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Agent Based Evacuation Simulation Using Leader-Follower Model

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Abstract— Agent based simulation is a widely developing area in artificial intelligence. The simulation studies are extensively used in different areas of disaster management. This work deals with the study of an agent based evacuation simulation which is being done to handle the various evacuation behaviors. Various emergent behaviors of agents are addressed here. Dynamic grouping behaviors of agents are studied. Collision detection and obstacle avoidances are also incorporated in this approach. Evacuation is studied with single exits and multiple exits and efficiency is measured in terms of evacuation rate, collision rate etc.Net logo is the tool used which helps in the efficient modeling of scenarios in evacuation.

Index Terms— Agent based modeling and simulation, Collision avoidance, Evacuation simulation, Leader-Follower, Multi-agent simulation, Net Logo, Way-finding process.

1 Introduction

Agent-based modeling and simulation is anew approach of modeling systems composed of autonomous and interacting agents. In this approach the dynamic processes of agent interaction are simulated over time. Applications of agent technology are widely used in different phases of disaster management cycle.

Aim of this work is to develop an agent based evacuation simulation system that studies and analyzes the different agent behaviors during evacuation. Traditional simulators omitted the personal differences in agent behaviors which are quite important to simulate real world environments. Another problem with them was the difficulty in converting human behaviors into physical models [1].

In an evacuation simulation, the main entities are people and their behaviors, so here we go for a multi-agent simulation. Multi-agent frameworks can be used to simulate human and social behaviors during evacuations efficiently. Here, basically a Leader-Follower model is incorporated where leaders and followers are the two main groups of agents in the simulation. Different cases, rules and scenarios are used to implement the simulation. The agents behave based on these rules and scenarios. Agents are grouped here based on various attributes like gender, color, health etc. All these attributes and behaviors are efficiently incorporated and simulated using a multi-agent simulation toolkit Net Logo.

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2 Related Works

In multi-agent simulations the human and social behaviors are simulated in an effective way. Human behaviors are complex emergent phenomena which are difficult to be captured by computers as mathematical equations [3]. To model such emergent behaviors and non-adaptive crowd behaviors we go for a multi-agent framework [2]. Most important part of evacuation simulation in any disaster event is the people involved. Different people exhibit different behaviors during panic situations. Traditional simulators omitted these differences and as a result they produced unrealistic outputs.

It was seen in [1], [3] that to make simulations realistic these differences in human behaviors has to be incorporated to the simulation system. It is found that most effective method of safe evacuation simulation is using Leader-Follower model in [9], [11]. It was seen in [1], [3] through that to make simulation realistic these differences in human behaviors has to be incorporated to the simulation system. It is found that most effective method of safe evacuation simulation is using Leader-Follower model in [9], [11]. Classification of agents is also important for efficient simulation. So the agents are broadly classified as leaders, followers and leavers. We see that classification of agents is also extended based on training factor and many other attributes in [1], [11], [3].

Incomplete knowledge of building geometry was considered to be the most important factor of panic. Grouping of agents is an important part, especially when we use Leader-Follower model in the simulation. Static as well as dynamic grouping schemes are proposed but it is recommended that dynamic grouping is to be used for more efficient simulations. Many parameters are considered as critical in simulation of evacuation such as number of exits, number of hazards, floor plan, number of agents, number of trained agents, and number of leaders and so on[11]. So all these factors are to be considered in an evacuation simulation performed in a building [8], [11, [2].Net Logo is a widely used multi-agent simulation tool and it is being used in most of the simulations. It helps to model the Leader-Follower concept in an efficient way. Net

Logo features provide a realistic simulation output, as well as a 3D output [6], [12]. Obstacle avoidance and collision check is also incorporated but only in a minor way as described in [13].

