# Multi-Agent System for School Shooter Specialist

Alberto Vegara Belmonte, Javier Prada de Francisco, Elías Alfonso Carrasco Guerrero, Juan Manuel González Santos, and Ian Bucu

University of Alicante, Spain

**Abstract.** This paper presents a multi-agent system (MAS) designed to simulate emergency scenarios involving school shootings, with the primary objective of minimizing casualties and identifying effective survival strategies. Developed using the GAMA platform, our system models interactions between multiple shooters and a large number of students, represented as BDI (Belief-Desire-Intention) agents. The simulation explores various factors influencing survival outcomes, including evacuation times, the relationship between the number of exits and casualties, and the impact of blocking classroom doors.
Key performance metrics analyzed include: time to eliminate all students, total evacuation duration, and statistical correlations between shooter numbers, exit availability, and fatality rates. Our findings indicate that increasing the number of shooters drastically raises the fatality rate, while additional exits can both improve evacuation efficiency and introduce confusion and congestion. Blocking classrooms significantly enhances survival rates by providing safe zones.
The simulated environment includes diverse agent behaviors such as survival strategies, hiding, door-blocking, and forming groups. This dynamic framework offers valuable insights into optimizing emergency responses, informing the design of safer educational environments. Our results highlight the complexity of evacuation dynamics and underscore the importance of strategic interventions to maximize survivability during active shooter incidents.

**Keywords:** Agent based model · Gama platform · multi agent system

## 1 Introduction

School shooting scenarios pose a significant challenge to emergency planning and decision-making. Modeling such incidents through simulations provides valuable insights into survival strategies and resource allocation. This research utilizes an agent-based model (ABM) powered by BDI principles to explore agent interactions under these critical conditions.

The system is designed to evaluate how students, shooters, and environmental elements interact, focusing on survival optimization. Agents operate in a dynamic grid environment, representing classrooms, safe exits, and hallways. By analyzing metrics such as survival rates and movement patterns, the study seeks to inform better emergency response strategies.

## 2 State of the art

Artificial intelligence (AI) has significantly transformed the way complex problems are solved, thanks to its ability to simulate human intelligence and automate processes in a variety of domains. Among the most prominent approaches to AI are multi-agent systems, which allow modeling and analyzing complex interactions between multiple autonomous entities, called agents. Agents are software entities that possess characteristics such as autonomy, perception, and decision-making capabilities, making them ideal for representing human and non-human behaviors in dynamic environments. This capability has broadened the scope of AI, enabling applications in fields as diverse as traffic management, e-commerce, video games, and emergency simulation, where coordination and adaptability are essential. By combining advanced modeling techniques and approaches based on conceptual frameworks such as Belief-Desire-Intention (BDI), multi-agent systems offer a powerful tool to study and optimize collective behaviors in highly complex scenarios.

The evolution of multi-agent systems has transitioned from simple rule-based models to more sophisticated approaches that integrate machine learning, real-time data, and adaptive behaviors. This progression has enabled their application in increasingly complex contexts, including emergency response scenarios and public safety simulations. However, while their versatility has grown, these systems also face challenges such as the simplification of complex human behaviors, reliance on accurate input data, and scalability issues in large-scale simulations. Addressing these limitations is critical for their continued advancement and broader applicability.

Multi-agent systems (MAS) have emerged as powerful tools for simulating and analyzing complex scenarios such as school shootings, thanks to their ability to model the dynamic interaction between multiple autonomous entities. In these simulations, each agent represents an individual with specific behaviors and goals, such as students seeking to evacuate, shooters trying to maximize damage, or police officers working to neutralize the threat and protect civilians. These simulations not only allow us to better understand the dynamics of highly complex events, but also to evaluate mitigation strategies such as evacuation routes and security technologies. For example, recent studies have used multiagent systems to analyze the effectiveness of gunshot detection systems, which have been shown to significantly improve evacuation rates and reduce casualties during active incidents Dai et al., 2023.

