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Ministry of Education and Higher Education
State of Qatar • دولـــة قطـــر

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Automated fire extinguishing using computer vision and modulated sound waves

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Outline

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- Methodology
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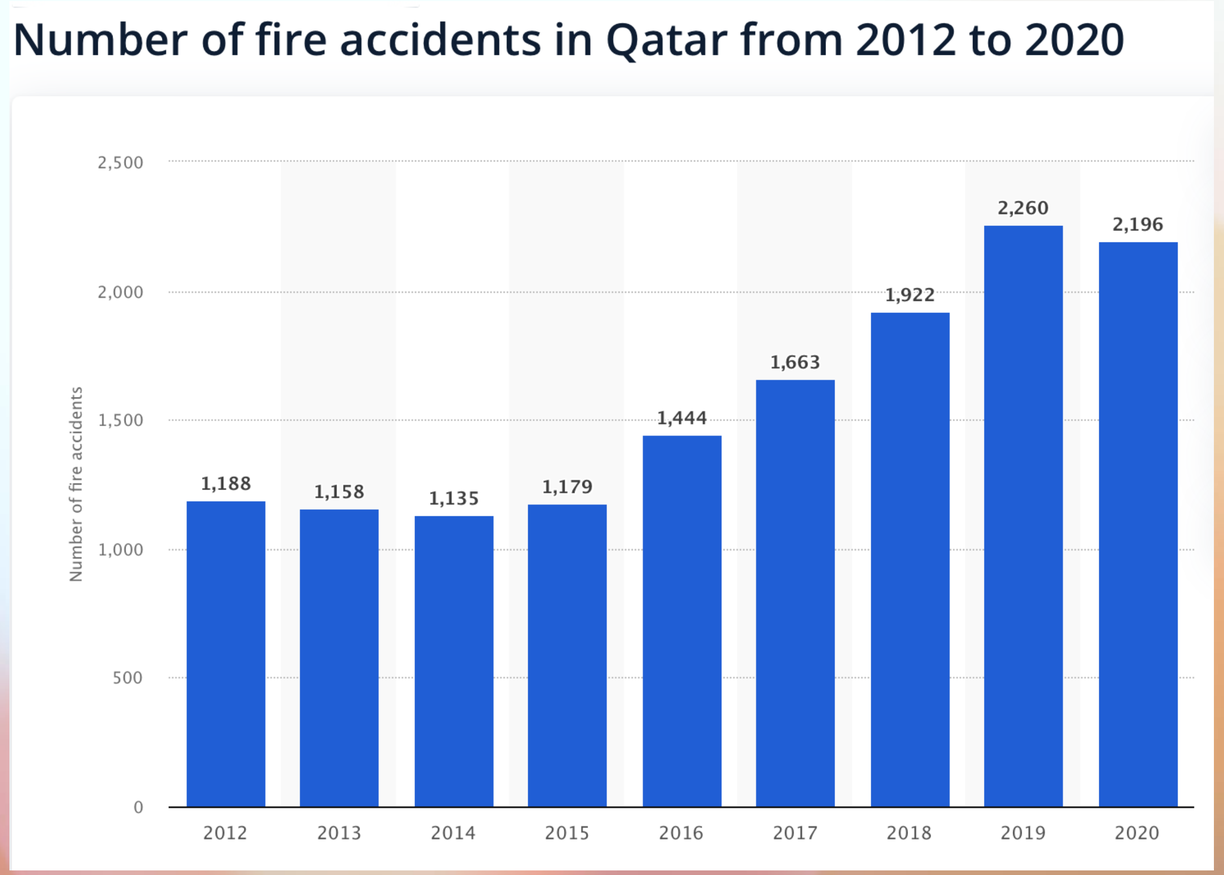
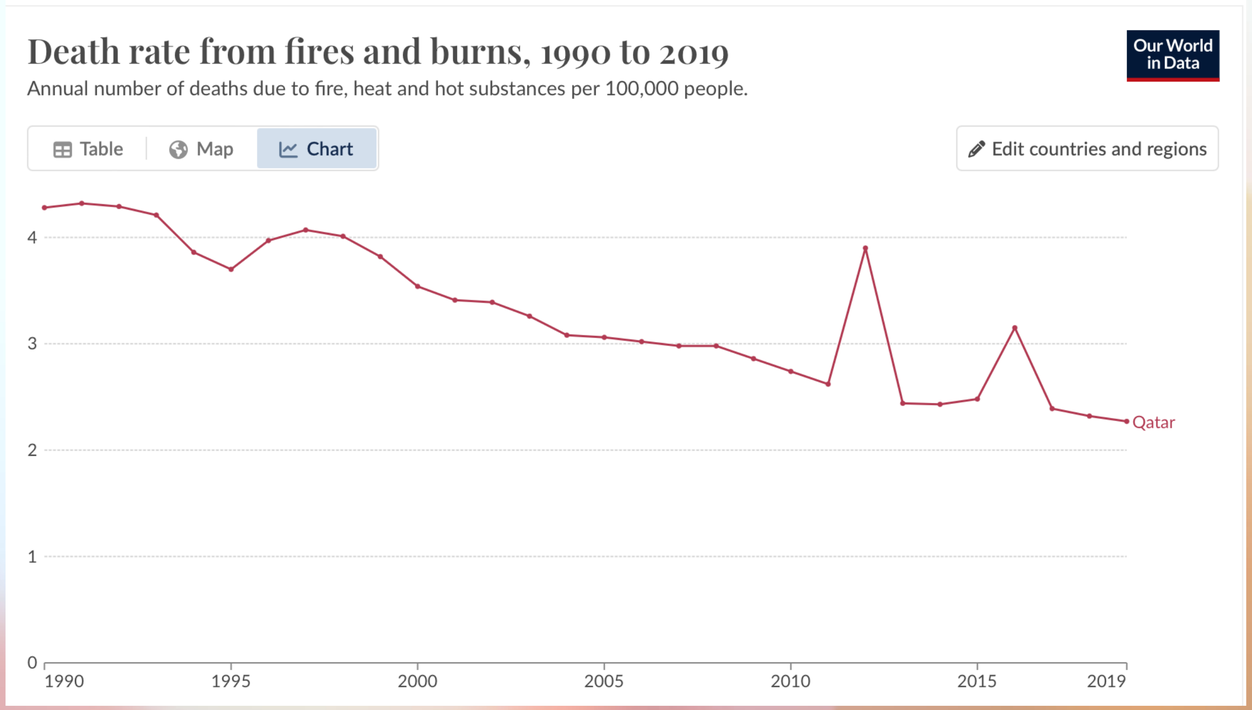
Research Problem



