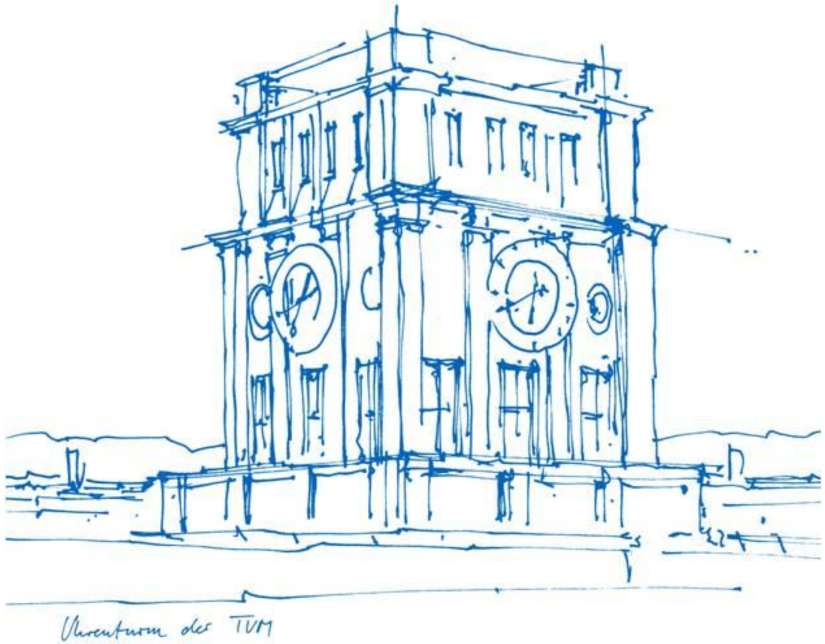
Search and Rescue of Avalanche Victims

Autonomous Systems WS 2021

Technical University of Munich

Presenter: Group aerial screw

Date: 24. March 2022



Outline

- Motivation
- Problem Description
- Search Method
- Path Planner and Controller
- Experiment
- Conclusion

Motivation

- Requirement: fast and accurate positioning
- Properties of drones: high speed, wide detection range, no terrain restrictions

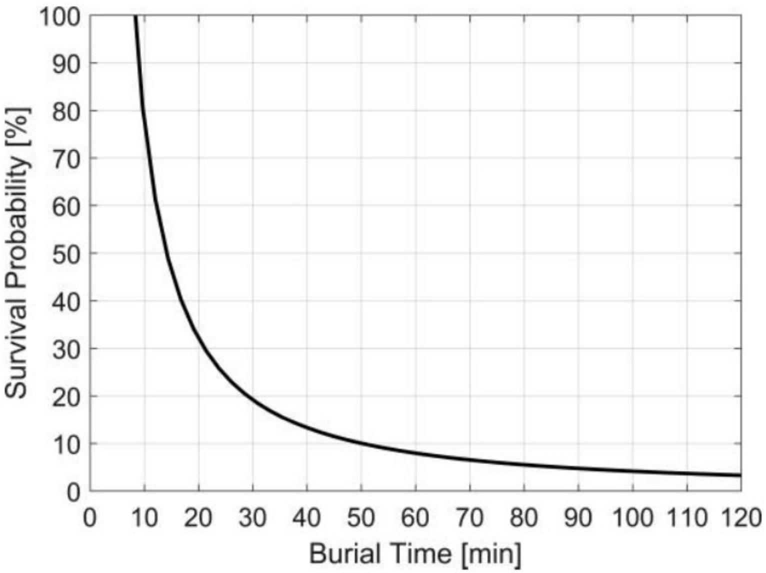


Fig. 1: Survival curve for people buried in avalanche [1]

Problem Description

- Avalanche Scenario:
  - Search area: rectangle
  - Angle of slope: 7°
  - Flight height: 5m
- Sensor Model:
  - Intensity signals with noise

$$\bar{i}_t = \frac{r}{dist_v} \qquad i_t = \bar{i}_t + \epsilon_t \qquad \epsilon_t \sim U([0,1]) \cdot \lambda e^{-\lambda \bar{i}_t}$$