One of the most widely used types of agents in these contexts is the Belief-Desire-Intention (BDI) agent. These agents play a key role in these simulations by providing a robust conceptual framework for modeling human behavior in emergency situations. This model is based on three essential components: beliefs, which represent the information an agent perceives from the environment; desires, which encapsulate the agent's goals, such as evacuating or surviving; and intentions, which are the concrete plans the agent decides to execute. In school shooting simulations, this approach allows agents to dynamically adapt their behavior to changes in the environment, such as blocked exit routes or proximity to the shooter. For example, a student might change his or her strategy from evacuation to hiding based on perceived real-time information, while a police officer might prioritize neutralizing the attacker or protecting specific civilians Lu et al., 2023.

The interdisciplinary nature of multi-agent systems has also made them valuable beyond computer science. They are increasingly used in fields such as psychology, sociology, and architectural design to model human behavior and improve public safety. For instance, these systems have contributed to designing safer infrastructures by analyzing pedestrian behavior under panic and optimizing evacuation protocols. However, the application of such simulations in sensitive contexts, like school shootings, raises ethical considerations. Issues such as the potential misuse of data, emotional impact on stakeholders, and limitations in the generalizability of models emphasize the need for responsible deployment of these technologies.

In addition, the use of these systems in practical simulations has made it possible to explore realistic scenarios and perform counterfactual analyses that would be unfeasible in real life due to the high stakes involved. Simulations based on events such as the Thousand Oaks shooting have been used to calibrate models and explore how different configurations—such as police arrival time or the architectural design of the space—affect the outcome of these events. Specific environments have also been developed for school simulations, incorporating variables such as classroom and hallway configuration, to study how response strategies influence survival and evacuation rates. These simulations not only help design more effective strategies for responding to active incidents, but also serve as valuable training tools for both civilians and law enforcement Stewart, 2017.

In terms of training and preparedness strategies, simulations have also been shown to be useful in guiding both civilians and first responders in emergency situations. For example, studies have explored the impact of different civilian response strategies, such as "Run, Hide, Fight" versus "Lockdown," concluding that dynamic strategies that prioritize evacuation tend to result in lower casualties compared to passive approaches. Simultaneously, these simulations allow the evaluation of law enforcement performance, identifying critical variables such as the optimal size of intervention teams and reaction times to maximize efficiency in neutralizing threats and minimizing collateral damage. Emerging trends in the field include integrating reinforcement learning to enhance agent adaptability, leveraging Internet of Things (IoT) data for real-time updates, and employing virtual reality (VR) environments for immersive training.

While multi-agent systems provide invaluable insights into crisis scenarios, they also highlight the need for continuous improvement. By addressing current limitations, embracing interdisciplinary collaboration, and incorporating ethical considerations, these systems have the potential to revolutionize public safety and emergency response strategies.

## 3 Experimentation

The simulation environment includes the following components:

### 3.1 Environment Layout

A 25x25 grid represents the school layout (see Fig. 1), including:

- **Classrooms:** Areas where students initially reside.
- **Safe Exits:** Locations for evacuation.
- **Hallways:** Pathways connecting classrooms and exits.