Crowd dynamics is also a critical part of evacuation. Crowd stampedes at staircases and elevators have been studied in [13]. Pedestrian flow rates and density effects are also critical. Decision skills of agents are considered to be influenced by factors like environmental complexity, changing situations and time pressure. It is found that during emergency most of the normal behaviors of people change and as nervousness increases there is less concern about comfort zone and safe exits. Normal people lose their ability to orient themselves in an environment. Thus they start showing non-adaptive crowd behaviors. So these behaviors must be analyzed thoroughly for simulating such an environment [8], [10], [13].

3 PROPOSED SIMULATION SYSTEM

In this section, the proposed method is discussed and each phase is explained briefly with screenshots of simulation behavior for each phase.

3.1 Leader-Follower Model

Leader-Follower model is used in simulating the proposed system where the followers follow leaders to escape .As the scenarios complication can extend to various levels, modeling of behaviors become complex.

In this simulation environment the main entities are people and they have obviously different behaviors. Thus the agents in system are grouped by giving them specific characteristics. The critical aspects of simulation include determining the best routes, foreseeing potential problems, addressing the chaos/panic factor and orchestrating the evacuation [8]. Grouping, learning, collision avoidance and rule based approaches are used to simulate different scenarios.

Inputs to the system are the agents and geometrical configuration of build and rooms. Agents are categorized based on different attributes. Agents are divided into 3 main categories:

- Leaders
- Followers
- Leavers

Each of these categories of agents has specific behaviors. The categorization can be done mainly based on training. Here leaders are supposed to be trained and thus they have good knowledge about geometrical configuration and help others in evacuation process. Leavers can be termed as an untrained leader, they are people who can handle stress situations and leave individually. The Last group followers can be termed as untrained non-leaders who might panic during disaster situations and need the help of others to get evacuated.

Training is specified in terms of learn value. Initially only leaders have knowledge about the building or room configuration. So they have learned value set to an arbitrary value. As the simulation progresses and when the agent perceives an obstacle, the corresponding path gets recorded. This path can be avoided in next move, thus avoiding the encounter with the same obstacle. The agent thus learns that path or gets trained. This is meant mainly for leavers who leave individually. Followers and injured agents merely follow the behavior of leaders to have safe evacuation.

The classification of agents can be extended in terms of the specific attributes that we assign to them. These attributes include:

- Color
- Shape
- Gender
- Speed
- Health

In Fig 1 the architecture of simulation system is given.

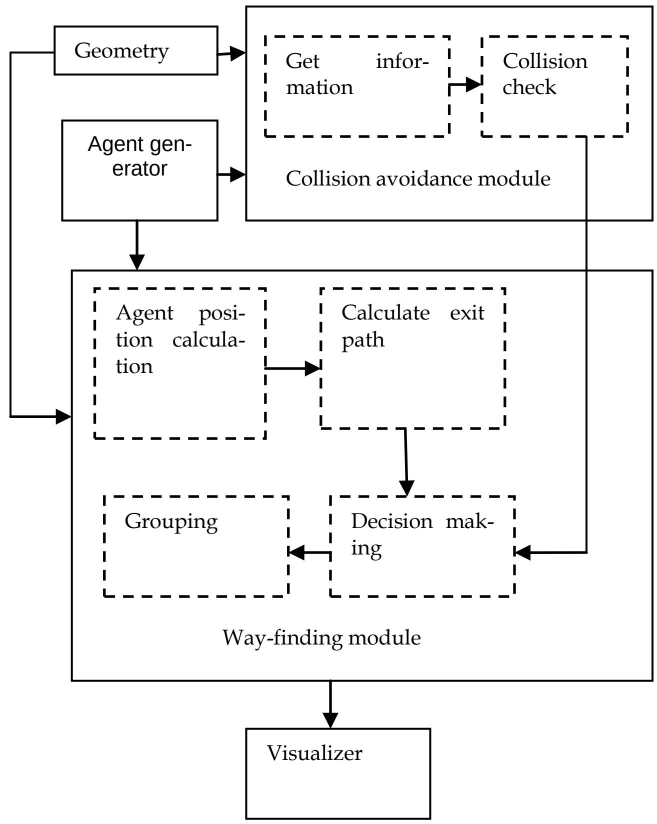

Fig 1.General architecture of the proposed system

3.2 Way-Finding Module

This module is the main part of simulation system. Here the exit path finding is performed. it includes the following submodules as in fig 1:

