Smart Navigation System for Emergency Exits

Computer Engineering Department

Project Advisor: Ishie Eswar

Lin, Han-Wei (MS Software Engineering)
Narvekar, Sheetal (MS Software Engineering)
Navarro, Roger (MS Software Engineering)
Narkhede, Swati Ganesh
(MS Software Engineering)

Introduction

Natural disasters, earthquakes and fire emergencies are common phenomenon that affect several people each year. California residents receive alerts from California State alert system in case of emergency. They follow the guidelines laid out by local authorities like fire department, sheriff or police department. Safe evacuation in indoor areas becomes challenging when local authorities are not available to assess the rapidly changing situation. Although the safe evacuation cannot be planned, there is a need of an efficient tool that allows people and local authorities to safely evacuate the indoor premise and reduce mortalities caused due to emergency hazard.

The objective of this project is to help the first responders to safely evacuate people in emergency situations from indoor places. This project is a mobile application that can be installed manually on iPhone devices. It is a blend of technologies like IoT, Amazon Web Services (AWS) Cloud Computing and Machine Learning. This project will ease the emergency rescue operations for first responders with increased possibilities of their own safety too.

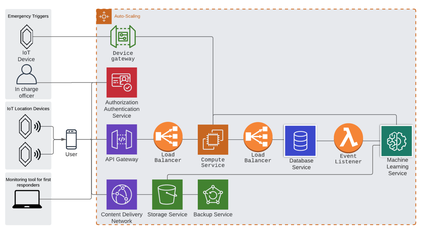
Methodology

State of the art

This project is inspired by the latest state of the art techniques in the area of indoor navigation such as indoor navigation maps, Bluetooth beacons, low latency cloud resources and Apple U1 chip which enables us to accurately detecting user's location in 2D and 3D levels.

System Architecture

The Client Infrastructure of this project serves users, emergency triggers or administrators and the first responders. It uses different cloud services shown in below figure to work as microservices. These microservices allow application to authorize and authenticate users, various cloud services to communicate

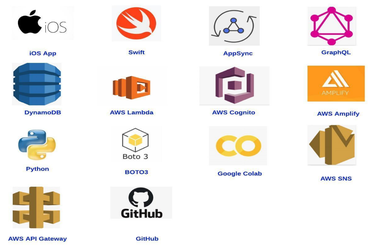


Methodology

with IoT devices, to process business logic and to store structured and unstructured data.
With GeoJSON data structure for indoor maps this application takes advantage of geolocation capabilities in smartphone devices. It uses different Software Development Kits for User Interface and Augmented Reality.

Technology Stack

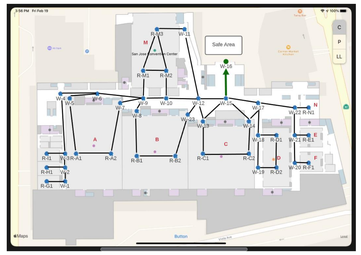
Following are the different software technologies and framework that have been used for this application.



Implementation

In Middle Tier technologies, AWS serverless compute Lambda functions is used to trigger the emergency notification and generate a path to the safe area. The Data Tier uses AWS DynamoDB, AWS Amplify and AppSync services for seamless database access from mobile application.

To generate the shortest safe path, this project uses Machine Learning. This project uses Q-Learning algorithm from Reinforcement Learning. The first floor of San Jose Conventional Center has been considered as an environment. It has been implemented in graphical format. The IoT devices have been simulated in all rooms and walkways in this environment. These IoT devices have been considered as nodes and connected them with edges.



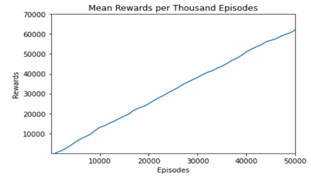
The Q-Learning algorithm uses Q matrix and R matrix. R matrix contains reward values mapping between all locations and environmental states. While training the reinforcement learning agent, it populates the Q matrix with the Q values generated by below Q function where s and a represent state and action, respectively.

$$Q(s,a) = r(s,a) + \gamma \max_{a} Q(s',a)$$

This Machine Learning model generates shortest path from the user location to the safe exit. If the path is unavailable, it generates an alternate shortest path from user location to the safe exit. In case these are no available paths, this application notifies users to wait for the first responder's assistance or to stay near windows if the user location has access to any nearest window.

Analysis and Results

The performance of machine learning algorithm has been evaluated and analyzed. Below figure shows mean rewards gained by an agent per thousand episodes throughout the training process. The agent's performance improved through training with rise in number of rewards gained



The Machine Learning model generates a list of nodes depicting the shortest path to the safe exit which is node 'W-16' in this environment. It works for below cases:
Case 1: The shortest path is available

Shortest path from node 'R-M2' to the safe exit:
['R-M2', 'W-10', 'W-12', 'W-15', 'W-16']

Case 2: When the shortest path is blocked, it generates alternate path.

Shortest path from origin 'R-M2' to the safe exit:
['R-M2','R-M3', 'W-11', 'W-12', 'W-15', 'W-16']

Case 3: When no path is available but has access to windows.

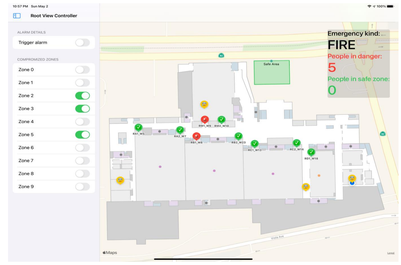
Shortest path from origin 'R-I1' to the safe exit:
'No safe path found, please move close to windows and stand by for rescue.'

Case 4: When no path is available and don't have access to windows.

Shortest path from origin 'R-E1' to the safe exit:
'No safe path found, please stand by for rescue.'

The users receive emergency notification on their screen when emergency is detected. Once user opens the notification, it shows a shortest safe path the safe exit.

If the premise is still under emergency, it shows a red background to provide a status of the emergency.
Below figure is first responder's application which enables them to monitor the emergency in real-time.



This application allows the first responders to trigger an emergency alert notification in all user accounts detected in the premise. They can see the type of emergency and total count of people in danger and in safe zone. This application makes the rescue operation easy by displaying the safe area in premise with a green tag and areas in danger with a red tag. First responders can block the zones in the map which are unsafe and compromised due to fire or some other danger. Blocking the compromised zones will help first responders to stop people from navigating from areas having danger and rescue them safely.

Summary/Conclusions

The application serves as a tool to assist people safely navigate to the safe area, thus reducing the chaos and optimizing the evacuation process. It allows the first responders to efficiently control an indoor emergency situation by monitoring and blocking unsafe areas.

Key References

1] "National Institute of Standards and Technology," 20 September 2017. [Online]. Available: https://www.nist.gov/ctl/pscr/research-portfolios/location-based-services. [Accessed 25 September 2020].

[2] R. P. P. Davidson, "A Survey of Selected Indoor Positioning Methods for Smartphones," in IEEE Communications Surveys & Tutorials, 2017.

[3] Marko Youngson, "Introduction to Reinforcement Learning". Available: https://medium.com/swlh/introduction-to-reinforcement-learning-63fb8923bd88 [Accessed 3 November 2020].

Acknowledgements

The authors would like to thank Professor Ishie Eswar for his constant support, advice and guidance throughout course of this project.