  - Intensity signals and direction signals

$$\hat{d}_t = \frac{\vec{d}_t}{||\vec{d}_t|| + c}$$

Global Search Method

- Global Search Method

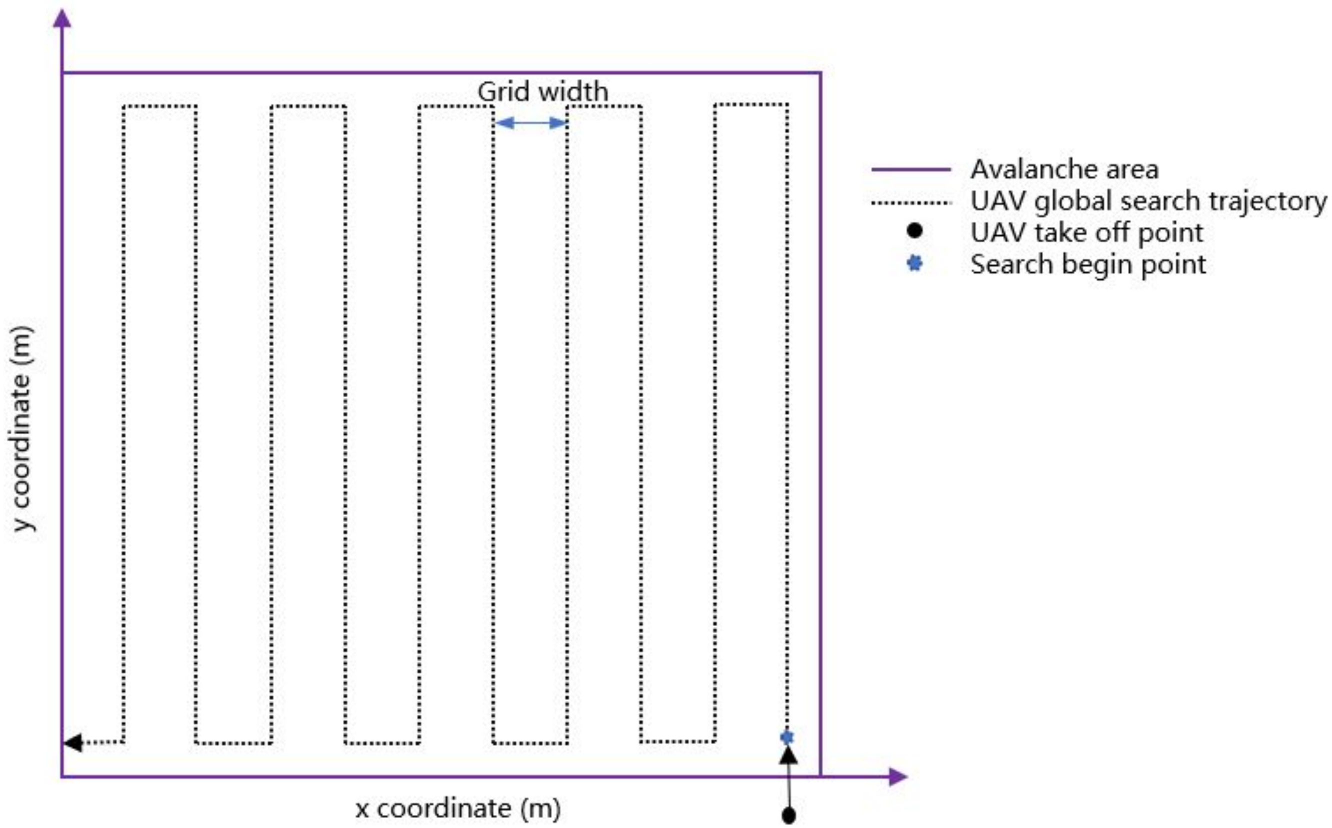
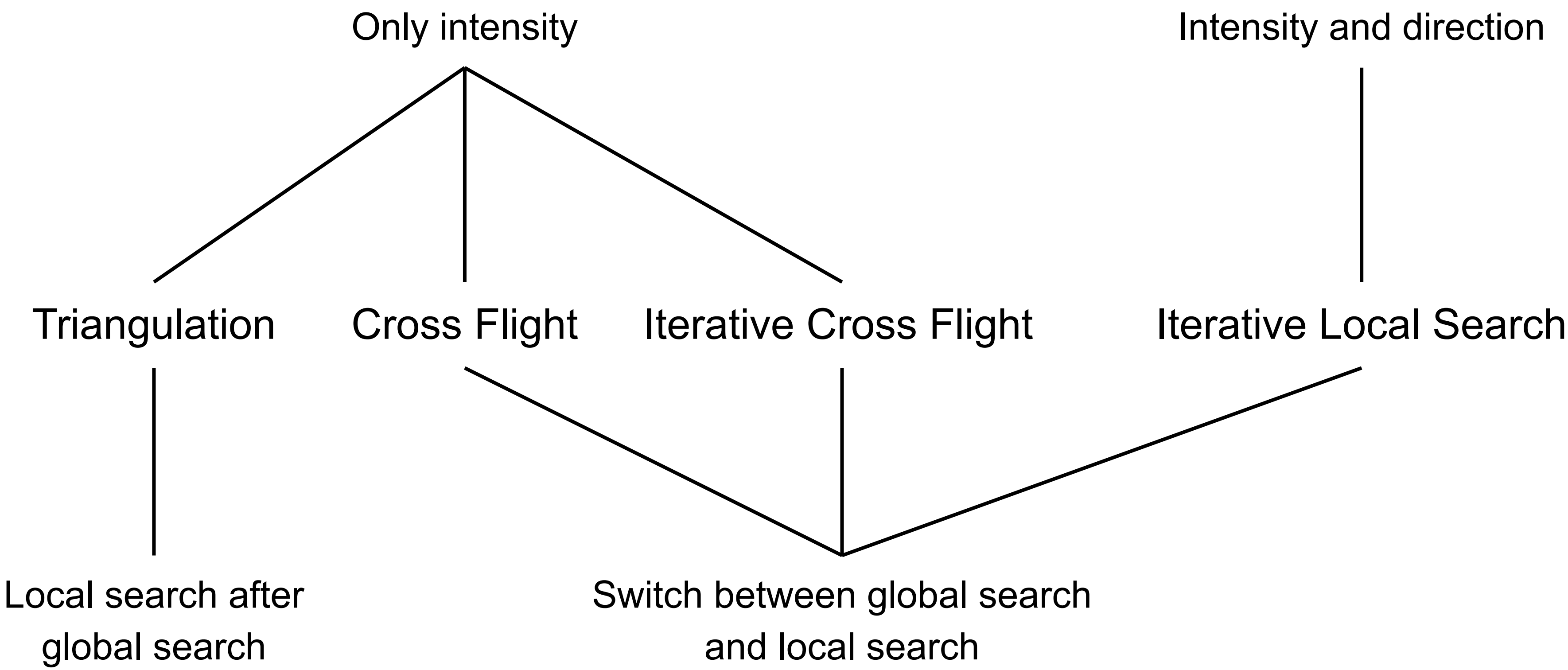


