IV. Methodology

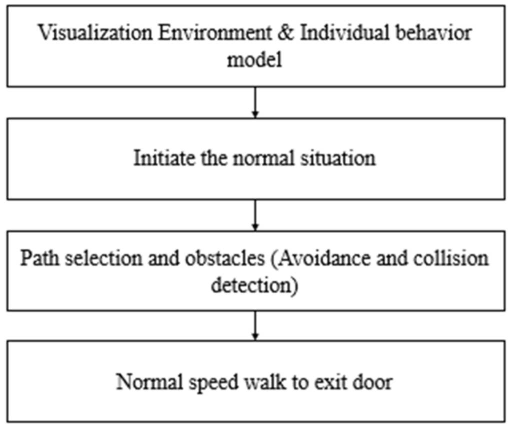

Fig. 3: Framework of Normal Situation Process Flow

Utilizing simulation techniques is a versatile approach for analyzing and predicting various scenarios across different disciplines. Creating an immersive crowd simulation during panic situations that accurately replicates real-world conditions poses a significant challenge in crowd simulation design. This challenge arises from the need to adhere to specific requirements that mirror real-life scenarios and allow testing of diverse strategies and scenarios. Hence, defining these requirements and planning the crowd simulation process becomes crucial, encompassing aspects like individual behaviour within the crowd, environmental layout, technical specifications, requirement goals, methodology, and more.

In this chapter, the development of the fire evacuation simulation will follow an iterative development cycle. This methodology involves breaking down the project into smaller segments, enabling a detailed focus on developing each part. This approach, especially crucial during the requirement phase, contributes to achieving a highly immersive simulation. Additionally, iterative development cycles offer flexibility in adapting to changing requirements, expedited delivery, and mitigated risks of project failure.

Moreover, specific boundaries have been established to ensure the scope remains tightly aligned with the defined objectives. The simulation is concentrated on the Theatre Multimedia lecture hall in Block A of UNIMAS's Faculty of Computer Science and Information Technology (FCSIT), involving at least 100 students and staff members. It utilizes a visually represented, agent-based model to accurately simulate and analyse crowd behaviour during a fire evacuation. This methodology provides valuable insights into movement, interaction, and exit strategies, enhancing overall safety measures.

Key functionalities such as collision detection and avoidance are incorporated to ensure realistic agent interactions. Factors considered include fire node, human density, walking speeds, velocities, room architecture, and stair inclines. Graphical representations are employed to evaluate evacuation times to designated safe zones at exit doors. The overall approach is focused exclusively on human behaviour during fire emergencies within the building, maintaining relevance and adherence to the primary objectives.

During the design phase, the objective is to translate the requirements into a detailed and comprehensive system design specification. This guarantees that the fire evacuation simulation in the lecture hall performs the intended processes. The Fig. 3 illustrates the framework depicting the process flow in a normal situation within the lecture hall when no fire-related event occurs, representing the typical daily routine of students (agents) entering the lecture hall without any unforeseen incidents, whilst Fig. 4 shows the framework for panic situation process flow.

This flowchart illustrates the visual sequence of events during an evacuation in a lecture hall when a fire breaks out. It begins with a "Visualization Environment & Individual Behavior Model," which sets up the simulation of the environment and the behaviors of individuals within it. When a fire is initiated in a specific node within the lecture hall, panic mode is triggered among the occupants. As panic sets in, the process of path selection begins, incorporating strategies for obstacle avoidance and collision detection to navigate through the environment safely. Despite these measures, the situation can lead to clogging and a stampede at the exit door due to the convergence of many individuals trying to exit simultaneously. This sequence underscores the complexity of managing crowd behavior and ensuring safe fire evacuation during emergencies.

