Dynamic Escape Signs for Safe Egress in School Shooter Situation

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School shooter situations can be a terrifying time for all involved. It is important that, if the situation occurs, there is a smart, efficient system in place to move each classroom to safety as quickly as possible. Methods like Run, Hide, Fight do not tell the civilians where to run, and messaging systems that attempt this are often thwarted by the shooter's movement. A dynamic system is needed to track the shooter's location and communicate to people how to best escape. Dynamic escape signs have been useful for improving trust and egress time during a fire. Similar smart signs could be used to respond to the shooter, updating to show safe egress routes, as well as shut down certain hallways when the shooter is within line of sight. This method has been implemented within a Unity virtual reality environment and will be tested in the future to validate its usefulness.

Introduction

Schools across the United States have various protocols in place to respond to a school shooter in the case that an emergency should arise. Many of these systems are text-based or email-based, sending updates and alerts to the students and faculty as soon as the person in charge receives the information at hand (Sattler et al., 2011). Systems like these are a step in the right direction for school safety and are more informative than the classic "Run, Hide, Fight" methodology (Johnson, 2017).

Unfortunately, these systems still leave much up to chance, with plenty of room for error. It could be possible that the messaging network was given incorrect information and is distributing it based on a frenzied report from someone that heard there was a school shooter. Or perhaps the information was already too dated to be useful by the time it reached the students and faculty, whether because of the shooter's movement or poor cellular reception.

Even in the case of correct information being presented at the appropriate time, the civilians could react improperly to that information. A visitor, for instance, could be alerted that the shooter is in the cafeteria. This visitor could run in the direction believed to be opposite of the cafeteria, but in fact be running (and perhaps leading a crowd) right toward the shooter's location.

Given all these possible safety hiccups with current systems, schools are in need of new methods that utilize current technologies to help students and faculty escape as efficiently and safely as possible. This paper explores a new method of dynamic signs that react as intelligent agents to the shooter's location throughout the building.

Practice Innovation

Most public buildings use standard exit and escape signs to show civilians where to go in case of an emergency, whether that be a fire, a power outage, or otherwise (Conway & Boyce, 1997). These are generally thought to be helpful to visitors or people unfamiliar with the building, as those who know the layout will generally first escape to the exit or entrance they are most accustomed to using (Chu et al., 2015). It is the case, however, that escapees attend to and trust escape messages more that have been updated recently based on the situation (Meier et al., 2015).

Based on this human tendency to ignore signs they see habitually (Duarte et al., 2014), but pay attention to recently updated, changing, or flashing signs (Kwee-Meier et al., 2017), dynamic escape signs that activate in a school shooter situation and change based on the location of the shooter could be quite helpful.

Signs of this nature have been proven useful in the past, but mainly in the context of a fire emergency. Asenesio et al. (2015) implemented an example of dynamic signs within a tunnel using smart signals to communicate between the signs, but again focused mainly on the context of a fire.

Hsu and team (2014) implemented a dynamic escape sign system as well but used the monitors for advertisements unless an emergency occurred. In an emergency situation, the monitor would switch over to escape mode and display the quickest way out of the building.

There has also been much research in the field of how what we display on our signs affects human understanding, whether they are static or dynamic. Rousek and Hallbeck (2011) found that signs with a clear image of a human led to better responses than signs with only text. They also found that red and black signs were preferred by their primarily American participants in emergency or stressful situations, over other color combinations such as red and blue or monochromatic signs. It has also been found that people prefer green and white exit lights to blue exit lights (Ronchi et al., 2016).

Adding more signage reduces the time needed to egress, and double-sided signage (with both sides showing important egress information) was more useful than single-sided signs (Chu et al., 2015). People are also much more likely to engage in the act of fleeing a dangerous situation when there is a perception that their escape routes are being limited (Mawson, 2005).

Given these past research findings, we have designed dynamic escape signs to be used for a school shooter situation. These signs would be double sided, with one side showing an escape sign and the other side showing a stop sign. The escape sign would be the standard green and white escape indication, with a person running toward the door. The stop sign would be red and black with the stop hand used at crosswalks to indicate that the pedestrians should not go that direction.

