

# Autonomous Systems

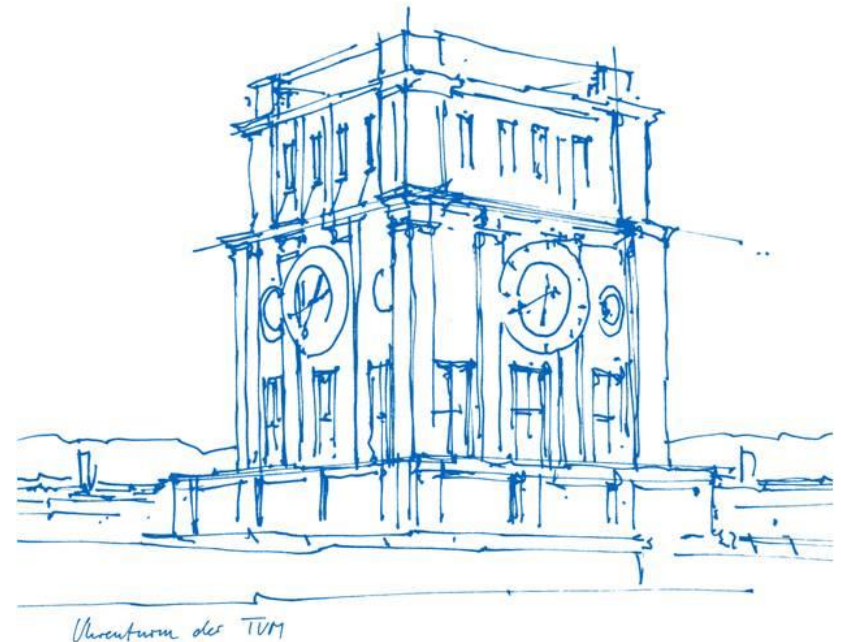
## Challenge 1 – Search and Rescue(Mission)

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# Background of Avalanche Scenario

- Avalanche is responsible for over 200 fatalities every year
- Golden rescue time is only 15 mins
- Risk of a second avalanche for the victims and rescuers
- UAV: Ability of autonomous searching without terrain restriction



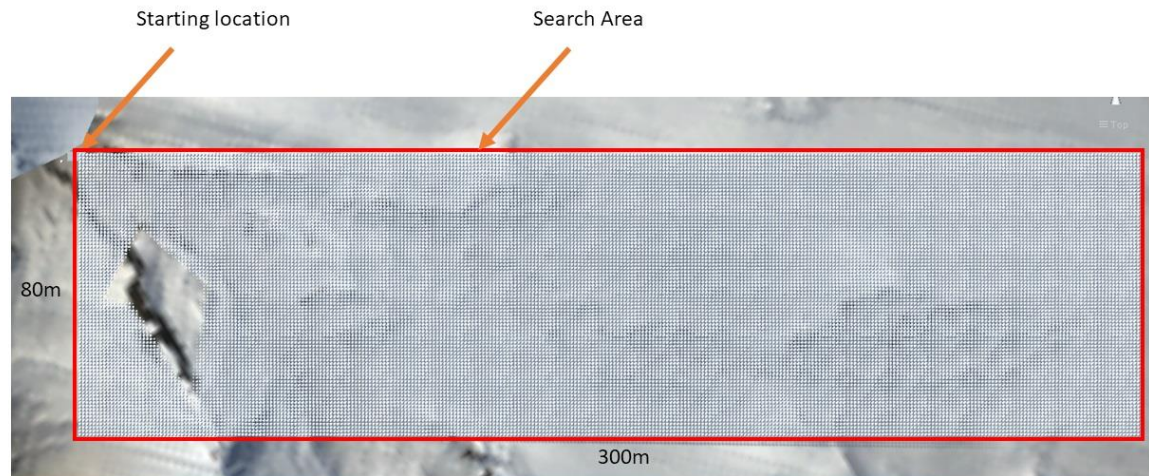
# Task Introduction

In this project, our main tasks are flying the drone over the avalanche and locating victims.

And the subtasks are:

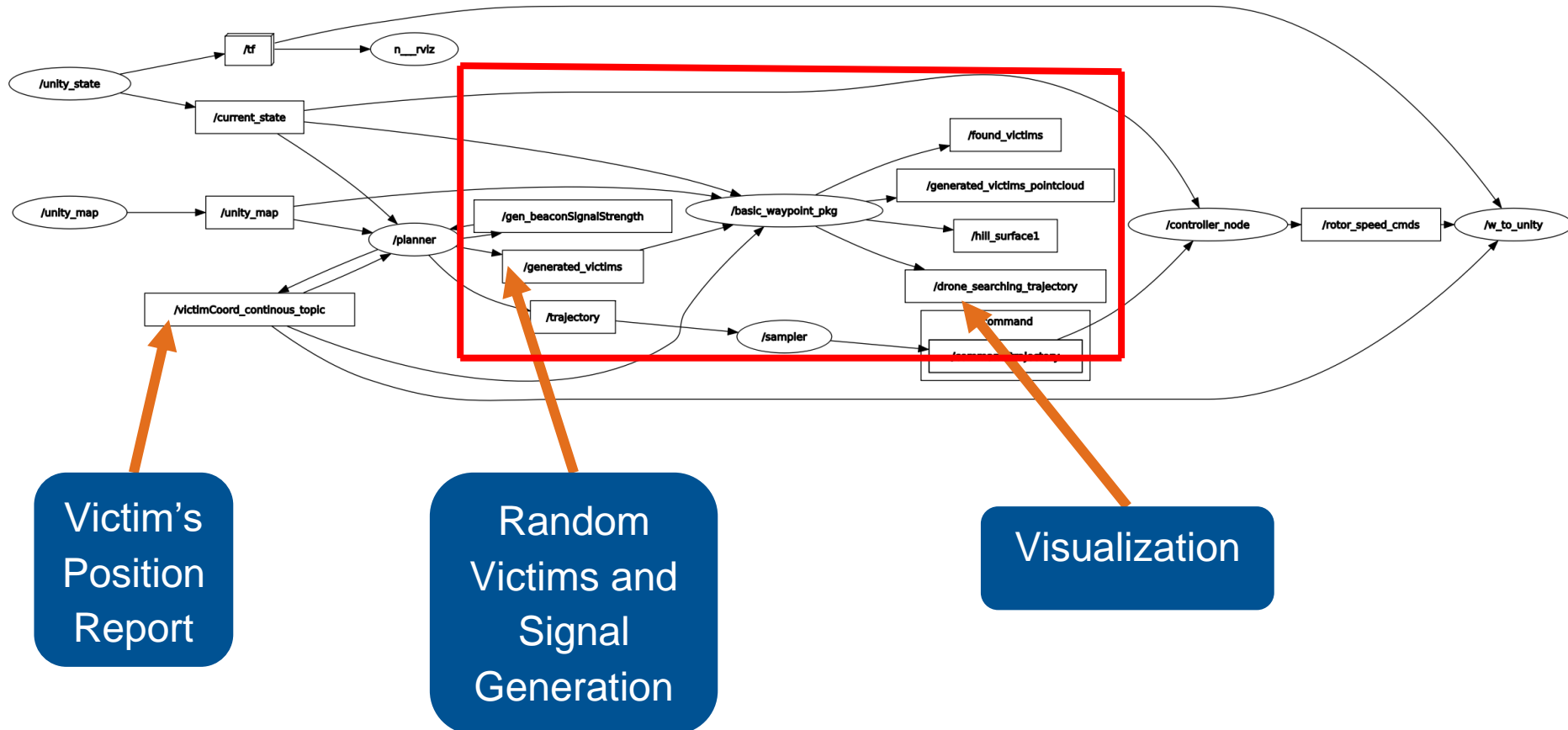
- Realistic sensor models for avalanche beacon( with noise & capabilities)
- Mission planning( global planning & local planning)
- Adaptive trajectory generation
- Location report

ROS



# Overall Framework

## Rosgraph



# Victims and Signal Generation

## 1. Random Victims Generation

- Distance of each victim  $> 32\text{m}$  ( Normally  $> 2 \times 15\text{m}$ , Considering noise)

## 2. Signal Generation

- Check the distance between the drone's current position and generated victims' positions.
- When distance  $< 15\text{m}$ , two signals will be generated into two topics:
  - `/gen_beaconSignalStrength`
  - `/gen_beaconAngle`



# Victims and Signal Generation

- Signal Strength:

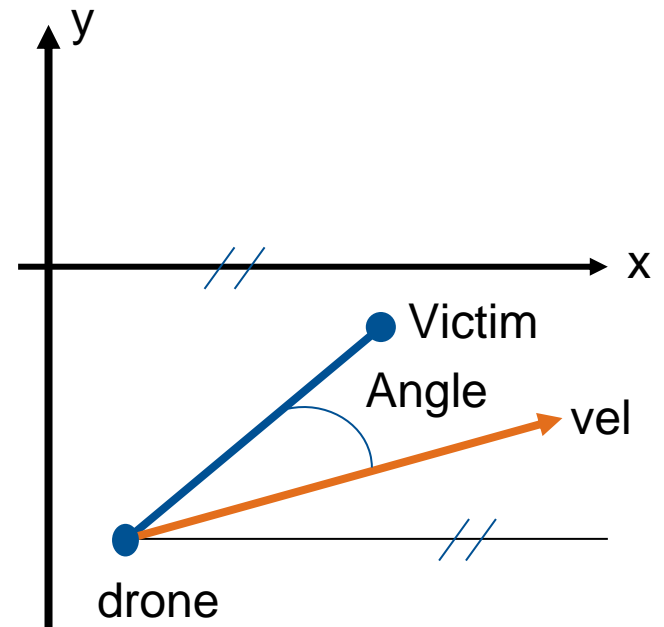
$$\text{SignalStrength} = 1 - \frac{\text{space\_distance}}{15} + \text{noise}$$

- Angle:

$$\alpha_{vel} = \tan^{-1} \left( \frac{v\_y}{v\_x} \right) \cdot \frac{180}{\pi}$$