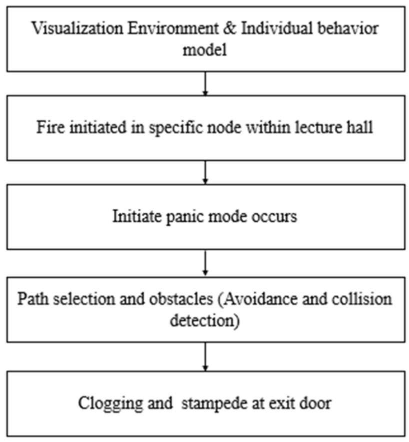

Fig. 4: Framework of Panic Situation Process Flow

Fig. 5 visualized the flowchart of path selection of agent within the lecture hall or theater. The evacuation process begins with the detection of a fire, which initiates panic mode. The system identifies all available exit doors and evaluates the safety of each one. Any exit doors obstructed by fire are disregarded, and the distances to the remaining exit doors are calculated. The system decides whether to choose a random path or follow a predefined path based on the nearest and fastest route based on the setting of the simulation. If a random path is chosen, it is selected from the available options. Regardless of how the path is chosen, it must pass a feasibility check to ensure it is free of obstacles and safe to use. If the path is feasible, the agent moves toward the selected exit door while avoiding obstacles and detecting collisions. This process continues until the agent reaches the exit door. If the initially chosen path is found to be infeasible, the system reevaluates and selects another path either random or predefined. Then repeats the feasibility check and navigation process. Once a feasible path is confirmed and successfully navigated, the agent exits the building safely. This method ensures that both randomly selected and predefined paths are carefully assessed for safety and navigability during an emergency evacuation.

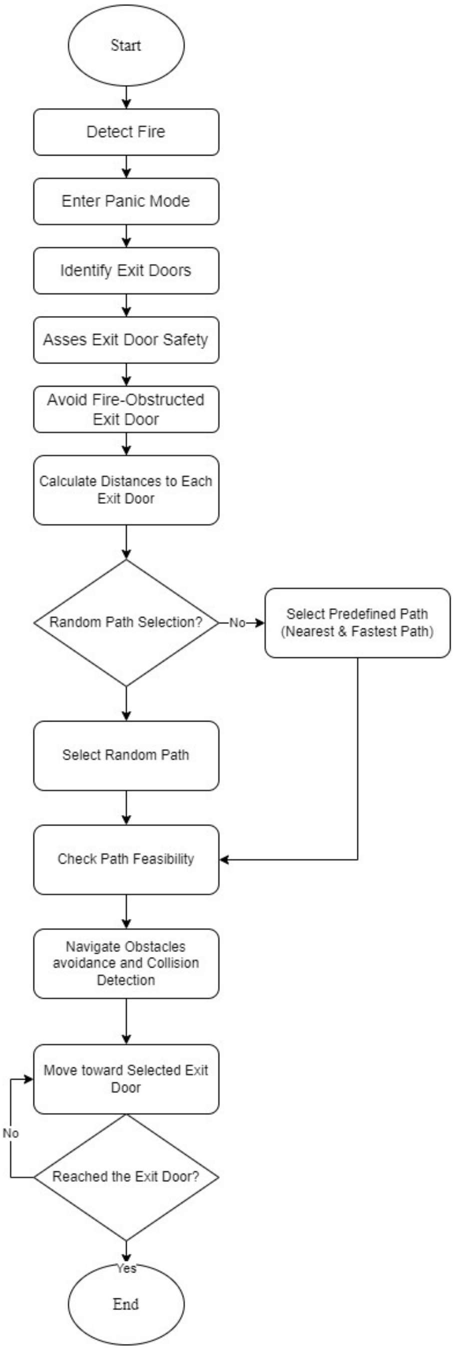

Fig. 5: Flowchart of Path Selection of Agent

Moreover, calculating the distance of agent to each potential safe exit door that agent can evacuate is important in designing the overall fire evacuation simulation. Fig. 6 below shows the pseudocode of calculating distance to potential exit door in algorithmic way using Euclidean distance formula in the form of 3 dimensions.

```
//Function to calculate the Euclidean distance between two points in 3D
def calculate_distance(point1, point2):
    x1, y1, z1 = point1
    x2, y2, z2 = point2
    distance = math.sqrt((x2 - x1)**2 + (y2 - y1)**2 + (z2 - z1)**2)
    return distance
```

