University of Exeter

Particle swarm optimisation applied to simulated forest fire detection

Jacob Maullin-Davies, 690019495

Introduction

- Forests are vital ecosystems that provide numerous benefits to both biodiversity and human habitation.
- Forests play a crucial role in mitigating climate change by absorbing greenhouse gases (CO2) and purifying the atmosphere.
- Act as natural buffers, preventing harmful toxins from entering waterways.
- Forests support a wide array of diverse species, contributing to the overall balance of ecosystems.

https://www.thoughtco.com/when-and-where-do-wildfires-occur-3971236

Keywords – *Particle Swarm Optimisation (PSO), Forest Fire Detection (FFD), Unmanned Aerial Vehicles (UAVs)*

DP 2022, North America Wildfires. (2022). Retrieved from https://disasterphilanthropy.org/disaster/north-america-wildfires/.

Motivation

- Wildfires pose a significant threat to rural and urban ecosystems, as well as human safety and infrastructure.
- The destruction caused by wildfires can have long-lasting impacts on forests, preventing them from fully recovering.
- Climate change, characterized by non-ideal weather conditions and droughts, has increased the frequency of forest fires.
- Human activities are the primary cause of wildfires, even with preventive measures in place.

A. Bouguettaya, H. Zarzour, A. M. Taberkit and A. Kechida, “A review on early wildfire detection from unmanned aerial vehicles using deep learning-based computer vision algorithms,” Signal Processing, jourvol 190, page 108 309, 2022

Existing Solutions

- Early fire detection and monitoring systems are crucial in mitigating the devastating effects of wildfires
- Traditional human operated watchtowers,
- Terrestrial vision systems such 360° cameras can provide a full environmental image capture, which is then later processed and analysed for fire detection.

V. Sherstjuk, M. Zharikova and I. Sokol, “Forest fire monitoring system based on uav team, remote sensing, and image processing,” in2018 IEEE second international conference on data stream mining & processing (DSMP) IEEE, 2018, pages 590–594

UAV applications

- UAV drone technology provides a wide and accurate perception of potential fire locations, making it an effective solution for FFD.
- UAVs excel in accessing remote and dangerous areas that are limited for fire-fighting crews due to their ability to move in 3D space.
- UAVs can monitor wider areas compared to stationary vision methods and can easily adapt to changing requirements using advanced technologies such as powerful cameras.
- The extension to this research area involves multi-drone systems, which significantly improve information collection, sharing, and processing capabilities.

I. L. H. Alsammak, M. A. Mahmoud, H. Aris, M. AlKilabi and M. N. Mahdi, "The use of swarms of unmanned aerial vehicles in mitigating area coverage challenges of forest-fire-extinguishing activities: A systematic literature review," Forests, jourvol 13, number 5, page 811, 2022

P. Barmpoutis, P. Papaioannou, K. Dimitropoulos and N. Grammalidis, "A review on early forest fire detection systems using optical remote sensing," Sensors, jourvol 20, number 22, page 6442, 2020.

Nature Inspired control

- Research aims include exploring the potential of naturalistic systems for environmental exploration and developing control mechanisms based on swarm intelligence for multi-drone swarm-based systems.

- Control mechanisms inspired by nature, such as animal behaviors or swarm intelligence, show potential in addressing the challenges of environmental exploration for UAVs.

- The Particle Swarm Optimisation (PSO) algorithm is a predominant naturalistic system inspired by flocking mechanisms in nature and has been used heavily by DeOliveira et al. for multi-drone control and self-organisation.

N. deOliveira, E. Moreira and P. Rosa, “Particle swarm optimization algorithm implementation for multi-ple drones control in continuous task simulation,” inLatin American Robotics Symposium (LARS), Brazilian Symposium on Robotics (SBR) and Workshop on Robotics in Education (WRE) IEEE, 2019, pages 363–368. doi: 10.1109/LARS-SBR-WRE48964.2019.00070.

