



Electrical & Computer Engineering

Student: Declan Doss

Advisor: Dr. Hovannes Kulhandjian

## Abstract

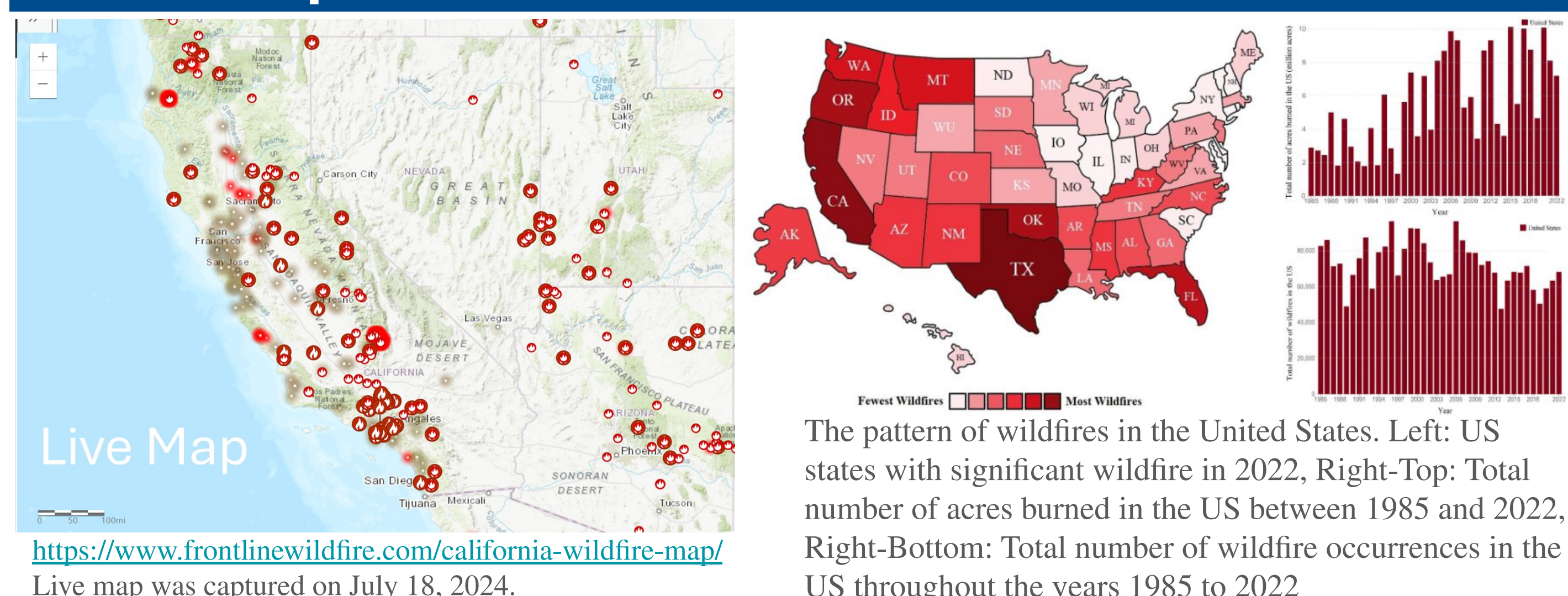
In this project, we propose to develop a unified framework for wildfire emergency response and evacuation that includes:

- **Dynamic Environment Modeling:** Utilizing machine learning algorithms coupled with infrared, visible light, and weather sensors including temperature, wind direction and speed detection mounted on a drone to predict forest fires before they occur.
- **Evacuation Route Optimization:** Leveraging a drone equipped with machine learning algorithms to optimize path planning during wildfire emergencies, enabling efficient and safe evacuation routes while aiding first responders in containment efforts.
- **Search and Rescue Operations:** Employing the framework to identify and locate firefighters trapped in wildfire, especially when communication links with the base station are lost.

## Introduction

- California faced devastating wildfires in 2017 and 2018, with the Thomas and Tubbs fires destroying thousands of structures and consuming over 318,000 acres across Ventura, Santa Barbara, Napa, Sonoma, and Lake Counties.
- The historic 2020 wildfire season included the August Complex Fire, the largest recorded wildfire in California's history.
- These wildfires caused significant loss of property, life, and habitat damage, underscoring the need for innovative approaches to wildfire prevention, early detection, and efficient response strategies.
- Although research has been conducted in areas such as wildfire detection, evacuation, and search and rescue operations, a comprehensive unified framework addressing these issues simultaneously is lacking.
- This project proposes a unified framework for wildfire emergency response and evacuation. Key components include dynamic environment modeling using drones equipped with machine learning algorithms and various sensors to predict fires before they occur, evacuation route optimization through efficient path planning, and search and rescue operations to locate trapped firefighters.
- Implementing this framework can significantly benefit wildfire control authorities, improving safety and response efficiency.