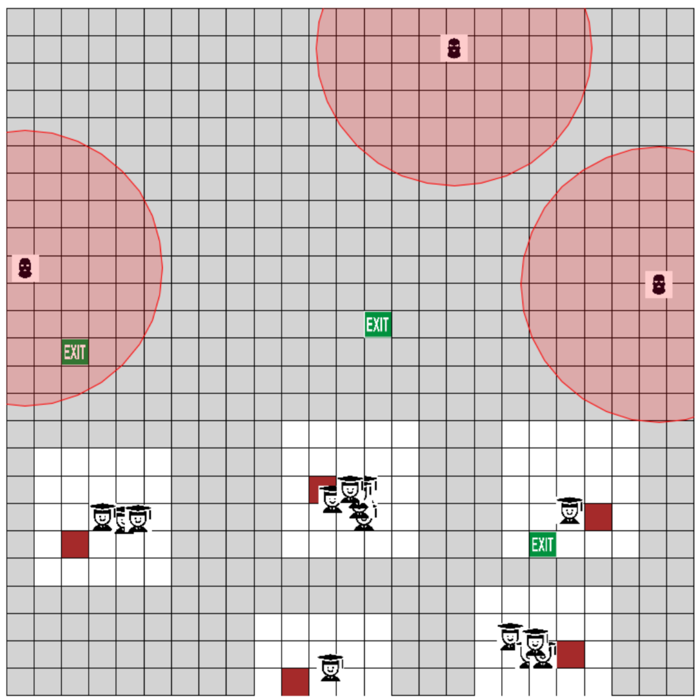


**Fig. 1.** The school at the beginning of the program execution

### 3.2 Agents

The system models four main agent types:

- **Students:** Tasked with surviving and reaching safe exits.
- **Shooters:** Pursue and target students (the ones with the balaclava).
- **Bullets:** Represent the trajectory of shots fired by shooters.
- **Dead Bodies:** Mark the locations of fatalities (represented with a rood (see Fig. 2)).

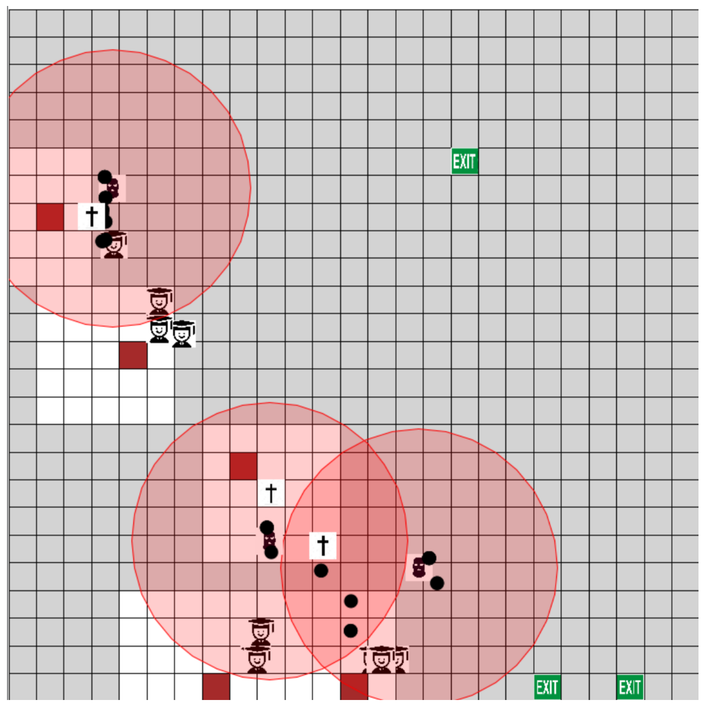


**Fig. 2.** The school at the middle of the program execution

### 3.3 Agent Behavior

Each agent type follows specific BDI-based rules:

- **Students:**
  - Prioritize survival by fleeing to the nearest safe exit.
  - Adapt behavior dynamically when a fatality is detected.
  - Transition between classrooms or wander within them.
- **Shooters:**
  - Pursue visible students within a predefined range.
  - Fire bullets aimed at specific targets.

## 4 Metrics

Key metrics analyzed in the simulation include:

### 4.1 Survival Rates

- The number of students who successfully evacuated.
- The proportion of fatalities relative to the initial population.

### 4.2 Evacuation Efficiency

This metric evaluates:

- Time taken for students to reach safe exits.
- The impact of immediate evacuation responses.

### 4.3 Shooter Efficiency

Measured by:

- The number of successful hits.
- The average time spent pursuing targets versus wandering.

### 4.4 Dynamic Metrics

- **Fatality-triggered Evacuation:** Evaluates how quickly students react to nearby fatalities (see Fig. 3).
- **Alive Metrics:** Tracks the alive students inside the chool, the ones which are safe (outside school) and dead ones to assess decision-making effectiveness (see Fig. 4).