C. Wang, D. Wang, M. Gu et al., “Bioinspired environment exploration algorithm in swarm based on levy flight and improved artificial potential field,” Drones, jourvol 6, number 5, page 122, 2022

Project proposal

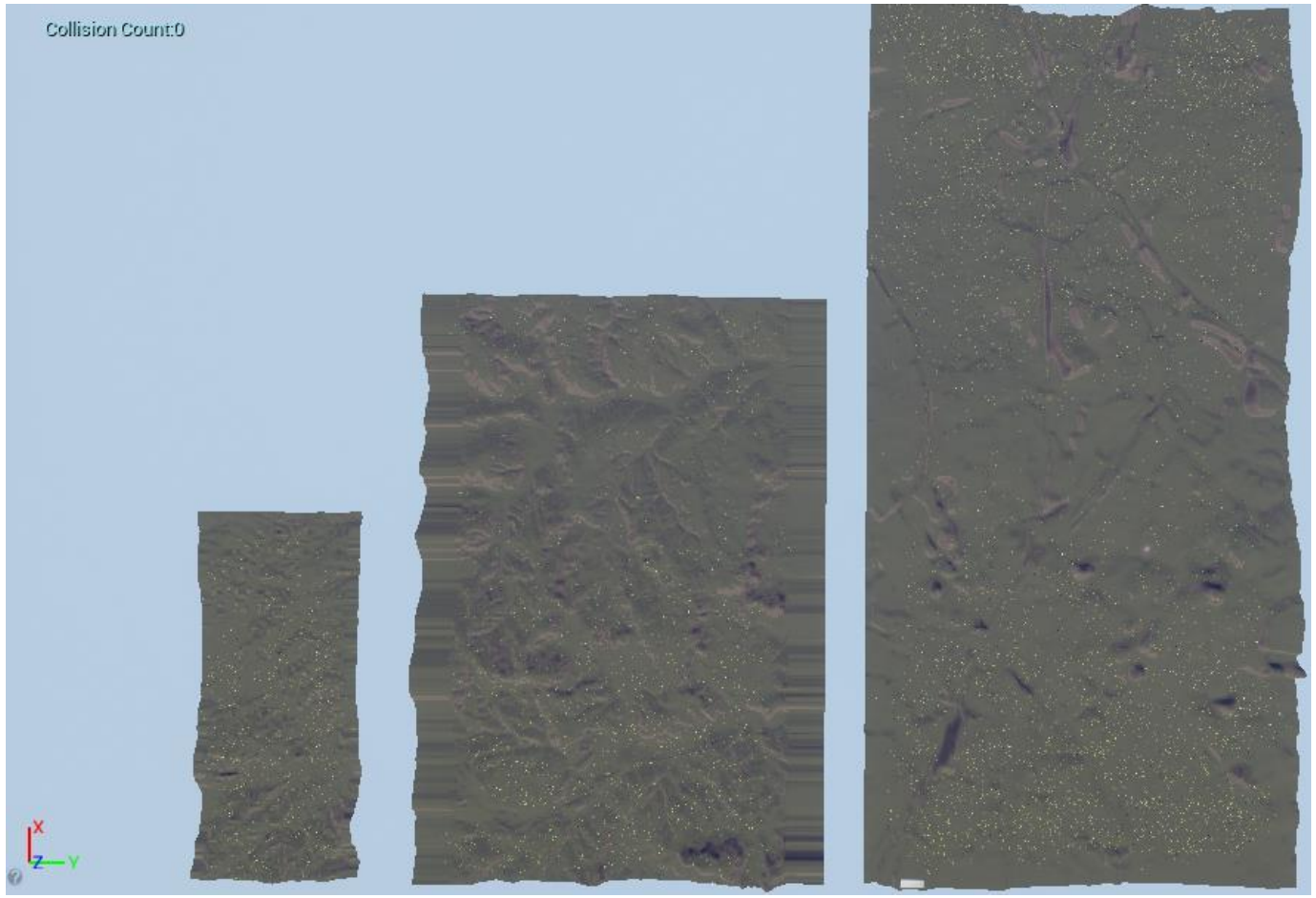
1) Simulation and Technical software methods used

2) Environment exploration techniques

Software specifications

- Unreal Engine is a game engine that can be used to create realistic environments and create scenarios for FFD

- Airsim is a simulation platform for AI research and experimentation built in Unreal Engine