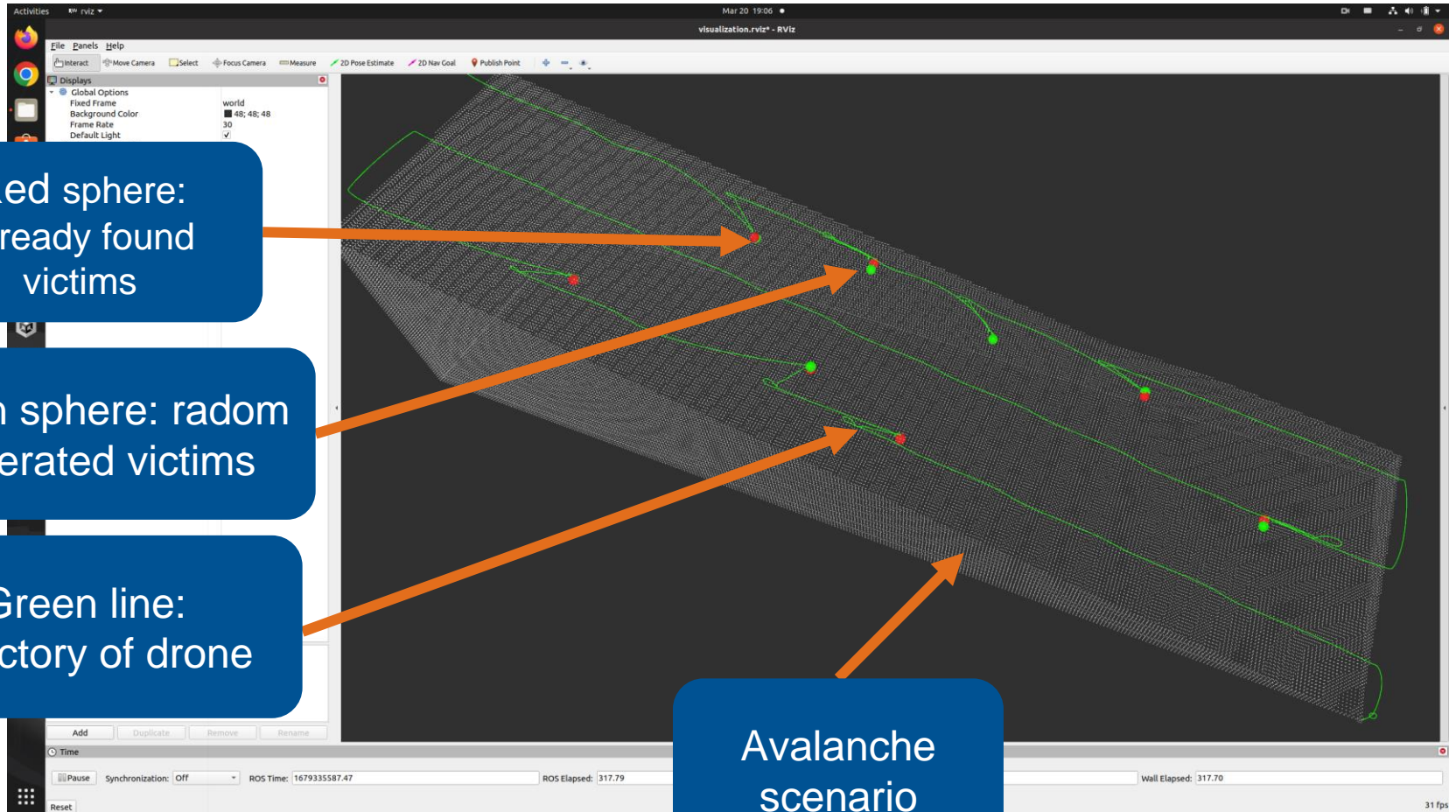
$$\alpha_{rel} = \tan^{-1} \left( \frac{y\_vic - y\_uav}{x\_vic - x\_uav} \right) \cdot \frac{180}{\pi}$$