Fig. 6: Pseudo-code of Calculating Distance in 3 dimensions

This research employs a variety of tools to develop an advanced fire evacuation simulation. It is recommended to use the latest versions of Windows, such as Windows 10 or Windows 11, as the operating system. Unity Pro is utilized for integrating and designing simulations due to its capability to structure three-dimensional environments. Additionally, software such as Blender and Visual Studio are integrated with Unity Pro to enhance the development process. The programming languages used in this project are C and C++. Web browsers, including Google Chrome, are used to source models and materials essential for constructing the fire evacuation simulation.

V. Proposed Design and Interface

Fig. 7*:* Theatre Multimedia Room, FSKTM, UNIMAS

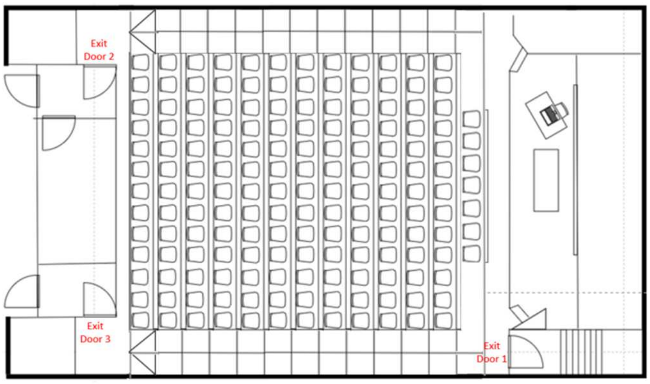

Fig. 8*:* Layout Structure of Theatre Multimedia Room, FSKTM, UNIMAS

Evacuation planning is a crucial component of building safety, especially in areas with complex layouts. Understanding the placement and immovability of obstacles is essential for developing effective evacuation strategies. Fig. 7 present the lecture hall or theatre layout in real world, while Fig. 8 above present the layout of the Theatre Multimedia room within the FCSIT structure in the 2 dimensional, which will be used as a reference for constructing the 3-dimensional fire evacuation simulation.

These illustrations detail the arrangement of obstacles in the room, such as pivot tables, walls, tables, chairs, and slopes/stairs. The fixed nature of most of these obstacles facilitates a smoother evacuation process, as there will be fewer scattered items throughout the room.