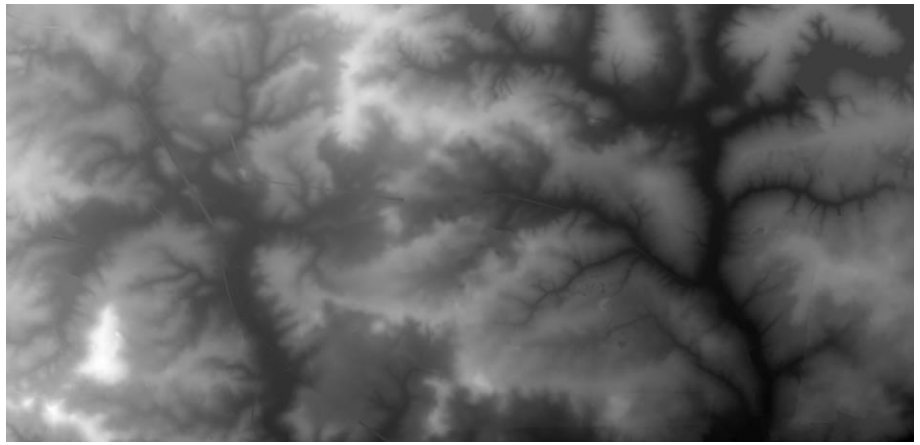


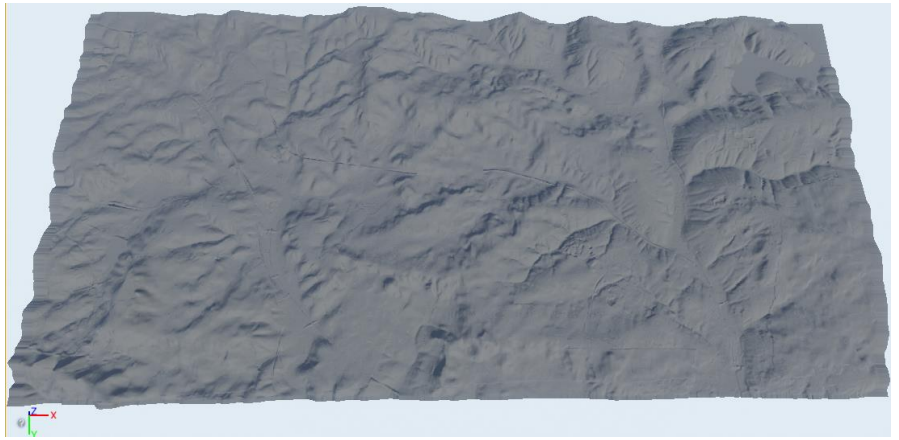
Epic Games, Unreal engine, https://www.unrealengine.com, 2019

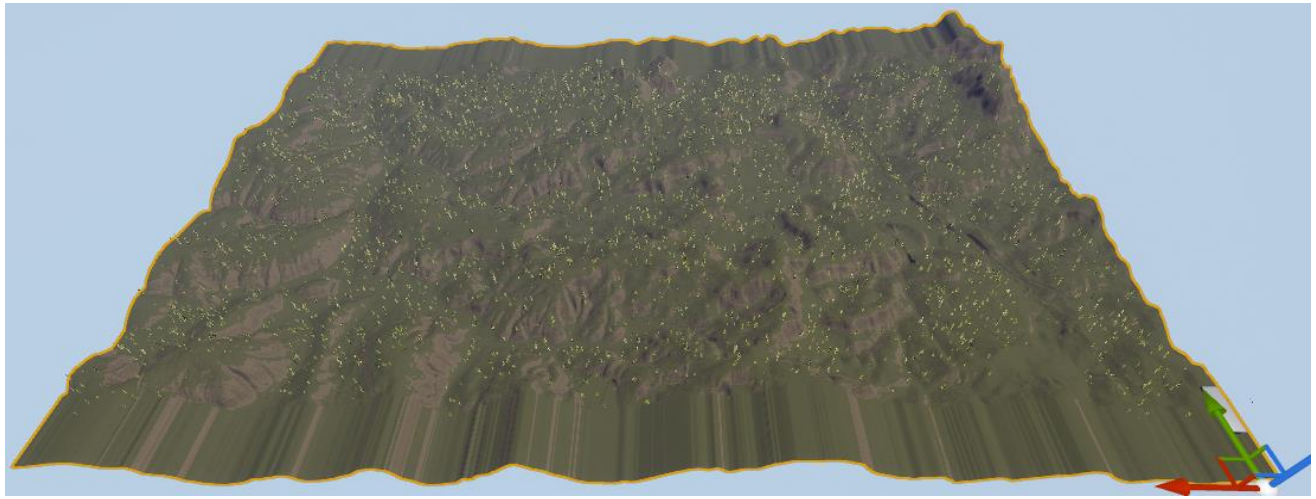
S. Shah, D. Dey, C. Lovett and A. Kapoor, “Airsim: High-fidelity visual and physical simulation for autonomous vehicles,” inField and Service Robotics 2017. eprint: arXiv:1705.05065. [Online]. Available: https://arxiv.org/abs/1705.05065.