www.statista.com

The graph clearly shows a big jump in fire incidents in Qatar between 2012 and 2020 . Reports show fire incidents went from around 1,100 in 2012 to over 2,500 in 2020. It is estimated that water requirements for fire suppression, ranged between 50,000 to 780,000 liters for the average one-story house depending on the size of the fire.

Research Problem



ourworldindata.org

This graph shows the death rates from fires and burns since 1991 till 2019 in Qatar per 100,000 decreasing from 4.28 deaths per 100,000 to 2.27 per 100,000 which returns to Qatars search for efficiency in extinguishing fires and ways to decrease reaction time and the safety measures taken by Qatar and its constant aim for development.

Research Problem

Research Problem

Now when we consider Qatars climate and the affects of global warming and the water scarcity, its not very difficult to realise that saving as much water as possible is essential. It is also worth noting that every 6 seconds a child dies of polluted water. Another important factor that we must consider is the fact that Fires are a great threat to the human life as it produces a lot of CO2 and the high level of heat can lead to the break down of the enzymes in the human body which can lead to death.
Thats why we came up with following idea:

Computer vision for early fire detection and extinguishment using amplitude modulated sound waves

Hypothesis & Objectives

Hypothesis:

Cameras with embedded machine learning algorithms are employed to identify emerging flames based on visual signs, enabling rapid location and response before the fire spreads significantly. Low frequencies and intensities of sound waves are then directed at the fire, disrupting the combustion process through producing a pressure change and manipulating oxygen flow causing the fire to die out because of the lack of fuel and therefore extinguishing it.

Objectives:

🎯Design a system for early and accurate detection of flames using Computer Vision.

🎯Implement a Sustainable fire extinguishing method aligned

with Qatar’s 2030 vision of sustainability, using sound.

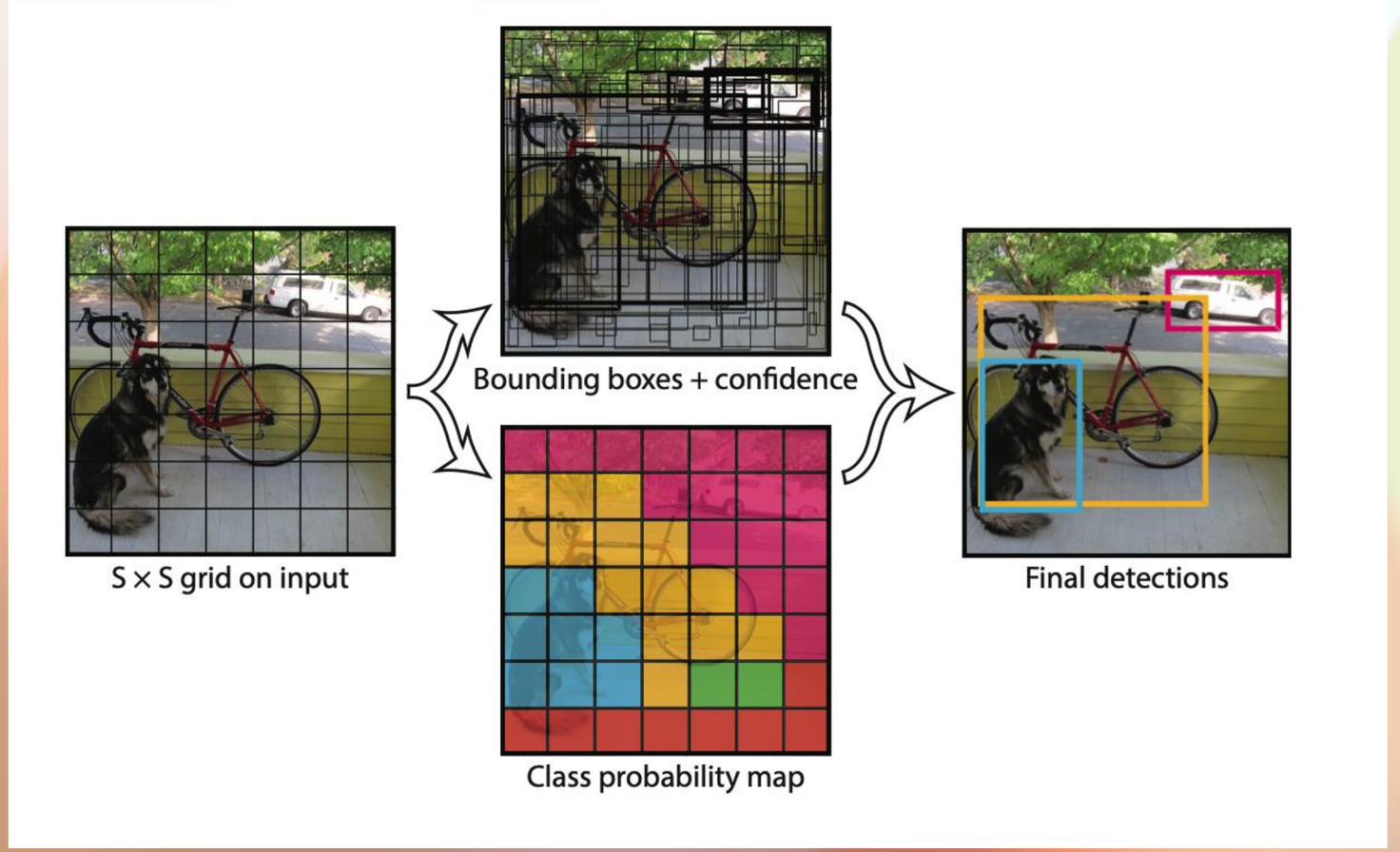
🎯Preserve water and chemicals previously used to extinguish fires.