- Agent position calculation
- Exit path finding
- Decision making
- Grouping

Initially the leaders calculate their current position and with respect to this position they find the exit paths. After this leaders find the nearest exits, which is the exit that is lying at minimum distance from the corresponding leader. So decision is made in finding the nearest possible exits. Here collision check is also performed which will be described in the next module. Through collision check agents avoid obstacles around them. Leavers also learn the geometrical configuration

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and proceed in the same way as leaders to find exit paths. Here leaders and leavers can find their exit paths but followers can't leave individually. Followers have to follow leaders and in some situation they follow the leavers to get evacuated.

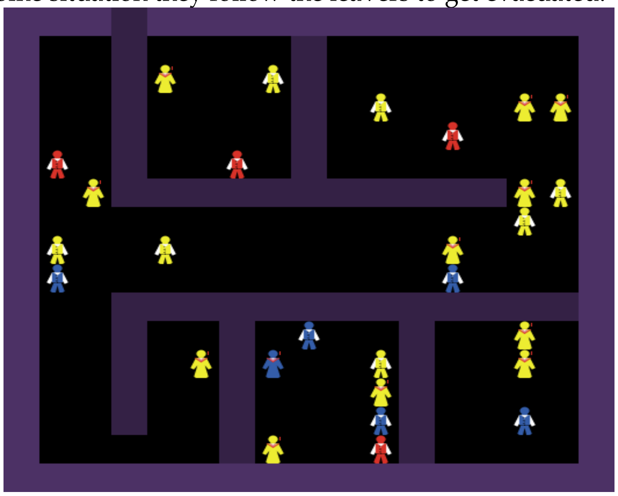

Fig 2. Initial set up of the system

The initial set up of system is shown in Fig 2. Here leaders are in red color, leavers in blue and followers in yellow color. To follow the leaders a grouping mechanism is used as shown in Fig3. Here the followers follow leader and leader has to ensure their safe evacuation. So grouping is done mainly between leaders and followers. If there are no leaders in a specified radius of vision of followers the grouping is also made with leavers. If the followers are healthy, they can find their nearest leaders in terms of geometrical distance. So these followers find their leaders and group with them by creating links with the leaders. If the followers are injured the leaders themselves find those followers nearer to them in some radius and group with them. The grouping is dynamic since it changes as agent move across the room or building (as agent moves their nearest neighbor's changes).

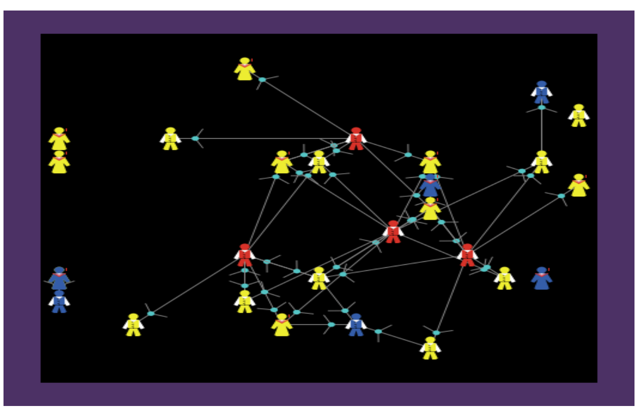

Fig 3. Grouping between agents

The flow chart representation of way finding procedure in blocked exit scenario is shown in Fig 3.