Fig. 2: Path of global search "S-shape flight"

Local Search Method



Local Search Method

- Cross Flight

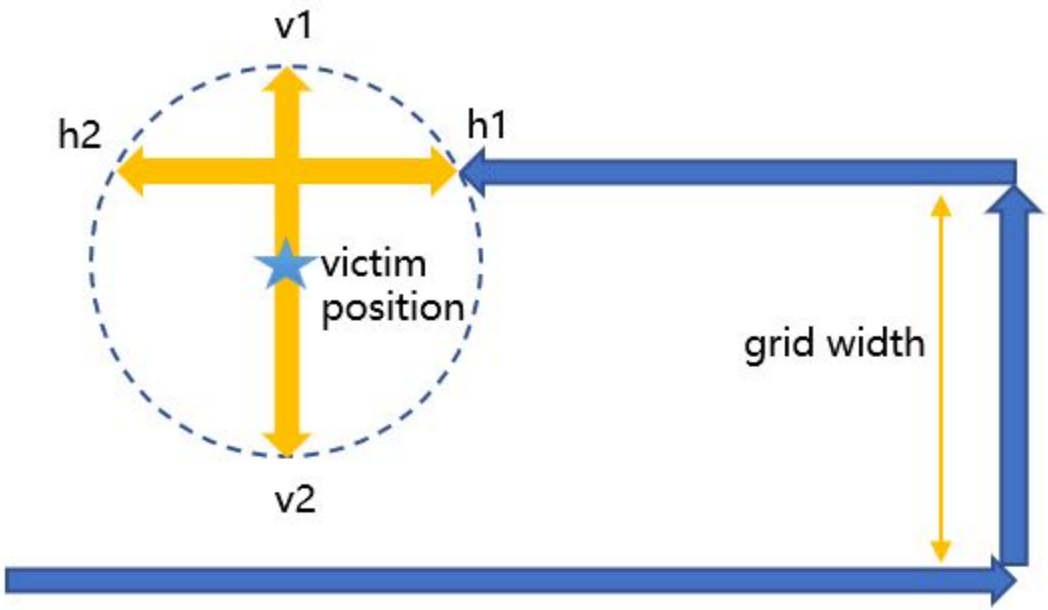


Fig. 3: Cross flight

Local Search Method

- Cross Flight

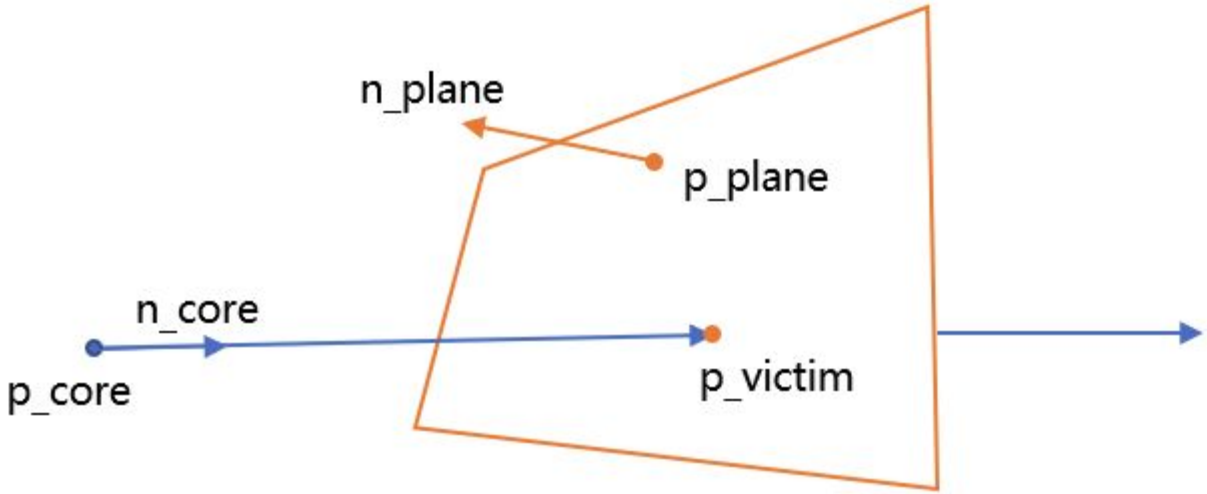


Fig. 4: Projection from search plane to victim plane