🎯Significantly decrease deaths caused by fires and fire-fighting.

Scientific Basis

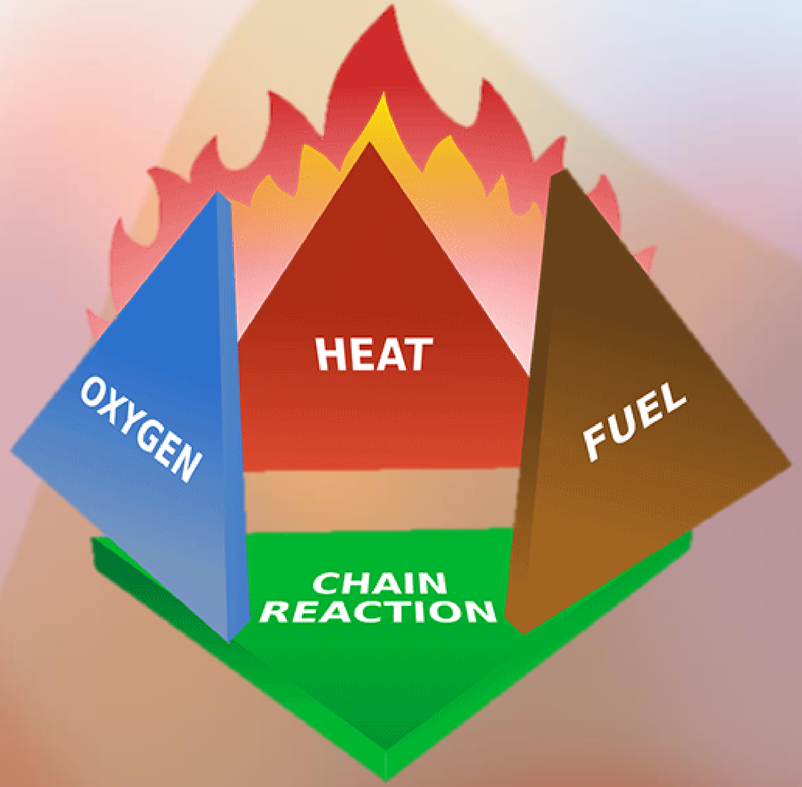
Fire detection:

YOLOv8 guesses object locations by splitting the image into a grid of smaller squares. For each square, it predicts bounding boxes that outline where objects might be. These bounding boxes include coordinates (like a map grid) that indicate the top-left corner and bottom-right corner of the object. The model also predicts confidence scores to estimate how certain it is about each detection. This process is repeated for all grid cells, allowing YOLOv8 to guess object locations across the entire image quickly and accurately.