$$\text{beaconAngle} = \alpha_{rel} - \alpha_{vel} + \text{Angle\_noise}$$





# Visualization



Red sphere:  
Already found  
victims

Green sphere: random  
generated victims

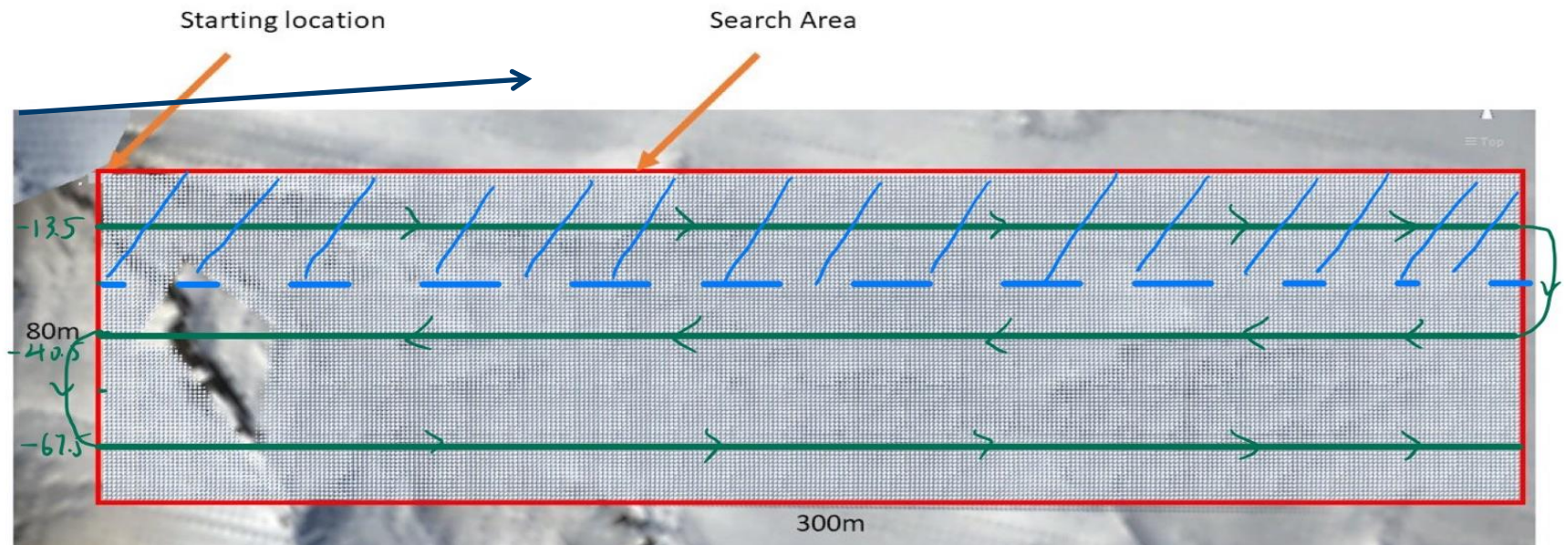
Green line:  
trajectory of drone