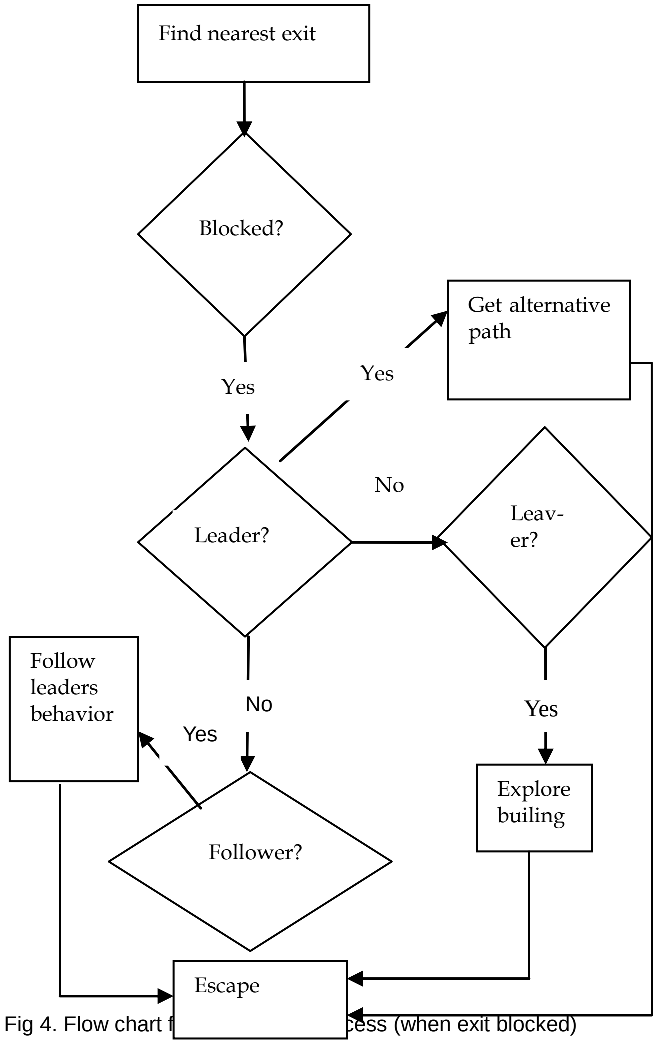

Fig 4. Flow chart f… cess (when exit blocked)

As shown in Fig 4 agents find their nearest exit initially .If the exit is blocked and if the agent is a leader (trained) it gets an alternative path. If the agent is not trained but leaver it starts exploring the building as this group can leave individually. Finally if the agents are followers (untrained) it follows the leader's behavior. The escape behavior through minor (light brown color) and main exits (dark brown color) is shown in Fig 5.

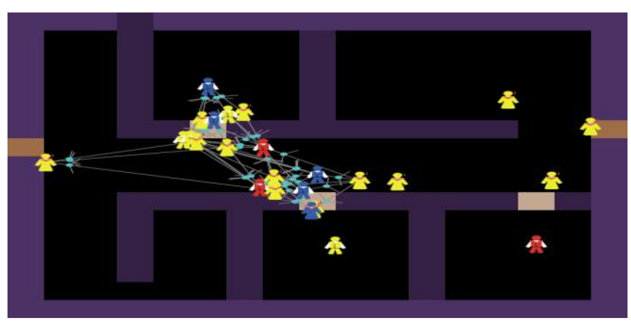

Fig 5. Escape behavior through exits

Here the agents in room firstly find their corresponding minor exits and then find the nearest main exits to have the safe escape. The leaders assure that all followers in their surrounding area escape safely for providing a complete evacuation.

3.3 Collision Avoidance Module

Here the various collision checks and obstacle avoidances are done in this mod. It has two sub-modules which include:

- Getting informations
- Collision check

Initially the agents perceive the environmental or world informations. Then they use these informations to do different collision checks to provide efficient evacuations. Collision check is basically performed to reduce the collision between agents and collision of agents with walls and this is mainly used for obstacle avoidance. This is performed in simulation by adding obstacles to the agent environment. The added obstacles block main exit. So if we have two main exits and one exit is blocked, agents have to choose the next nearest exit (the other exit).This is implemented using a learning scheme. First time when the agent encounters an obstacle (other than walls) it will learn so that next time it can avoid that obstacle. If one agent learns this, it can also take the other agent away from obstacle. Obstacles can be fire, broken walls or any other thing that blocks the exit path. In Fig 6 the obstacle is shown in green color.