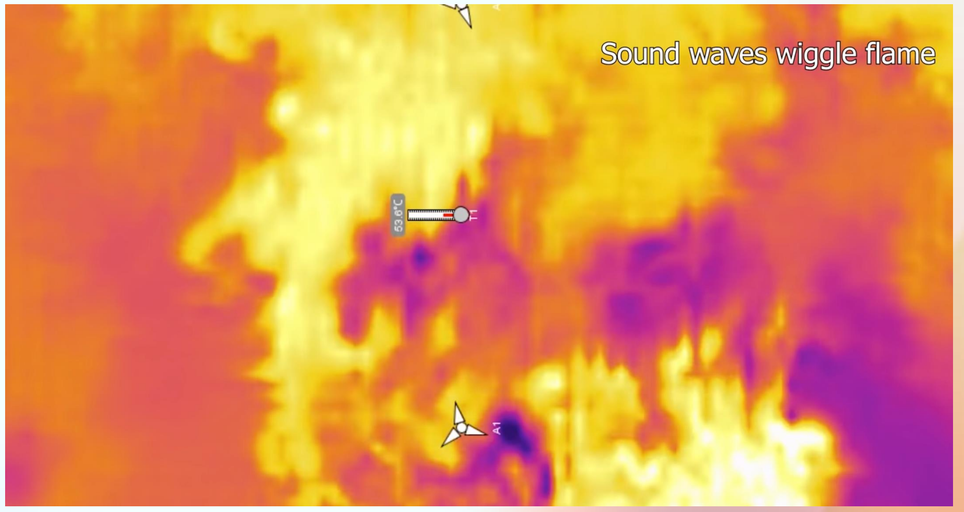


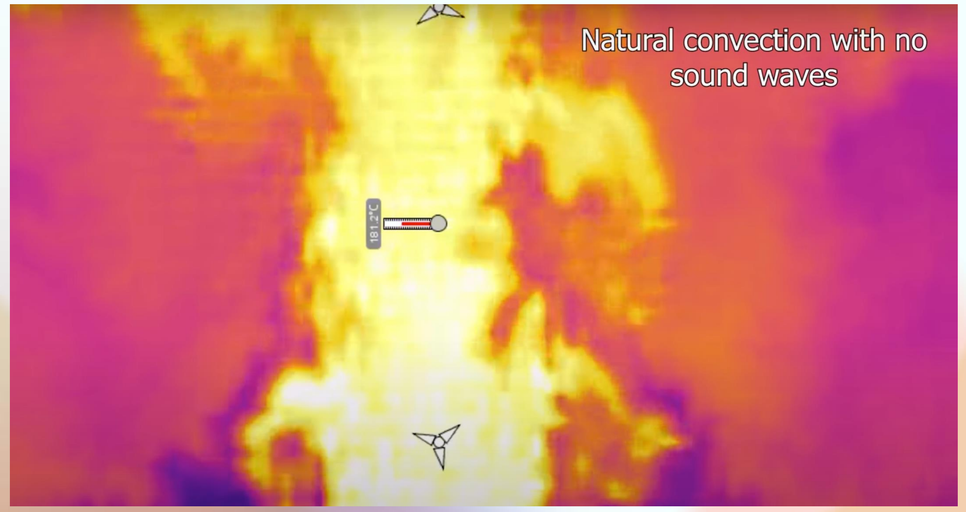
Scientific Basis

Fires consist of 3 main parts Fuel, Oxygen and Heat. In order for a fire to be extinguished one of these elements need to be removed



Scientific Basis





Fires typically heat the air which causes that warm air to rise and fresh air to come in from the bottom but when you're using sound waves to wiggle the flame around it it disrupts that natural flow of air and keeps the old air there and prevents the circulation of the air therefore starving the fire of oxygen therefore causing the flame to die out.

Literature Review

- Xiong et al. (2021): Proposed using acoustic waves to destabilize and extinguish diffusion flames.
- Ivanov et al. (2021): Integrated DNNs and acoustic waves modulated by triangular waveforms for fire extinguishing.
- Hirst & Booth (1977): Provided insights into measuring flame-extinguishing concentrations and related apparatus.
- Torikai et al. (2011): Explored fundamental aspects of using inert gases for flame suppression.
- Giannuzzi et al. (2016): Investigated shock waves and high-speed vortex rings for flame extinguishing.
- Sato et al. (2014): Proposed a robotic fire-fighting system using aerial extinguishers with inert gas capsules.