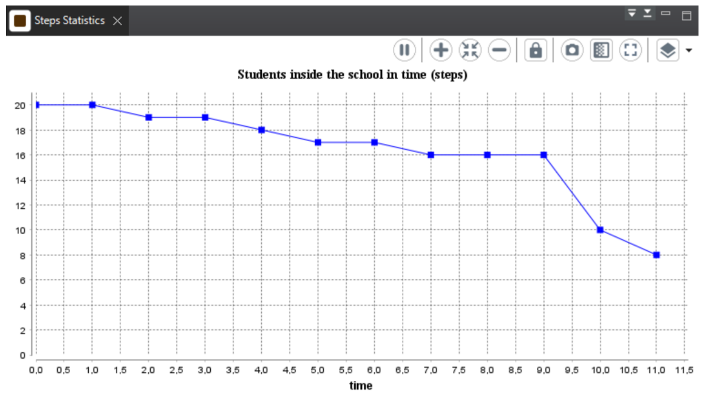


**Fig. 3.** Line chart: how many students are alive inside the school over time.

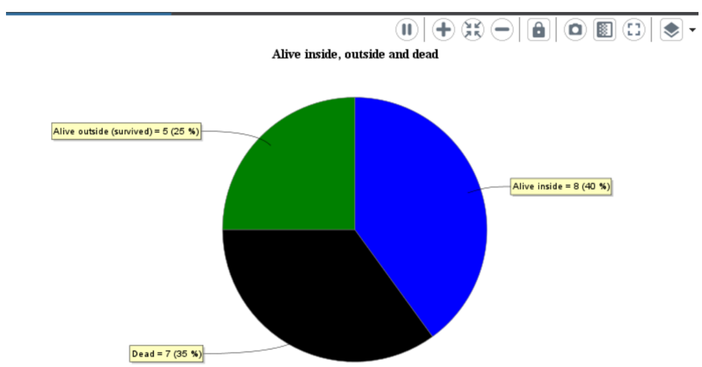


**Fig. 4.** Pie chart: the status of the students (inside alive, outside alive or dead)

## 5 Implementation and Results

The following snippet illustrates key aspects of the implementation of students behavior (when they see someone dead or they listen shots, the desire change to evacuation):

```
reflex global_evacuation {
    if (student_died) {
        ask student {
            do remove_intention(wander_desire, true);
            do remove_intention(transfer_desire, true);
            do add_desire(immediate_evacuation);
        }
        student_died <- false;  // Reset the flag
    }
}
```

Simulation results demonstrate:

- A 25% increase in survival rates with immediate evacuation responses.
- Improved evacuation efficiency with additional exits.
- Decreased shooter efficiency with shorter vision ranges.

To watch a video of how the execution works and how the metrics change over time, click on this link.

## 6 Conclusions

This study demonstrates the potential of multi-agent BDI systems to model complex emergency scenarios. Key findings include:

- Immediate evacuation responses significantly improve survival rates.
- Adaptive agent behaviors, such as fleeing upon detecting fatalities, enhance realism and system effectiveness.
- Metrics such as proximity and evacuation time provide actionable insights for emergency planning.
- Having more spread classes makes evacuation easier (better surviving rate).

Future work will focus on incorporating additional variables such as panic behaviors, varying shooter strategies, and real-time communications between agents to further enhance the model's applicability.

## 7 Bibliography

## References

Dai, W., Singh, Y. P., & Zhang, R. (2023). A multi-agent simulation for the mass school shootings. *IEEE Transactions on Simulation Modeling.*

Lu, P., Li, Y., Wen, F., & Chen, D. (2023). Agent-based modeling of mass shooting case with the counterforce of policemen. *Complex & Intelligent Systems*, *9*, 5093–5113.

Stewart, A. (2017). *Active shooter simulations: An agent-based model of civilian response strategy* [Master's thesis, Iowa State University].