Environmental setup

- Greyscale Heightmap — Terrain generation — Texture and Asset additions

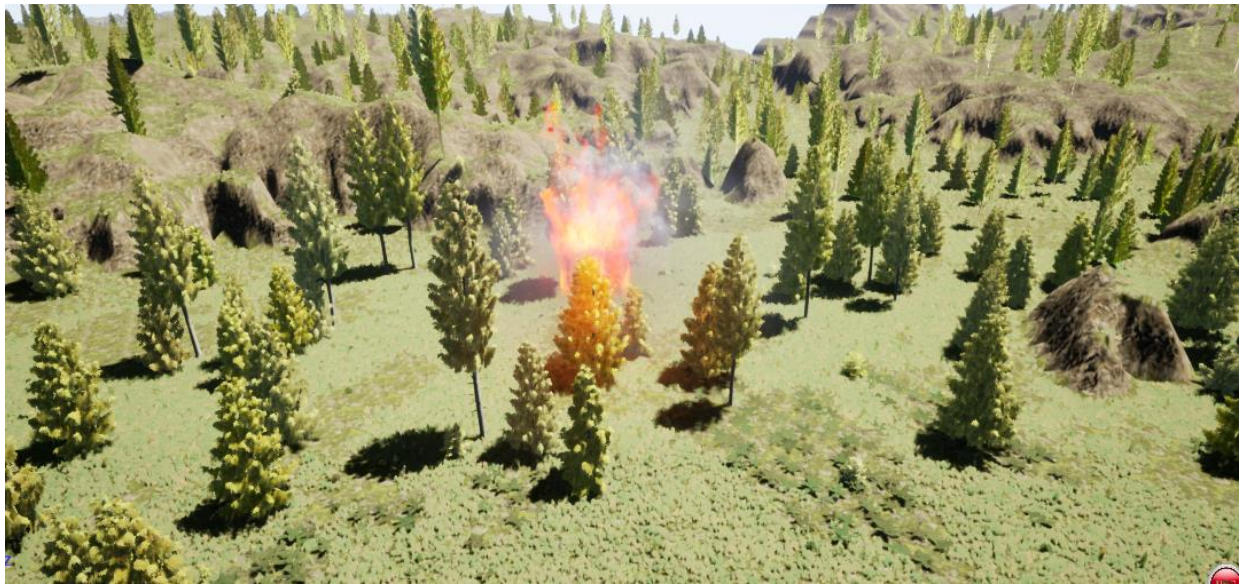






Fire simulation

Fire is added to the simulation to imitate a potential fire hazard for the system to investigate



UAV simulation setup

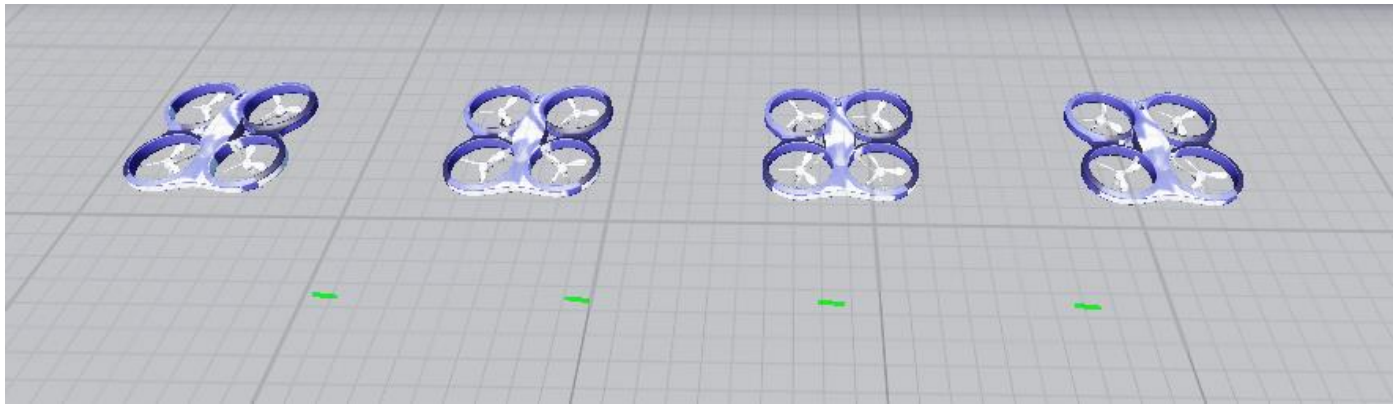
UAV setup is as follows:

LiDAR downward facing scanner →

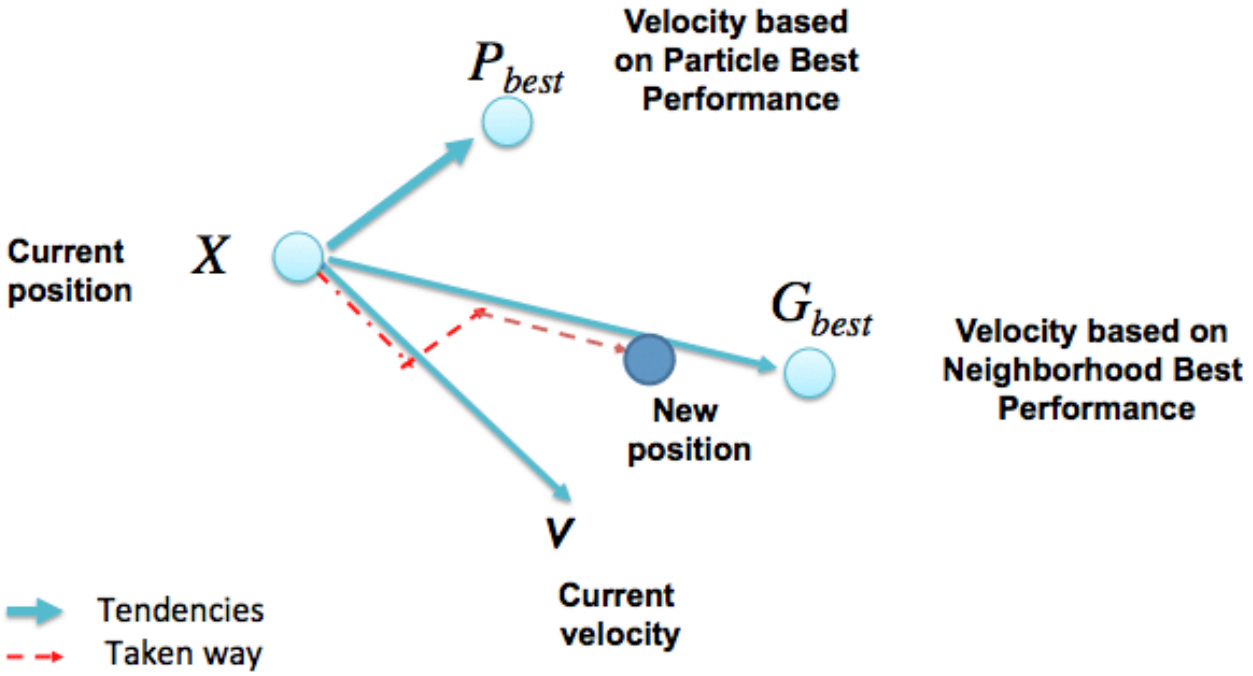
This is sensor is used for elevation detection to ensure correct elevation is maintained.

Front facing camera →

This is used for Visual data collection for the purpose of FFD



PSO



University of Exeter

Zemzami, M., Makhloufi, A., Elhami, N., Elhami, A., Itmi, M. and Hmina, N., 2017, June. Applying a new parallelized version of PSO algorithm for electrical power transmission. In *IOP Conference Series: Materials Science and Engineering* (Vol. 205, No. 1, p. 012032). IOP Publishing.