These signs would be placed above each teacher's door and would show their name and room number throughout the day. They could also be programmed to display messages such as, "Testing, please do not disturb." If a school shooter were to be identified in the building, the signs would switch to emergency mode.

In emergency mode, the signs would dynamically update based on where the shooter is currently located in the building. For example, if the shooter were north of the sign, then the sign would tell the civilians to escape to the south, and vice versa. The signs would ultimately communicate to a server via a wireless communication network and would be updated based on cameras tracking the shooter throughout the building. Before this implementation occurs, however, the signs need to be tested within a virtual environment as a communications tool. The limitations of the signs would also need to be further tested to determine if they can effectively handle fringe cases such as multiple shooters at once.

This research goes beyond the previous work of Asensio and Hsu by using smarter signs in a more dynamic situation. In a fire situation, the fire generally starts somewhere in the building and moves out in a central pattern from there. A shooter is less predictable and can move any number of directions – therefore, the signs will need to be able to update in real time in response to the shooter's movements. This higher level of intelligence necessitates a higher level of trust from the end user. If the users are not able to trust the technology (e.g., if the sign logic is faulty or the cameras have false positives), or simply do not trust the signs and therefore do not follow their instructions, it could lead to potentially dangerous situations. If the users do trust the signs, however, they could ultimately lead to a quicker and safer egress.

Practice Application

The research team has built a virtual environment to display this innovation within the Unity development engine. The environment includes a virtual school, complete with classrooms, hallways, and a cafeteria, pictured in Figures 1, 2, and 3.

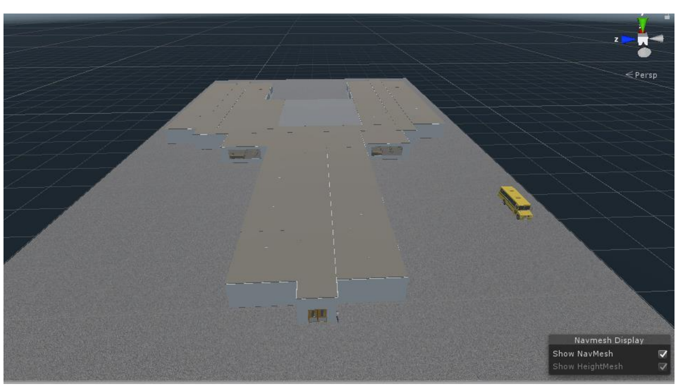

Figure 1: School Overhead View: This virtual school has four main hallways with six main exits to offer various egress strategies for testing.

Figure 2: Classroom Interior: Some of the classrooms have windows while others have none to simulate various levels of safety.

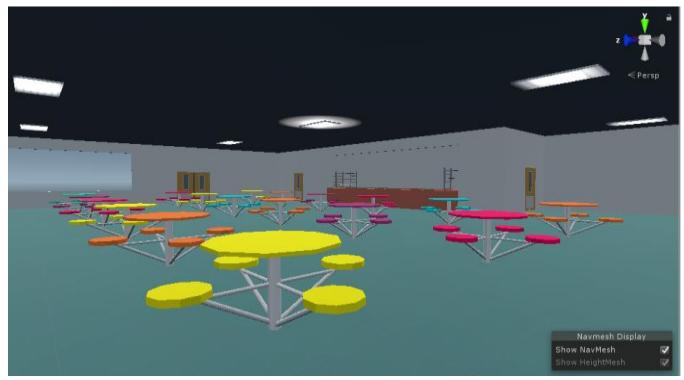

Figure 3: Cafeteria: The cafeteria is a wide-open space within the school, designed to complement the narrow hallways and classrooms.

Within the school, there is a shooter that has been implemented to interact with dynamic escape signs throughout the hallways. As the shooter passes a sign, it will update to show that it is no longer safe to go that direction by displaying the red and black stop hand (Figure 4).

A player moving throughout the building would see a series of signs either showing the escape symbol (Figure 5) or the stop symbol depending on which direction they are facing.