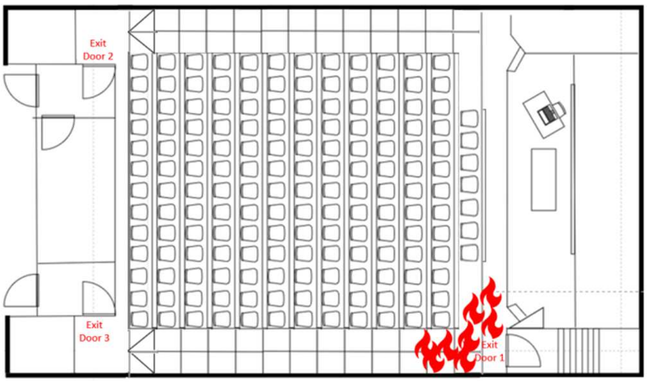

Fig. 9: Initiation of Fire Near Exit Door 1

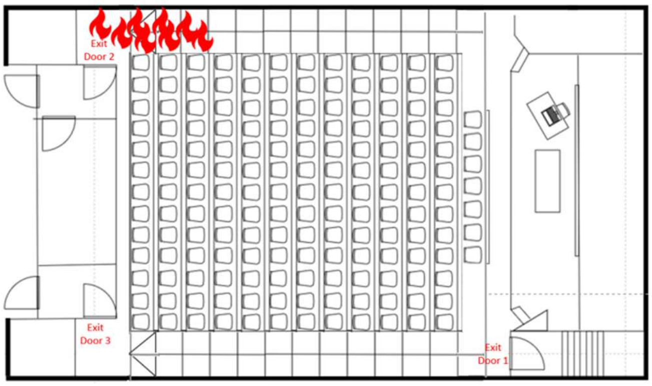

Fig. 10: Initiation of Fire Near Exit Door 2

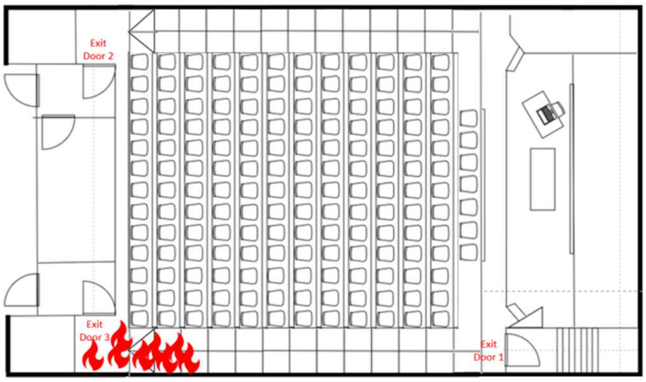

Fig. 11: Initiation of Fire Near Exit Door 3

Fig. 9, Fig.10 and Fig. 11 above depict the layout of the obstacle of fire within the lecture hall or theatre when the fire initiated in specific node such as near exit door 1, near exit door 2 and near exit door 3. By systematically changing the fire initiation node and analyzing the outcomes, safety planners can develop a robust, flexible evacuation and emergency response plan that enhances safety for all occupants, regardless of where a fire might start. This approach not only saves lives but also significantly reduces the potential for panic and injury during a fire emergency. Thus, enhancing occupant safety education.

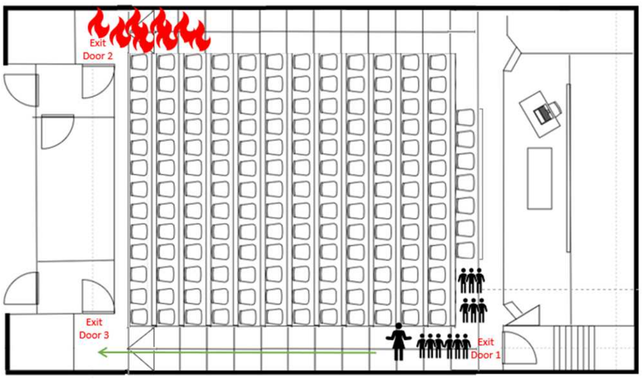

Fig 12: Path Selection When Fire Occurs Near Exit Door 2 and Blockage Near Exit Door 1

Meanwhile, Fig. 12 showcase one example of path selection of agents when fire occurs near exit door 2 and at the same time, blockage due to overwhelm agents near exit door 1 is blocked. The green arrow shows the alternative path that agent can take which is the exit door 3 to evacuate the lecture hall or theatre by avoiding traffic near exit door 1.