Avalanche  
scenario

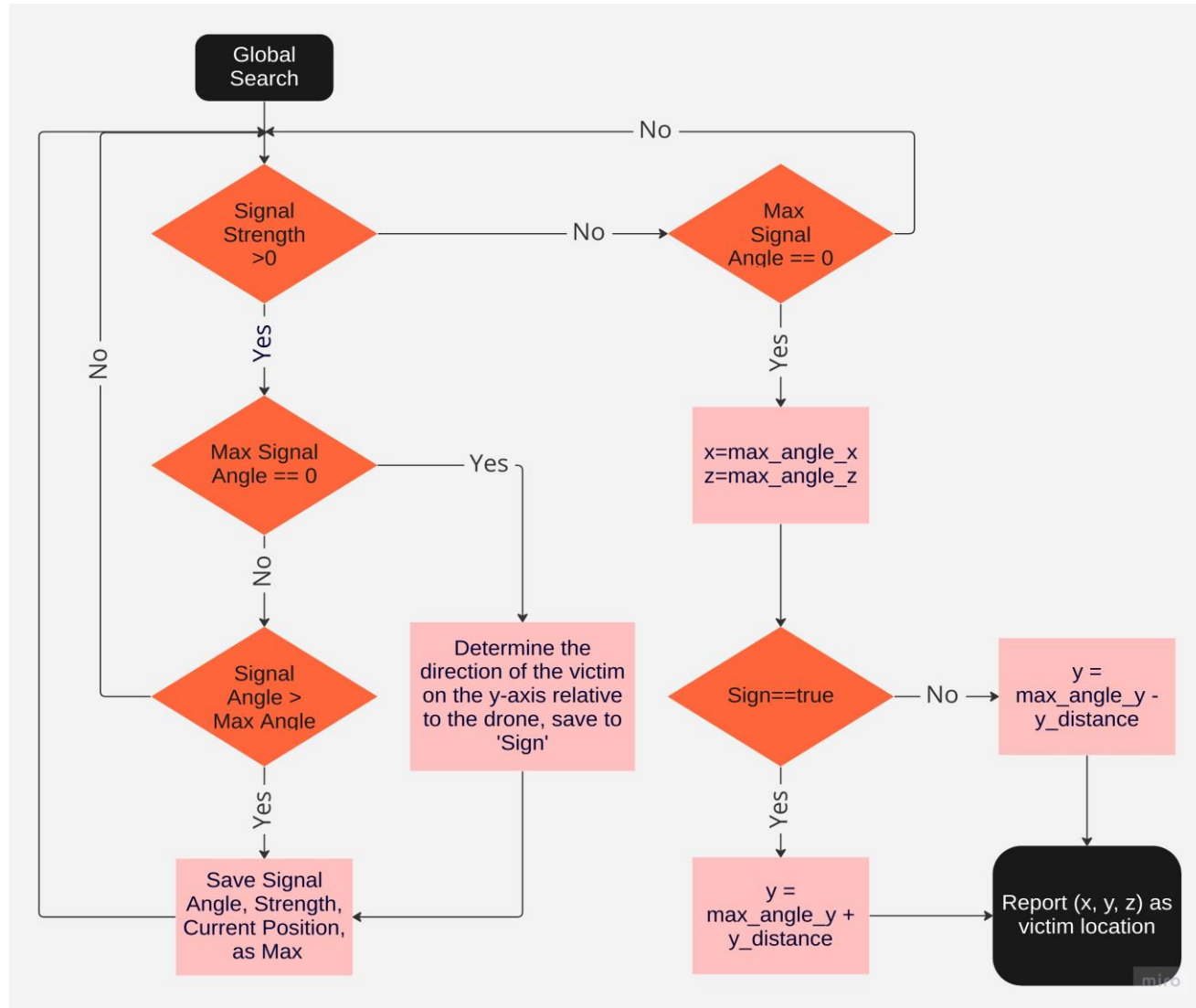


# Global Planning

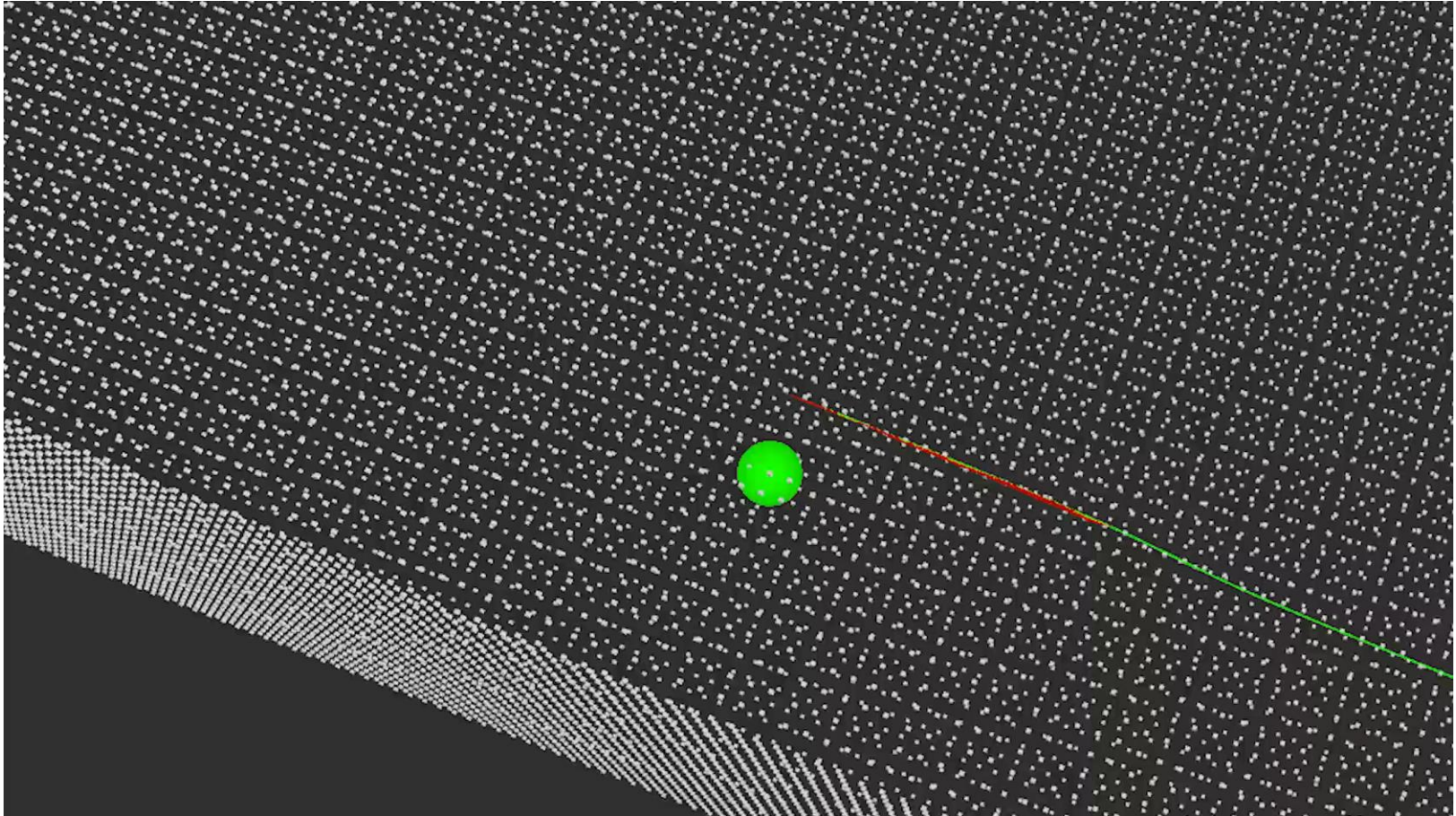
- Flying height: 5m
- Distance between trajectories: 27m
- Starting point: (0, -13.5)
- If receive signal, start local search