Collision avoidance is done in the following way:

1. If heading (head) of two agents direction = opposite
   Then set heading (180-heading)//take side shift
   //avoiding collision between agents
2. If xcor & ycor = max or wall coordinate
   Then take side shift.//avoid collision between walls
3. If obstacle of patch-ahead = true//an obstacle in front
   Then set heading (heading +90) or (heading -90) and forward.//avoiding any obstacle

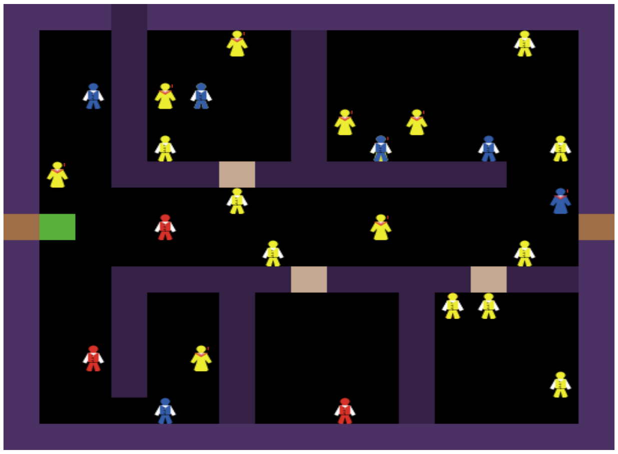

Fig 6. Blocked exit (in green patch)

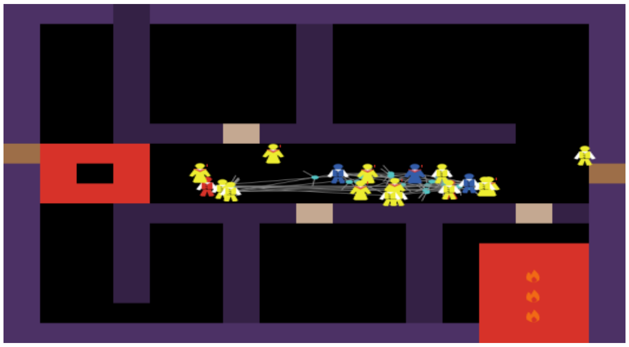

Fig 7. Avoiding obstacles

In Fig 7 the obstacle represented by fire is shown and also the affected area is shown in red color.

4 TOOL USED

Multi-agent based Simulations (MAS) is used to efficiently simulate human and social behaviors during emergency evacuations. The problem here is to make the simulation realistic such that the agents act as real world entities. The complexity of scenarios can extend to various levels, and modeling of the agent behaviors become complex. Hence we go for a tool that sorts out these problems to a great extent. The tool used here is Net Logo.

Net Logo is a multi-agent modeling environment and it is used for simulating natural and social phenomena. It is particularly well suited for modeling complex systems evolving over time. We can give instructions to thousands of independent “agents” which are all operated concurrently. This makes it possible to explore connections between micro-level behaviors of individuals and macro-level patterns that emerge from their interactions. Historically, Net Logo is the next generation of series of multi-agent modeling languages including Star Logo. Net Logo is a standalone application written in Java so that it can run on all major computing platforms and it is a free-ware.

As a language, Net Logo is a member of Lisp family that supports agents and concurrency. Mobile agents called “Turtles” move over a grid of “patches” which are also programmable. All of the agents can interact with each other and perform multiple tasks concurrently.