Methodology

This model features a high-powered, environmentally friendly acoustic extinguisher equipped with a Raspberry Pi camera for real-time flame detection. Compared to traditional fire extinguishers, this system boasts several advantages, including continuous operation, multi-class fire suppression capabilities, independent operation, rapid response times, high portability, and, notably, its commitment to environmental sustainability. This innovative approach holds significant promise for firefighters, potentially offering a safer, more effective, and environmentally conscious method for tackling diverse fire scenarios.

Sampling Strategy :

- Selective (for choosing fire type test material)

Analysis Techniques :

- Qualitative
- Quantitive

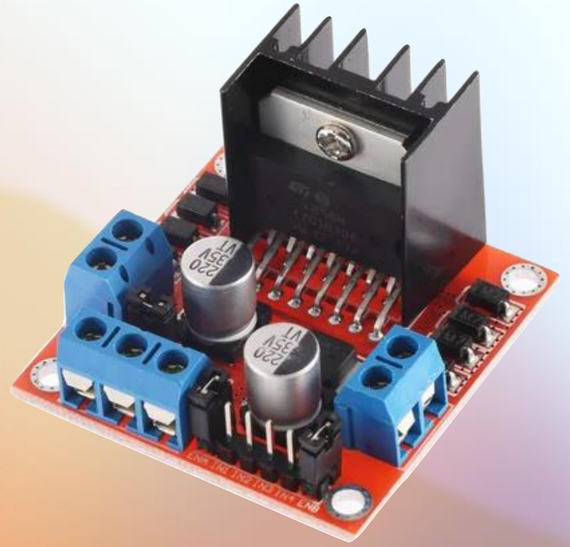
Data Collection Tools:

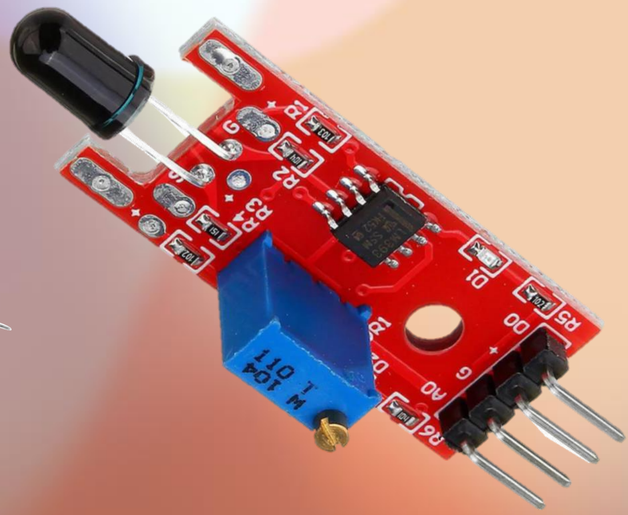
- Experimental methods
- Observation
- Archival Research

Methodology

Hardware:

- Raspberry Pi
- Speaker
- Raspberry Pi Camera
- L298N Motor Driver
- TT Geared Motors