# Local Planning method 1



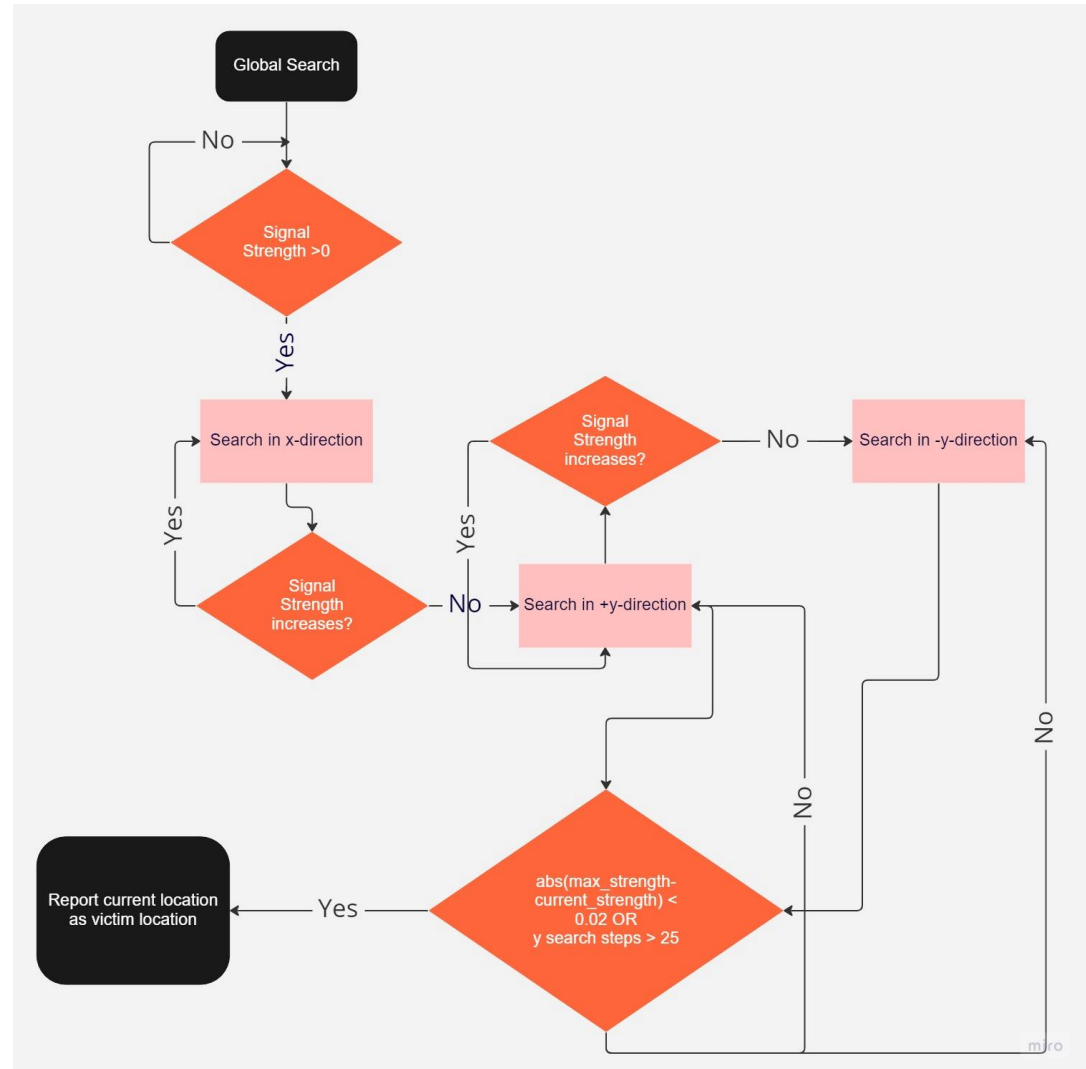
# Local Planning method 1



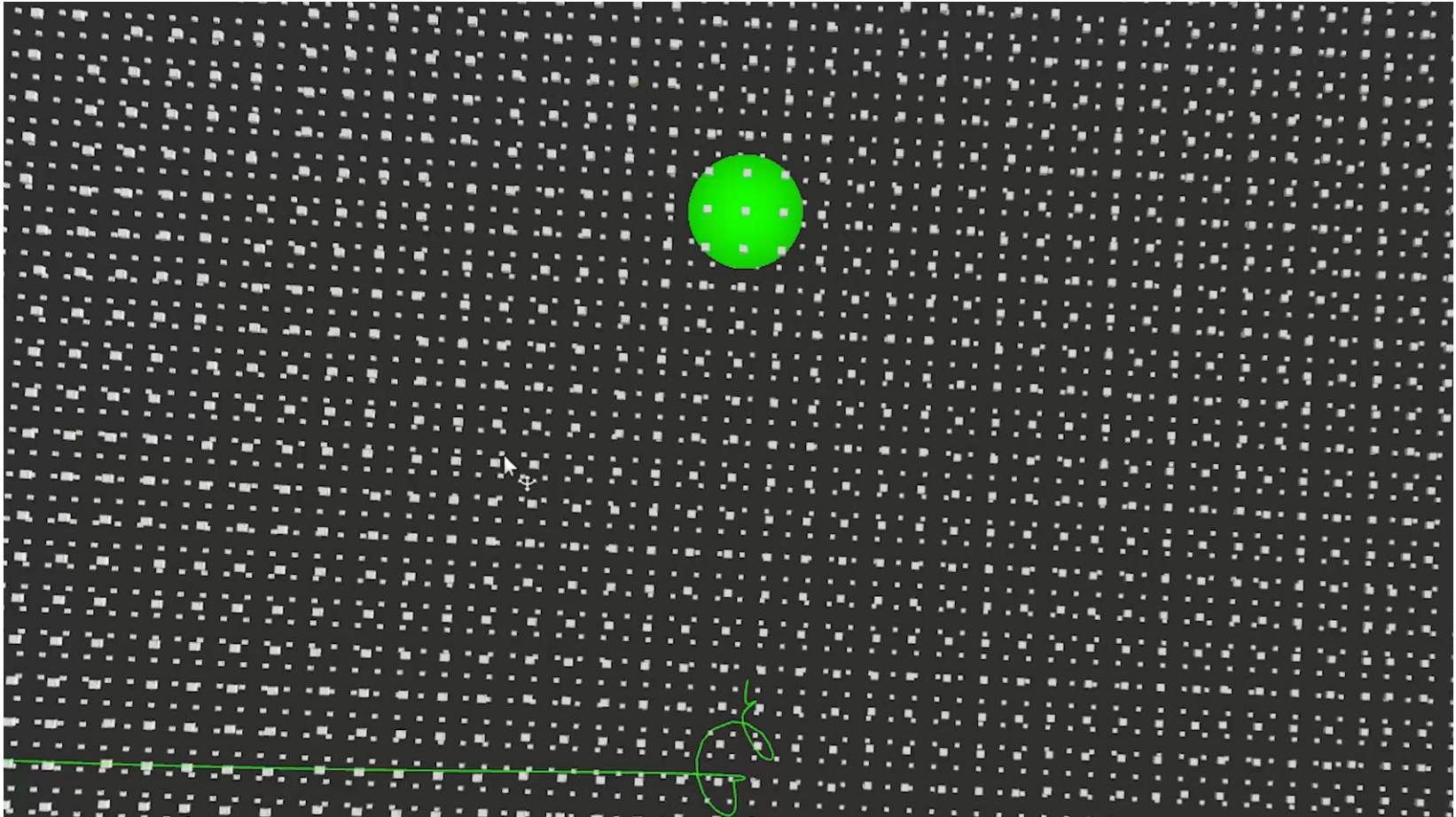


# Local Planning method 2

- Two step gradient search methods
- Search in small steps until signal strength satisfied/  
upper limit of steps is reached



# Local Planning method 2



# Evaluation: Total Search Time

- Scenario 2:  
Signal strength  
random noise  
 $\pm 0.02$ ,  
signal angle  
random noise  $\pm 10^\circ$