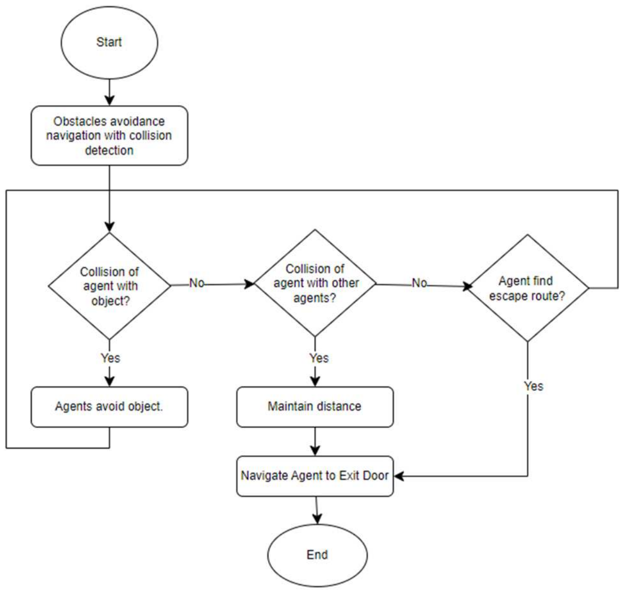

Fig. 13: Flowchart of Obstacle Avoidance and Collision

Fig. 13 above shows the flowchart of obstacles avoidance and collision of agent individual behaviour in overcoming between agents and object within the lecture hall or theatre. It begins with initialize agent such as density of agents, setup simulation environment and fire initiation. When panic movements are initiated, each agent is tasked with selecting their preferred evacuation path from the lecture hall. If the agent and object collide, agent must avoid the object and agent collide with other agents, agents must avoid the agents. Throughout the agent's evacuation, agents must maintain a minimum distance between themselves and objects to avoid collisions. Finally, if agents have found the escaped route, agents can evacuate from the lecture hall or theatre. Additionally, they need to steer clear of any objects obstructing their pathway towards the exit doors to ensure a smooth evacuation process by choosing the right path to evacuate.

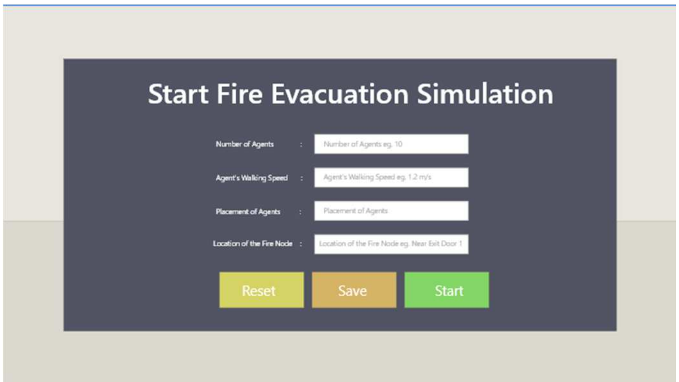

Fig. 14: Wireframe of Fire Evacuation Simulation Setting Parameter User Interface.

Fig. 14 presents the simulation setting interface, where users begin by selecting various parameters from dropdown menus, such as the quantity of agents, their walking speed, placement within the scene, and the fire node's location. This interface empowers users to tailor the simulation to their specific needs, enhancing data visualization effectiveness. Additionally, the interface features buttons like "save," "reset," and "start." The "save" button stores user-selected parameters for future reference. After selecting the necessary parameters, users can trigger the evacuation simulation by choosing the "start" button. This action not only generates a 3D scene reflecting the provided parameters but also initiates the evacuation process, prompting agents to exit the room. The commencement of the fire evacuation process is indicated. The "reset" button allows users to swiftly clear all selected parameters, streamlining navigation within the simulation interface.

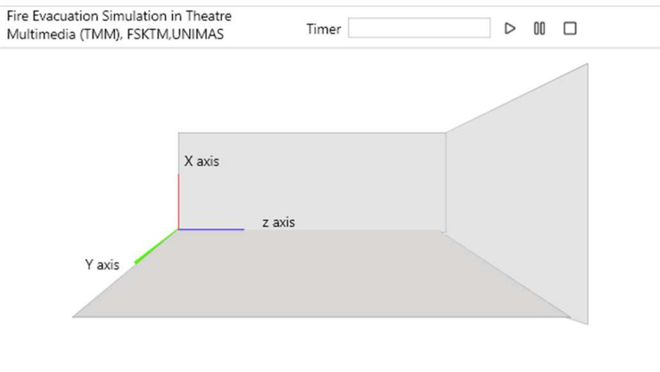

Fig. 15: Framework of Fire Evacuation Simulation Starting User Interface

The central focus of the user interface design in this project lies in its pivotal role of facilitating user interaction, thereby enabling users to effectively control and engage with the fire evacuation simulation. This interaction is aimed at heightening user immersion within the simulation environment. Within the interface, users will find various buttons, including start, restart, stop, and resume, providing them with the capability to initiate, pause, and resume the simulation as needed. Additionally, a stopwatch or timer feature will be integrated to allow users to monitor and analyse the overall evacuation duration of agents from the lecture hall. These features will be positioned at the top of the 3D dimensional simulation within the user interface, operating seamlessly alongside it. In Fig. 15, it shows the 3D simulation employs x, y, and z axes; the stopwatch feature will be displayed in a 2D format. The combination of these 2D and 3D dimensions in the user interface will provide enhanced flexibility in integrating the simulation.