## Map of Wildfires in California and USA

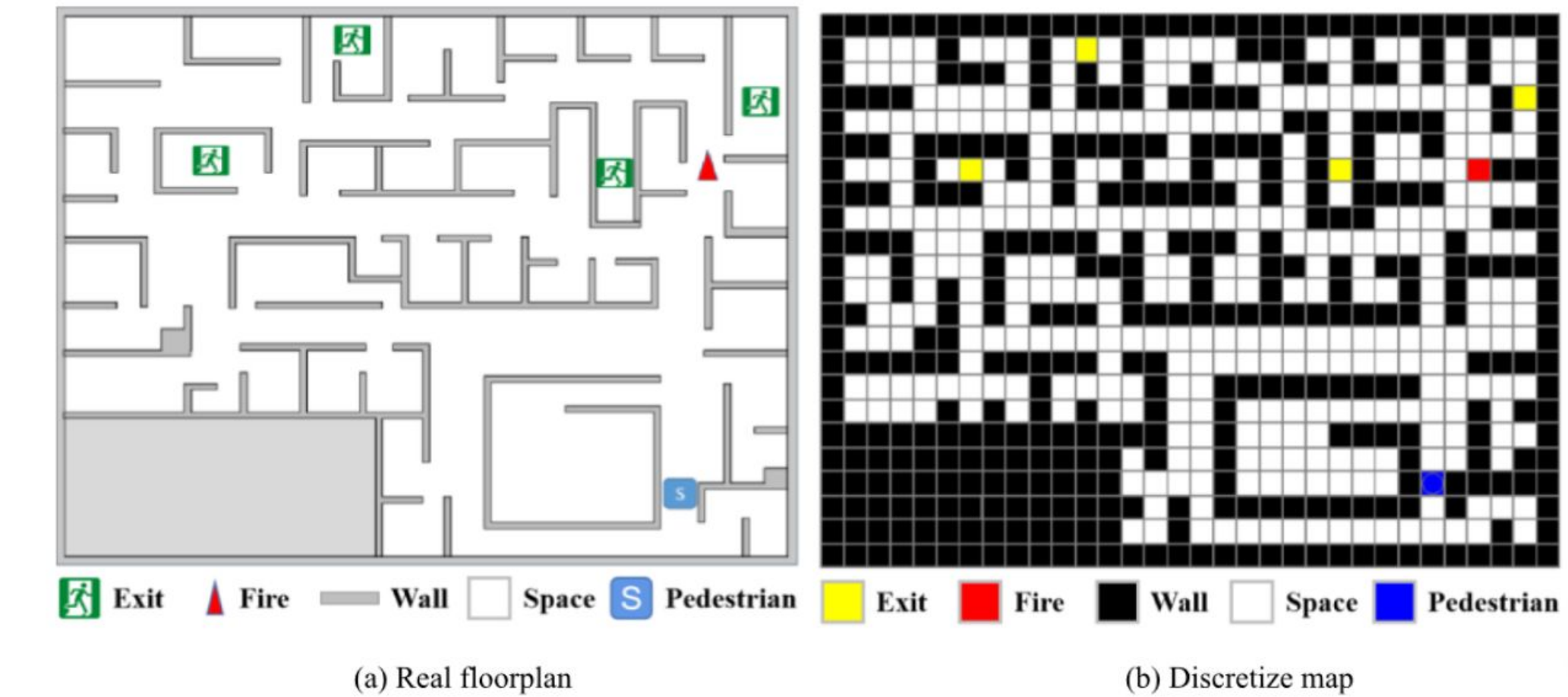


## Methodology

- Previous research tends to fall into one of three categories:
  - Dynamic Environment Modeling:
    - Creating fire maps from satellite imagery, helicopters, and ground personnel.
    - How to identify fire using a range of imaging, sound, and chemical based sensors.
  - Evacuation Route Optimization:
    - Comparing different types of evacuation route algorithms, such as bacteria chemotaxis, particle swarm optimization, Artificial Bee Colony, etc. where pros and cons are weighed.
    - Use of historical wildfire evacuation data from smart cars to inform new traffic distribution models.
    - Use of mobile app for relaying evacuation route information.
  - Search and Rescue Operations:
    - Usage of satellite GPS, infrared, and radio waves to establish communication between aerial and ground systems.
    - Technologies for detecting humans and animals in heavy smoke using radar and IR cameras.