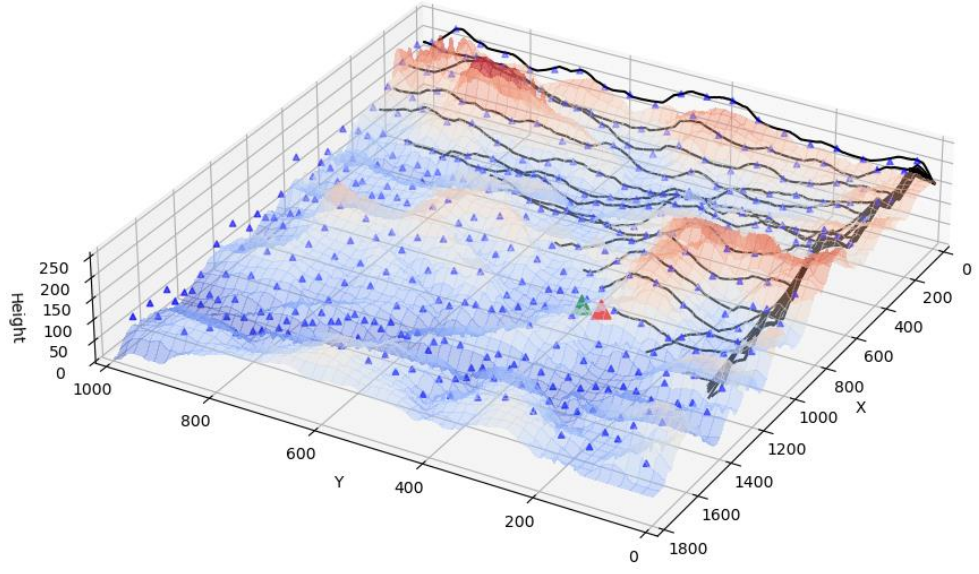
Implemented search methods

- Sweep method:
  - Waypoints are uniformly split across the swarm.
  - Drones are assigned subsets of waypoints to navigate to.
  - Each drone moves to the assigned waypoints in order continuously until a termination criteria is met.

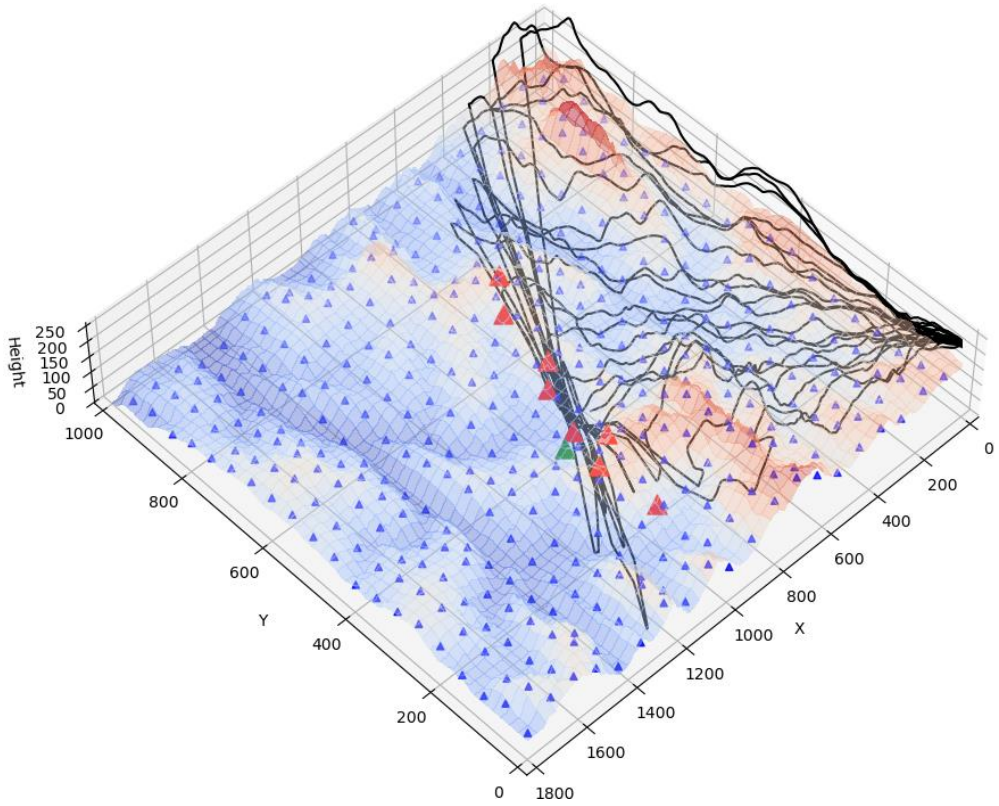
- PSO greedy:
  - Each drone selects the closest point as its waypoint.
  - Waypoints are divided into a greedy search exploration.
  - Assignment of waypoints can be adjusted if another drone is closer to a specific waypoint.
  - Allows for dynamic movement and adaptation to the swarm's behaviour in the environment.

- These methods contrast:
  - Predefined waypoint exploration, as expected in typical exploration.
  - Adaptability of cooperative swarming algorithms

Exploration and exploitation



Scan search method



PSO search method

Project demonstration

- The next section of this presentation will demonstrate this project's final system.

- The demonstration will consist of:

1) HSV flame thresholding demonstration and runtime investigation of fire and non-fire images

2) Code explanation and system setup

3) A runtime of the final system under a fire test case scenario using the PSO greedy search method will be demonstrated and then evaluated.

Project demonstration Video

- DemoY4.mp4