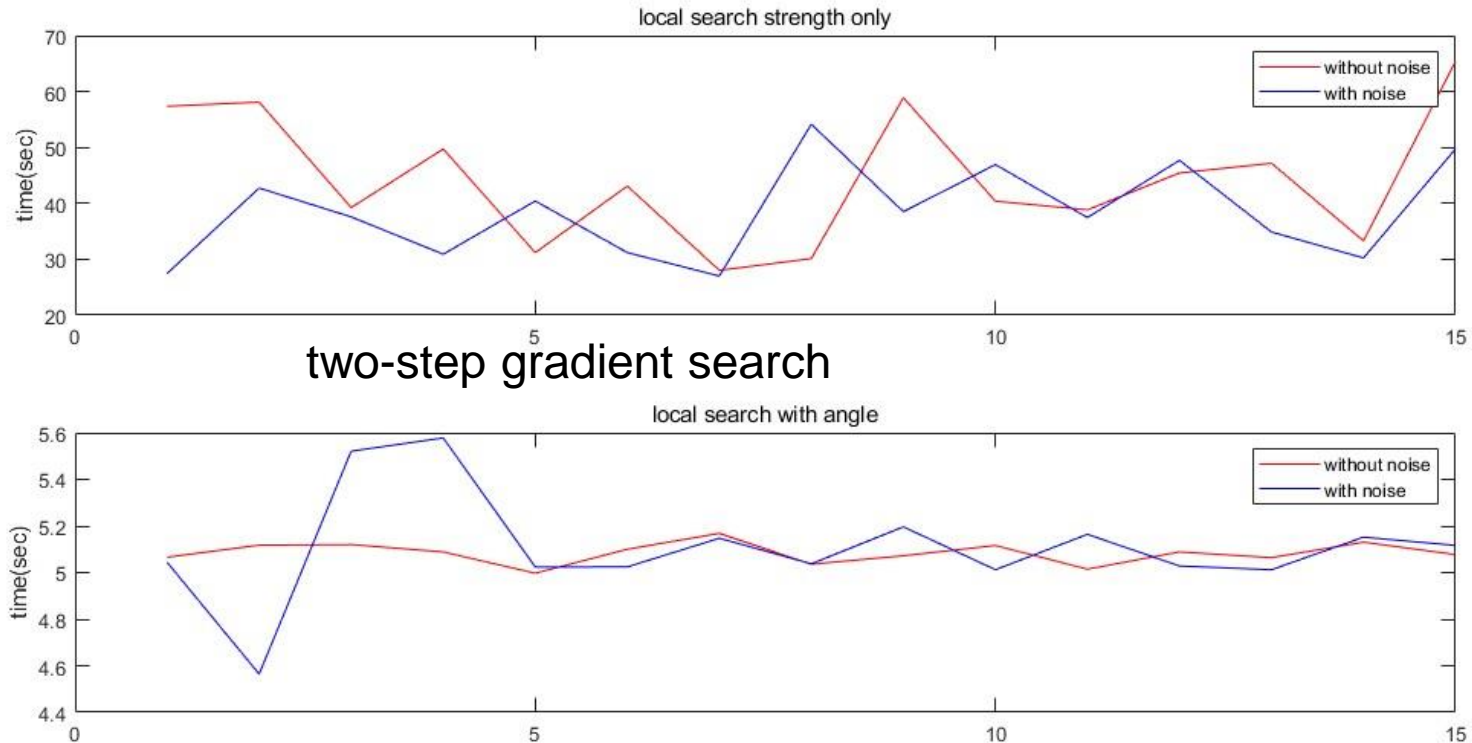
TABLE III  
SCENARIO 2 MODE 1

Information	Test 1	Test 2	Test3
global search time	290.698381	273.59735	256.29099
average local search time	5.146234	5.083524	5.094643
standard deviation (local)	0.138154	0.005491	0.003964
average distance error	0.706028	0.963725	0.653671

TABLE IV  
SCENARIO 2 MODE 2

Information	Test 1	Test 2	Test3
global search time	405.359339	413.126449	426.346457
average local search time	35.818823	39.55433	40.001796
standard deviation (local)	5.762559	9.959535	7.515077
average distance error	2.255175	1.780168	2.065041

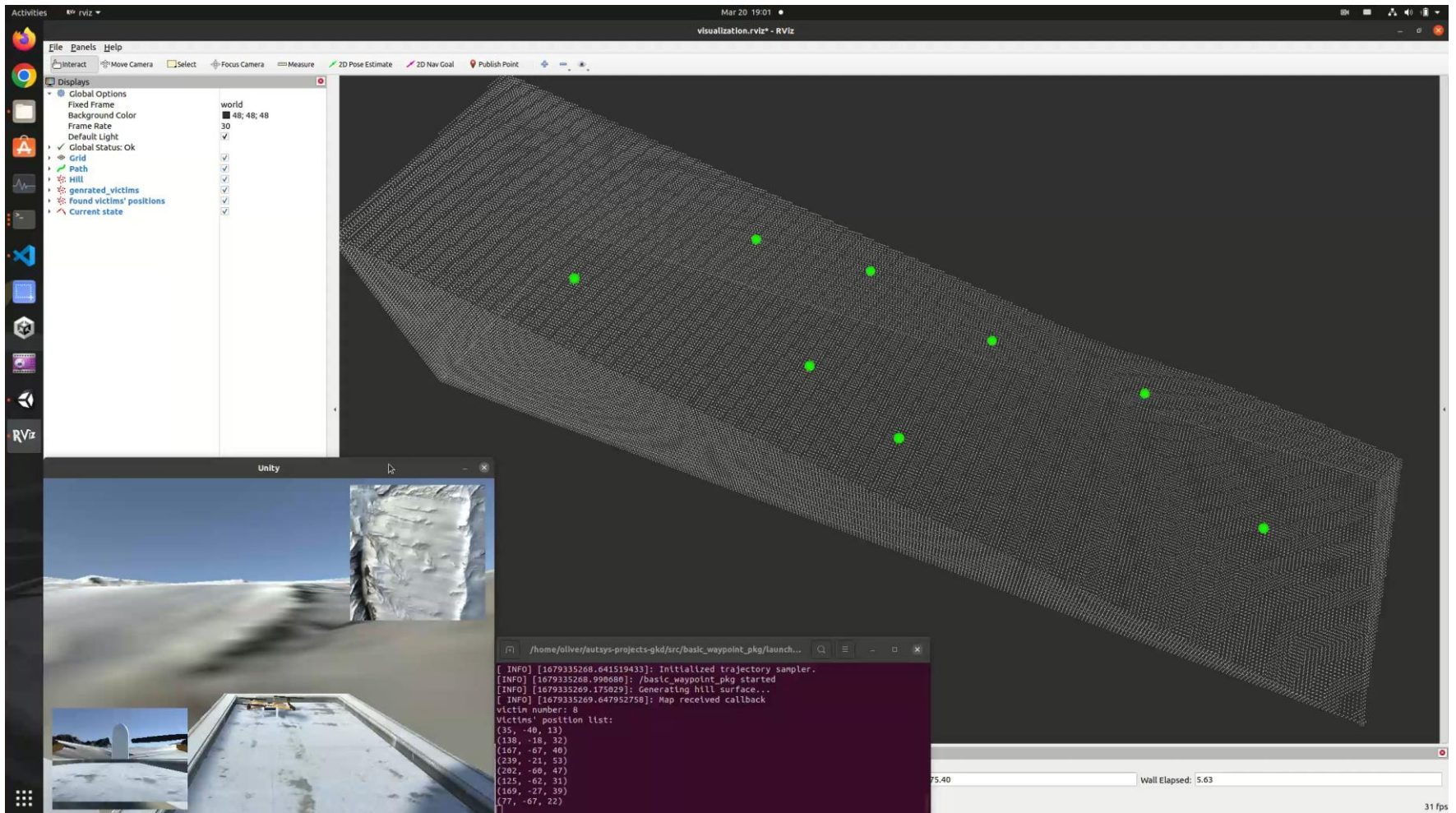
# Evaluation: Comparison of Local Search Time