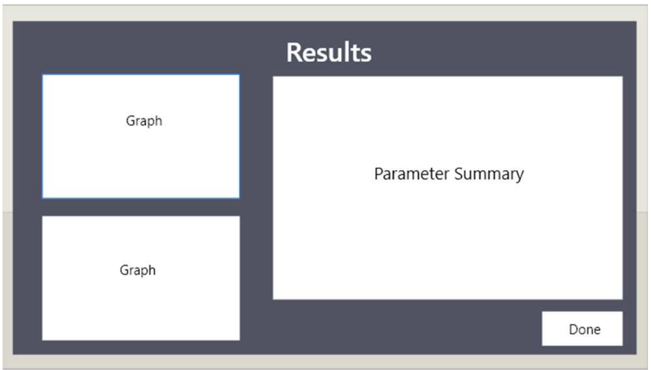

Fig. 16: The proposed interface for evacuation time analysis

Furthermore, Fig. 16 shows the proposed interface for evacuation time analysis result. The user interface will feature a graphical representation in visualization layout in 2D form, providing users with a visual tool for monitoring and analysis purposes. These graphical graphs will display multiple metrics of the simulation result, such as the analysis of total evacuation time concerning the number of existing agents and other relevant factors after the end of the simulation ended which means every agent has evacuate from the room. Additionally, the project will conduct scenarios based on the fire's location within the lecture hall, adding depth to the simulation's usability and analytical capacity. The result will be important for the analysis of the further fire evacuation simulation.

VI. Evaluation

The focus revolves around testing and implementing the simulation into a base model application. The primary goal is to integrate the dynamics of fire evacuation within the lecture hall into a simulation format that aligns with all established requirements and design specifications. Should the simulation fall short of meeting these criteria, a series of testing and troubleshooting procedures will ensue until the simulation aligns with the overarching requirements, goals, objectives, and other specified criteria.

In the evaluation phase of this project, a critical examination of the fire evacuation dynamics simulated within a lecture hall will take place. This assessment aims to thoroughly assess the simulation's quality across various dimensions: how immersive it feels, its accuracy in replicating real-world scenarios, its scalability in accommodating different conditions, its interactivity for engaging users, and its overall performance in simulating fire evacuation scenarios. The analysis of these facets will provide insights into the simulation's effectiveness and usability.

This evaluation holds immense importance as it serves as a benchmark to determine if the simulated fire evacuation in the lecture hall aligns with the project's overarching goals and objectives. It acts as a litmus test, ensuring that the simulation achieves its intended purpose of providing a reliable and effective tool for preparing individuals for fire emergencies in educational environments like UNIMAS.

Post-implementation of the fire evacuation simulation, a comprehensive survey will be conducted among UNIMAS students and staff. This survey seeks to understand their decision-making processes when selecting exit pathways during fire emergencies. The objective here is not just to gather data but to actively enhance awareness and preparedness among the participants.

The survey methodology involves a three-stage process. Firstly, participants will be presented with scenarios representing various fire locations within the lecture hall. The participant will be asked to choose their evacuation routes without any prior knowledge or guidance. Next, they will be given a brief presentation on the correct evacuation procedures while observing the simulated scenarios. This stage aims to educate and inform them about the best practices during fire emergencies.

Finally, participants will be requested to revisit the survey questions, providing an opportunity to gauge how their responses have evolved after receiving guidance and witnessing the simulated evacuation scenarios. This comparative analysis of their initial and final responses will offer insights into the effectiveness of the simulation in enhancing the participants' awareness and preparedness for fire emergencies. This structured approach allows for a thorough assessment of the simulation's impact and effectiveness in addressing the project's objectives and challenges.

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