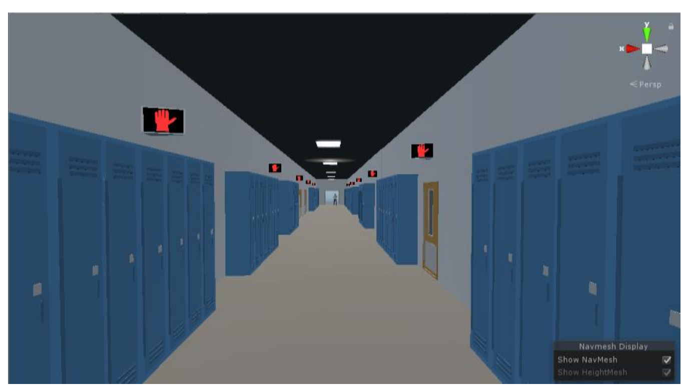

Figure 4: Stop Signs: These signs are based off of the familiar crosswalk stop sign that indicates an unsafe time to walk that direction.

Figure 5: Escape Signs: These standard escape signs indicate that it is safe to escape that direction, as it is moving away from the shooter.

The virtual school does not use in-game cameras to track the shooter, though it does keep track of his location through a series of geometric calculations. The current algorithm to determine sign status based on shooter location is as follows. Each sign sends out a vector perpendicular to the wall, as well as a vector that traces from the sign to the shooter (Figure 7). The cross product is then taken between the two rays. If the cross product is positive, then we know the shooter is in front of the sign and can have it display the stop sign. If it is negative, we know that ahead of the sign is safe, and can therefore show the escape sign. If we are showing the stop sign on one side of the sign, the other side will show the escape sign and vice versa.

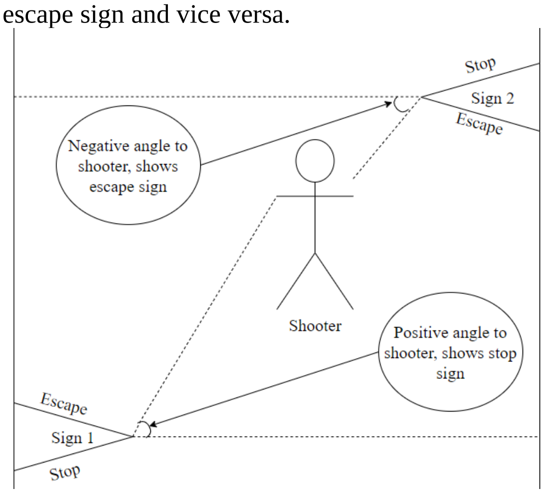

Figure 7: Sign Logic: The signs send out a vector between them and the shooter and a perpendicular vector to determine the shooter's location.

Overriding this base algorithm is a check to determine if the shooter is in the same hallway as the sign. If the shooter is in hallway 1, for example, it is no longer safe to enter or move anywhere within that hall. This means that all signs in that hallway should automatically show the red stop sign on both sides to let people know it is unsafe. This algorithm will face challenges when applied to a more complex building, such as one with multiple stories, and a more robust algorithm will need to be developed prior to real-world implementation.

Discussion

Dynamic escape signs could have a tremendous effect in civilian safety during a shooter situation. Updating signs have been proven to garner people's attention and earn their trust far more than static escape signs (Duarte et al., 2014) and could be switched over to the best escape route instantaneously given the correct technology and algorithms.

In future work, the research team will run willing participants through a virtual simulation of a school shooter escape. We will have the shooter move in set paths throughout the building, and have the signs update accordingly. The goal is to test users with standard escape signs versus dynamic escape signs to see if there is any statistical difference in their speed and safety during egress. As the algorithm is still in its preliminary stages, the signs will be primarily tested as a communications tool. Eye tracking technology within VR headsets could help to determine if the participants are looking at the signs as well as how long they are paying attention to them.

After testing this in a virtual environment, it will also be tested within a real school building, using school drills to test their level of intuition and effectiveness. It will also need to be tested with first responders, making sure they understand the signs as well. These could potentially help police officers find the shooter more quickly by following the signs in reverse, with the stop signs leading to the shooter's position.

Though it has been tested in a fire situation, the usefulness of dynamic signs have yet to be tested in the high-stress situation of a school shooter. A fire emergency could be considered more common and less stressful than a school shooter; therefore, it is important to know whether or not people are looking at the signs, paying attention to them, and following their instructions once they have been seen in this situation as well.