4.1 Implementation

Net Logo is widely used in MAS. For the proposed simulation system Net Logo 5.0 is used. The main three agents in the system, viz. Leaders, Followers, and Leavers are designed as turtles (agents) of Net Logo world. They are assigned with specific shape and color. Attributes like gender and health are also added to them. Different group of agents are created using the concept of “breeds” (Breeds are groups of agents).

In Net Logo, the environment of agents is designed using patches concept. Patches are used to design different room configuration. These configurations can be chosen manually using “chooser” utility in Net Logo. “Setup” button is used to start the initial configuration. The number of each breed of agents and speed is set using "slider" utility.

We can also label the nearest exit and nearest leader if needed using switch utility. Next we have to place exits using "place exit" button that helps us to place major and minor exits. Obstacles can be chosen using "obstacle button" only if switch is on. The leaders, leavers and followers can be labeled. "Ride" button implements the function ride in Net Logo that helps to follow the behavior of single agent in the view window. The results are obtained in an output display and monitors. The monitors give the number of agents initially present, number of agents after evacuation simulation, number of agents escaped etc. Graphical results are obtained in plots. We can also make the movie of the current simulation using the Net Logo command 'movie'.

5 RESULTS

The aim of this work was to efficiently simulate the various behaviors of agents in evacuation simulation. The main result is the simulated output that can be seen in 3D and 2D using Net Logo. Other results are obtained in the various interface builders of Net Logo like monitors, plots and outputs. Experiments were conducted with mainly two room configurations, one simple and other complicated. To compare and analyze different factors like evacuation rate, collision rate etc experiments were conducted in different scenarios. Simulations were conducted by varying the number of each group of agents, varying the number of main exits and running simulations with and without obstacles. Two main configurations of room with different complexity are selected for performing the simulations and the results are compared.

In the first experiment a simulation with 18 followers, 4 leaders and 6 leavers with a speed of 0.10m/s is done as shown in Fig 9.

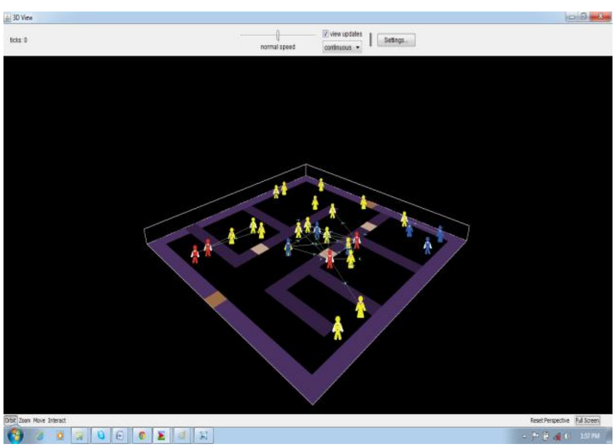

Fig 9. 3-D view of experiment1 setup

In the next experiment a simulation with 10 followers, 6 leaders and 5 leavers with speed 0.10 m/s in the same room configuration with 3 main exits is performed as in Fig 10.

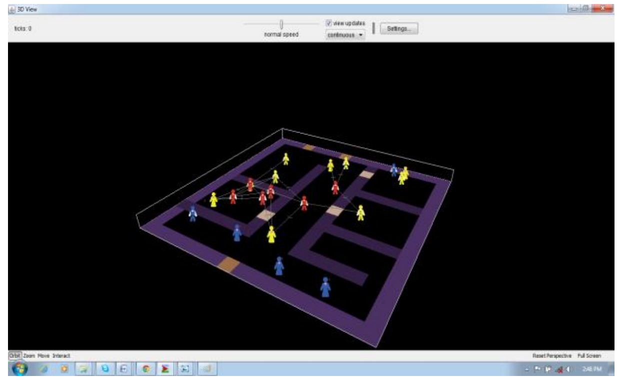

Fig 10. 3-D view of experiment2 setup

Now the various behaviors in these two different scenarios are compared. The graphical plots for evacuation rate and evacuee numbers are given.