With noise: Signal strength random noise  $\pm 0.02$ , signal angle random noise  $\pm 10^\circ$

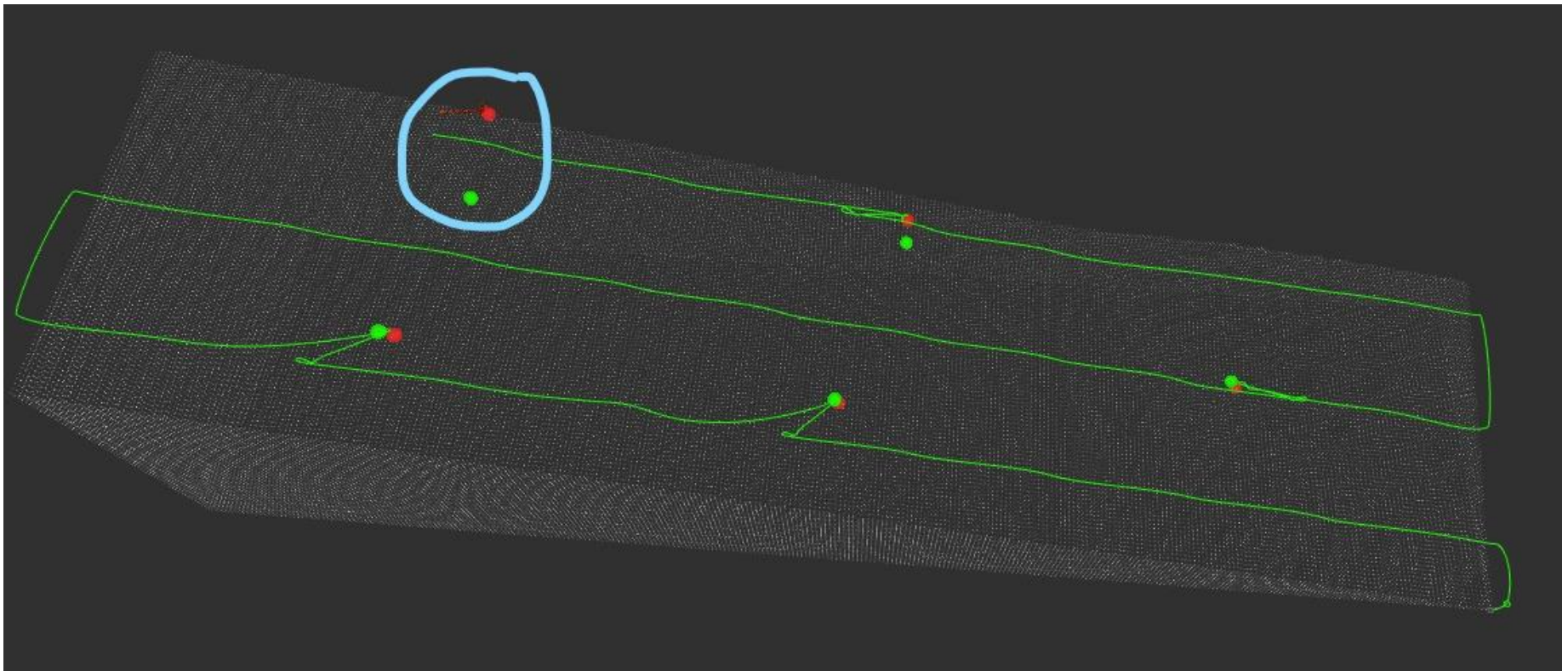


# Visualization (using local search method 1)



# Evaluation: with large angle noise

- Angle signal based on EM-field may be not reliable
- Possibility of discriminating the y-direction incorrectly
- Useless excavation operation



# Conclusion

- Total Search time 5 victims:  
UAV-based search : 4 – 8 Min VS.  
Human rescuer: 27 Min (speed : 0.5556m/s)
- Eliminate the risk of second avalanche
- Excavation still by human rescuers

✓ Human – Robot Collaboration

## Future Improvement

- Magnetic field simulation for a more realistic model of the signal
- Noise types and strength may be gained through real-world measurements
- Explore more advanced local search methods
- Multi-UAV Collaboration for large area

# Contribution

- **Chenming Wang**
  - Local search method 1
  - Part of global search
  - Part of overall code construction and optimization
- **Tao Ma**
  - Modification of planner code
  - Part of local search method
  - Part of overall code construction and optimization
- **Yiwei Wang**
  - Local search method 2
  - Part of global search
  - Literature and conceptual research
- **Yiyang Li**
  - Overall code construction and optimization
  - Victim and signal generation
  - Visualization

# Thanks for your attention!

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