## Findings

- Deploying autonomous UAVs are cheaper and more efficient than satellite for confirming reports of and determine fire severity [1, 3].
- Minimizing interference and aerial collisions by shutting down the airspace near and above the fire is critical.
  - An underexplored area, though anti-drone and drone redirection technologies do seem promising [3].
- Utilize leader-follower framework for real-time, extensive aerial surveillance [4].
  - H/MALE (High/Medium Altitude Long Endurance) and quadcopter UAVs are likely to provide the best balance of uptime, instrumentation, and computational power [3, 8].
- An app called EscapeWildfire was shown to be effective in providing escape routes when participants were near roads [2].
- Use of SARSA and discretized maps of the surrounding topography is promising based on indoor performance [6].
- Analyze previous wildfire evacuation data [9], build conceptual and engineering models [7] to benefit escape route optimization greatly, especially on roads.
- Use ABC (Artificial Bee Colony) algorithm in follower UAVs is suggested due to efficacy of findings stranded individuals and efficiency in doing so.
  - How ground personnel interact with nearby UAVs for victim locations is unclear, however it would stand to reason a mobile app could be used [2].
  - This app may also be of use if SaR personnel couple it with RSARSA for real-time fire evasion, should the flames spiral beyond initial predictions [6].



Floor plan of a building, turned into simplified map for SARSA algorithm to use and compute safe paths to exits for pedestrians

Proposed usage of the leader-follower framework. Each group autonomously monitors its own area. Leaders handle resource intensive tasks; followers scout area for fire victims



## Future Research

Future research should examine the possibility of predicting forest fires based on environmental data, such as temperature sensors, wind speed, etc. Additionally, it should be explored how drones could map out the topography of an area, possibly using sound sensors, even during an active fire in addition to communication protocols that UAVs may use to communicate with base stations. Finally, we suggest using EscapeWildfire as a jumping off point for developing an app capable of providing escape route information through

## Conclusions

- The goal of the ongoing project is to establish a unified framework that seamlessly integrates with existing emergency response protocols, working in collaboration with local authorities.
- By advancing wildfire management strategies, the project aims to improve emergency response efficiency and ultimately save lives.
- As the project continues, the team will focus on expanded research and refining this framework for practical deployment, ensuring it effectively meets the challenges of future wildfires.

## Acknowledgements

Support and funding for this effort were partly provided by the U.S. Department of Education, Title V Promoting Postbaccalaureate Opportunities for Hispanic Americans (Finish in Five), Project Grant P031M210039 and by the Fresno State Transportation Institute (FSTI).

## References

[1] Aditya Dhall, Akash Dhasade, Ashwin Nalwade, Mohan Raj V.K., & Vinay Kulkarni (2020). A survey on systematic approaches in managing forest fires. Applied Geography, 121(102266). <https://doi.org/10.1016/j.apgeog.2020.102266>

[2] A. Kamilaris, J.B. Filippi, C. Padibidhi, R. Kooze, & S. Karatsiolis (2023). Examining the potential of mobile applications to assist people to escape wildfires in real-time. Fire Safety Journal, 136(103747). <https://doi.org/10.1016/j.firesaf.2023.103747>

[3] Daniel Gaffney, Melissa Taha, Charvi Pande, Cristian Gonzalez, & Pedro Garcia (2021). Drone Applications for Wildfires and Other Emergency Situations. NASA Technical Reports Server. <https://ntrs.nasa.gov/dataset/20220001826>

[4] F. Afghah, A. Razi, J. Chakareski, & J. Ashdown (2019). Wildfire Monitoring in Remote Areas using Autonomous Unmanned Aerial Vehicles. IEEE INFOCOM 2019 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHOPS), 835-840. <https://doi.org/10.1109/INFOCOM4109.2019.8845309>

[5] Hafiz Sultan Munawar, Zahra Ghaffar, Humaid Alkaram, & Sara Inam Khan (2022). A Framework for Burnt Area Mapping and Evacuation Problem Using Aerial Imagery Analysis. Fire, 5(4). <https://doi.org/10.3390/fire504022>

[6] Ping Huang, Xijun Liu, Changsheng Liu, Libi Fu, & Longping Yu (2024). A real-time automatic fire emergency evacuation route selection model based on decision-making processes of pedestrians. Safety Science, 169(106322). <https://doi.org/10.1016/j.ssci.2023.106322>

[7] Salim Ahmad, Asad Ali, Hafiz Usman Ahmad, Ying Huang, & Pan Lu (2023). Evaluating Traffic Operation Conditions during Wildfire Evacuation Using Connected Vehicles Data. Fire, 6(5). <https://doi.org/10.3390/fire6050163>

[8] S. Karim, E. Zorba, G.C. Pallas, G. Stathopoulos, I. Batta, K. Mikell, ... M. Stathopoulos (2015). Use of unmanned vehicles in search and rescue operations in forest fires: Advantages and limitations observed in a field trial. International Journal of Disaster Risk Reduction, 13, 307-312. <https://doi.org/10.1016/j.ijdrr.2015.07.009>

[9] Zhao, X., Lovreglio, R., Kuligowski, & E. et al. (2021). Using Artificial Intelligence for Safe and Effective Wildfire Evacuations. Fire Technol, 57, 483-485. <https://doi.org/10.1007/s10994-021-00729-x>