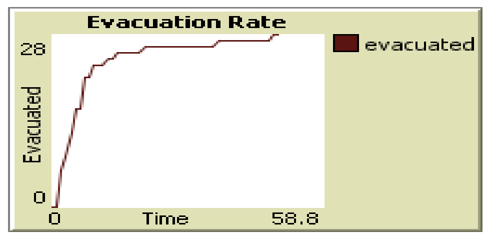

Fig 11. Experiment 1 evacuation rate

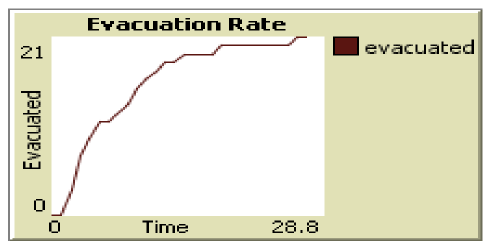

Fig 12.Experiment 2 evacutaion rate

Fig 11 and Fig 12 give the plots that describe number of people evacuated at each time tick. It gives the evacuation rate of the particular scenario. Finally after the safe evacuation the number of left people is zero (all people get evacuated).In the fig 11 it is shown that all 28 people get evacuated. Similarly in Fig 12 it is observed that all 21 people get evacuated. The time taken can be compared from X-axis of the plots. By comparing the two plots it is observed that evacuation time increases as number of people increases. It also increases when configuration complexity of room increases and when the number of blocked exits increases.

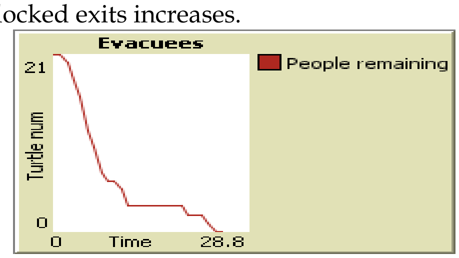

Fig 13.Experimental result

Fig 13 shows the plot that shows that after complete evacuation the people remaining will be zero.This means that a safe evacuation is ensured.

The table below gives the main observations obtained by the two experimental set-ups.

TABLE 1
EXPERIMENTAL RESULTS

Exp No	Parameters			
	Evacuation rate	Collision rate	No.of Exits	Observations
1	28 people evacuated in approx 59 ticks.	Approx 42 collisions in 59 ticks.	With 2 main exits total evacuation time 59 ticks approx.	Evacuation rate decreases. Collision rate increases. Total time for evacuation is more.
2	21 people evacuated in approx 29 tiks(seconds).	Approx 23 collisions in 29 ticks.	With 3 main exits ,29 ticks approx.	Evacuation rate increases. Collision rate decreases. Total time for evacuation decreases.

It is observed that collision rate increases with increase of total number of people. It decreases by a considerable amount when number of leaders increases. Collision rate mainly depends on complexity of room or building configuration.It is seen that as number of exits (main exits) increases the evacuation time required decreases. If the number of blocked exits increases then the time taken is found to increase.

6 CONCLUSION

Agent based fire evacuation simulation which is a multi-agent simulation is effectively simulated with the use of Net Logo. The special features of Net Logo were used to create the agent behaviors in the proposed simulation environment. Results are obtained that were used to analyze and compare various scenarios of simulation. The graphical outputs 2D and 3D were used to study various agent behaviors. 3D outputs created a more realistic agent environment. It was observed that the evacuation rate and collision rate increases as the complexity of building configuration increases. The total number of people and the number of leaders also greatly influence evacuation and collision rates. As the number of leaders increases the rate of collision decreases and evacuation time decreases. The simulation system can be mainly used to find the best floor plans or building configurations. The required floor plans are to be used as world of agents to conduct the simulation. Then the results can be compared to get the efficient floor plans. The simulation system can be used to analyze the different agent behaviors in different scenarios. This helps to simulate a system for safe and efficient evacuation during disasters.

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