Future work beyond the communications aspect of the signage would be making sure that these signs could be updated accurately and efficiently in the real world. The server would need to use artificial intelligence to identify and track the shooter in order to update the signs appropriately. The system would also need to know to some degree how close the shooter is to the civilians and if there is a line of sight between them and the shooter. This would prevent classes from leaving safe rooms if the shooter was too close outside for them to escape yet.

It would also be of interest to incorporate this sort of system into other school safety drills, such as fire or tornado drills. It could ultimately be used for all sorts of emergencies and could reduce the hassle of each group trying to figure out where to go and when.

There is still much research to be done to improve school shooter safety, but this extension of the previous work on dynamic fire safety signage could be a significant help.

Practitioner Take-Aways

- The currently available options for safe egress communications during a school shooter situation are limited.
- Much research has been done regarding the usefulness of dynamic escape signs during fire emergency situations.
- Applying these dynamic escape signs to a school shooter situation could be quite helpful, with the

signs updating based on the shooter's location in the building.
- A low-level algorithm has been developed to update the signs based on whether the shooter is in front or behind them within the building, but could use further refinement before real-world implementation.
- It is vital to test the communications potential of these signs further, both in a virtual school shooter simulation and in real-world practice drills prior to implementation.

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References
Asensio, Á., Blanco, T., Blasco, R., Marco, Á., & Casas, R. (2015). Managing emergency situations in the smart city: The smart signal. Sensors (Switzerland), 15(6), 14370–14396. https://doi.org/10.3390/s150614370

Chu, M. L., Parigi, P., Latombe, J. C., & Law, K. H. (2015). Simulating effects of signage, groups, and crowds on emergent evacuation patterns. *AI and Society*, *30*(4), 493–507. https://doi.org/10.1007/s00146-014-0557-4

Conway, K. M., & Boyce, P. R. (1997). Expanding the market for visually effective, highly efficient exit signs. Vol. 2, 47.

Duarte, E., Rebelo, F., Teles, J., & Wogalter, M. S. (2014). Behavioral compliance for dynamic versus static signs in an immersive virtual environment. *Applied Ergonomics*, *45*(5), 1367–1375. https://doi.org/10.1016/j.apergo.2013.10.004

Hsu, H. P., Yu, K. M., Chine, S. T., Cheng, S. T., Lei, M. Y., & Tsai, N. (2014). Emergency evacuation base on intelligent digital signage systems. *Proceedings - 2014 7th International Conference on Ubi-Media Computing and Workshops, U-MEDIA 2014*, 243–247. https://doi.org/10.1109/U-MEDIA.2014.31

Jonson, C. L. (2017). Preventing School Shootings: The Effectiveness of Safety Measures. Victims and Offenders, 12(6), 956–973. https://doi.org/10.1080/15564886.2017.1307293

Kwee-Meier, S. T., Mertens, A., & Schlick, C. M. (2017). Age-related differences in decision-making for digital escape route signage under strenuous emergency conditions of tilted passenger ships. *Applied Ergonomics*, *59*, 264–273. https://doi.org/10.1016/j.apergo.2016.09.001

Mawson, A. R. (2005). Understanding mass panic and other collective responses to threat and disaster. *Psychiatry*, *68*(2), 95–113. https://doi.org/10.1521/psyc.2005.68.2.95

Meier, S. T., Bützler, J., & Schlick, C. M. (2015). *The influence of information presented on digital escape route signage on decision-making under mentally and emotionally strenuous conditions*. (August), 1–8.

Ronchi, E., Nilsson, D., Kojić, S., Eriksson, J., Lovreglio, R., Modig, H., & Walter, A. L. (2016). A Virtual Reality Experiment on Flashing Lights at Emergency Exit Portals for Road Tunnel Evacuation. *Fire Technology*, *52*(3), 623–647. https://doi.org/10.1007/s10694-015-0462-5

Rousek, J. B., & Hallbeck, M. S. (2011). Improving and analyzing signage within a healthcare setting. *Applied Ergonomics*, *42*(6), 771–784. https://doi.org/10.1016/j.apergo.2010.12.004

Sattler, D. N., Larpenteur, K., & Shipley, G. (2011). Active Shooter on Campus: Evaluating Text and E-mail Warning Message Effectiveness. Journal of Homeland Security and Emergency Management, 8(1). https://doi.org/10.2202/1547-7355.1826