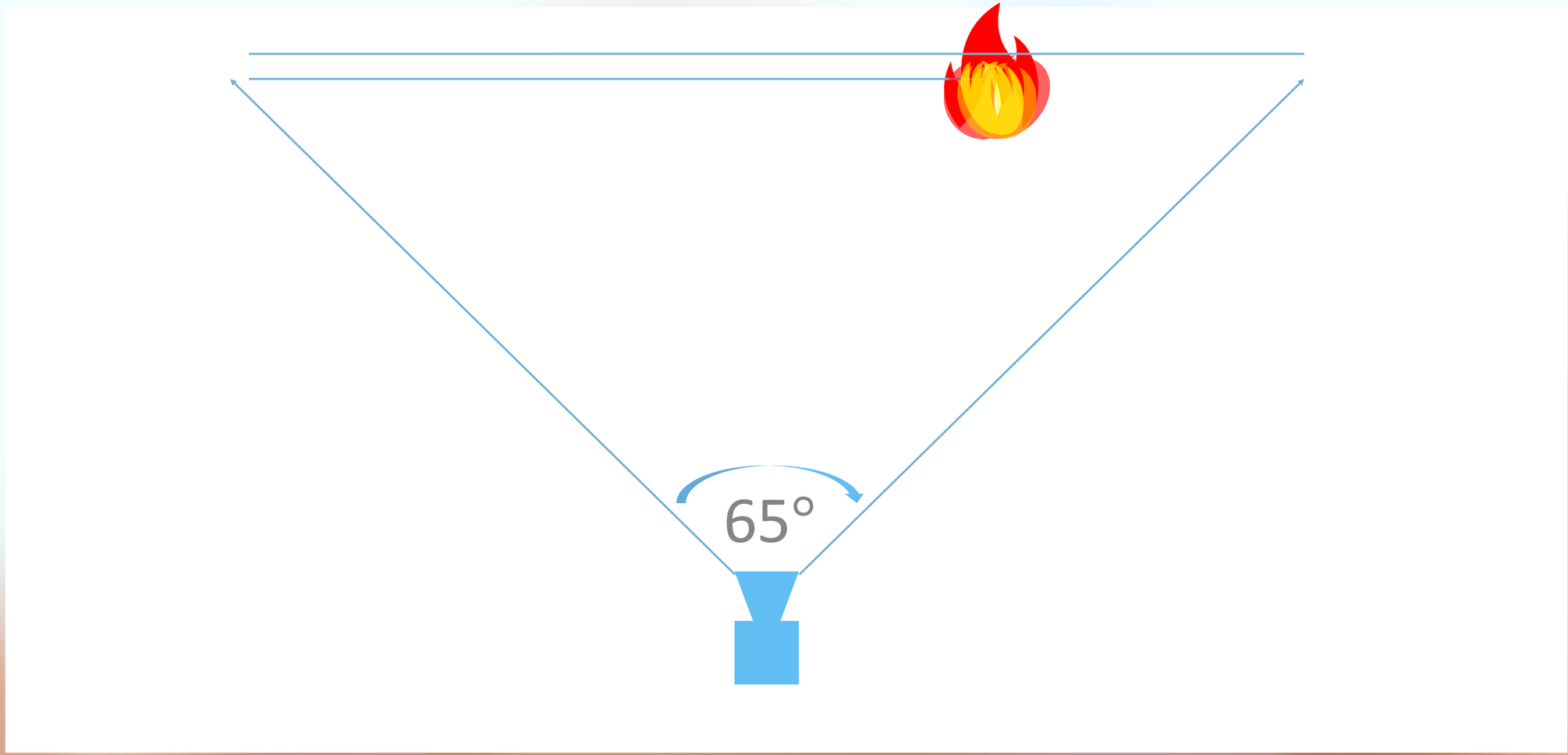




Software:

- Python

Algorithms



Algorithms

$$\text{Angle to fire} = \frac{\text{x-coordinate} \times \text{FOV}}{\text{image width}}$$

$$\text{Angle to center} = \text{Angle to fire} - \frac{\text{FOV}}{2}$$

$$\text{Arc Length} = \frac{n}{360} \times 2\pi r$$

$$\text{Rotations} = \frac{\text{Bow length}}{\text{Wheel perimeter}}$$

$$\text{Motor time} = \frac{\text{Rotations}}{\frac{\text{RPM}}{60}} = \frac{\text{Rotations} \times 60}{\text{RPM}}$$

Results

Our robot was able to successfully to detect flames and extinguish gas, wax and small alcohol fires with limited resources such as a regular slightly modified speaker. This shows it ability to extinguish a large variety of fires autonomously, without human intervention. We also discovered that for our robot design optimum operating frequency was an average of 145HZ well within the 20Hz- 200Hz expected range.