Local Search Method

- Iterative Cross Flight

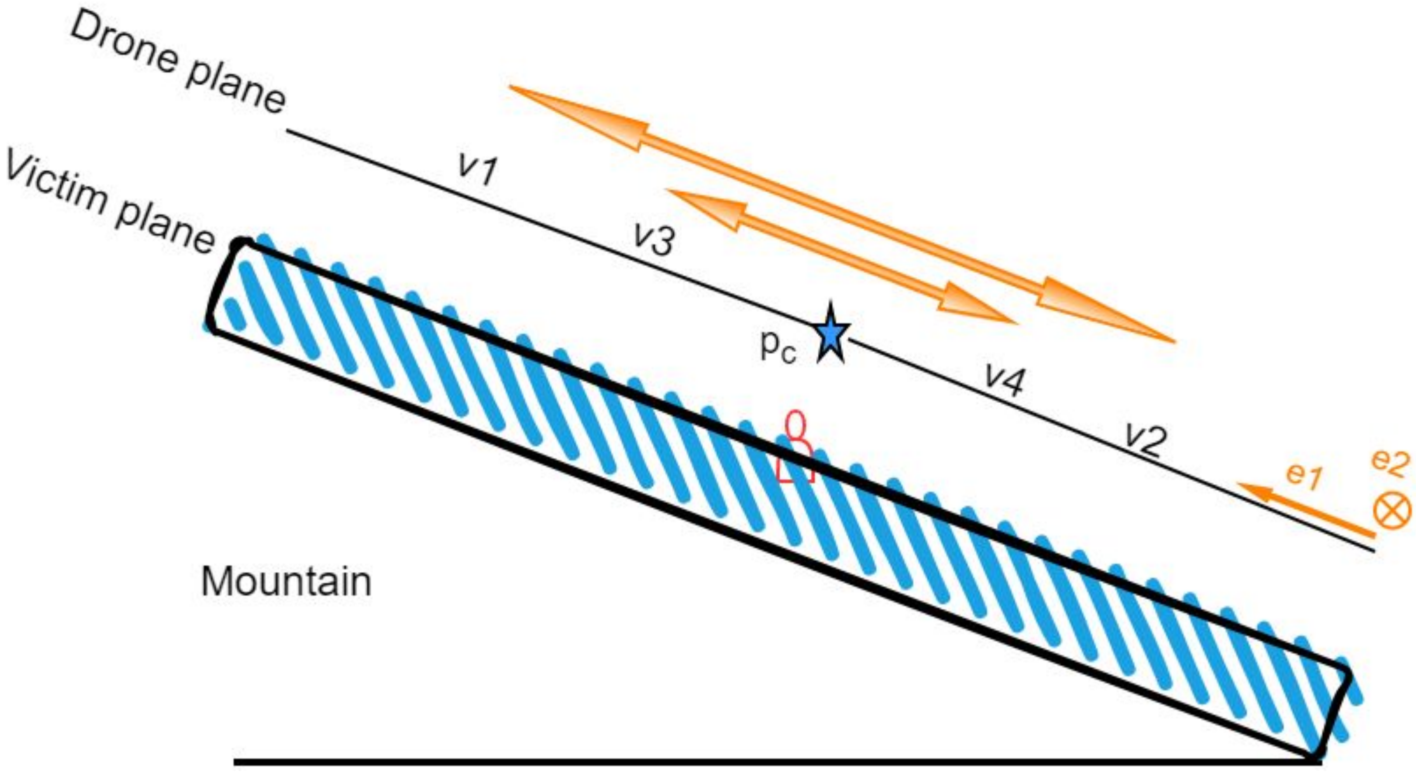


Fig. 5: Iterative cross flight

Local Search Method

- Iterative Cross Flight

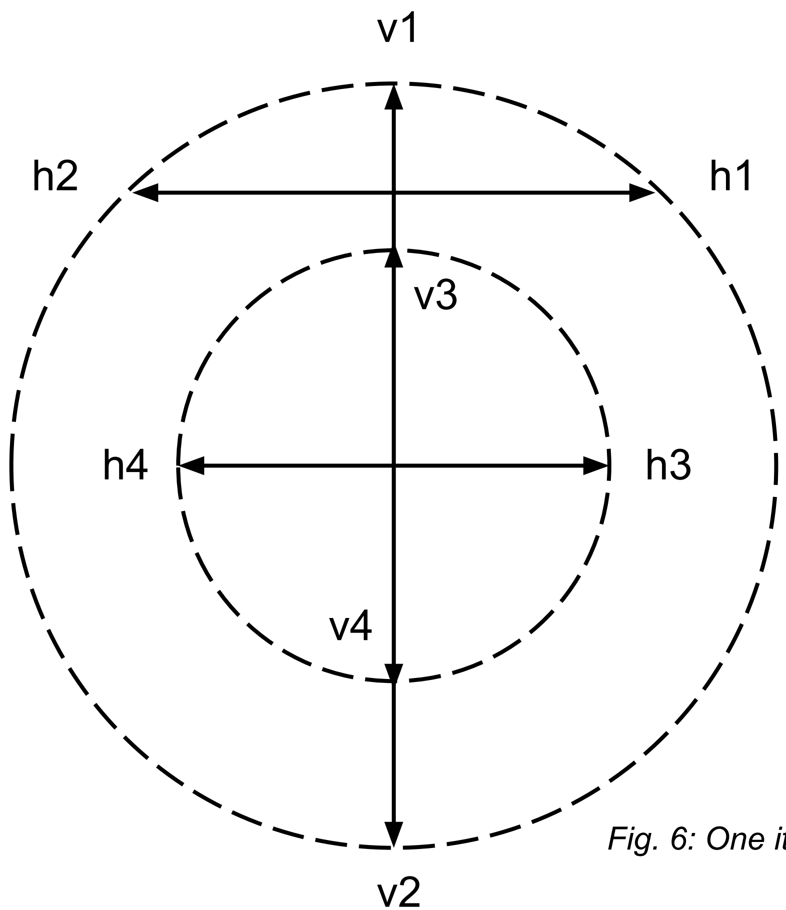


Fig. 6: One iteration will smaller intensity threshold

Local Search Method

- Triangulation

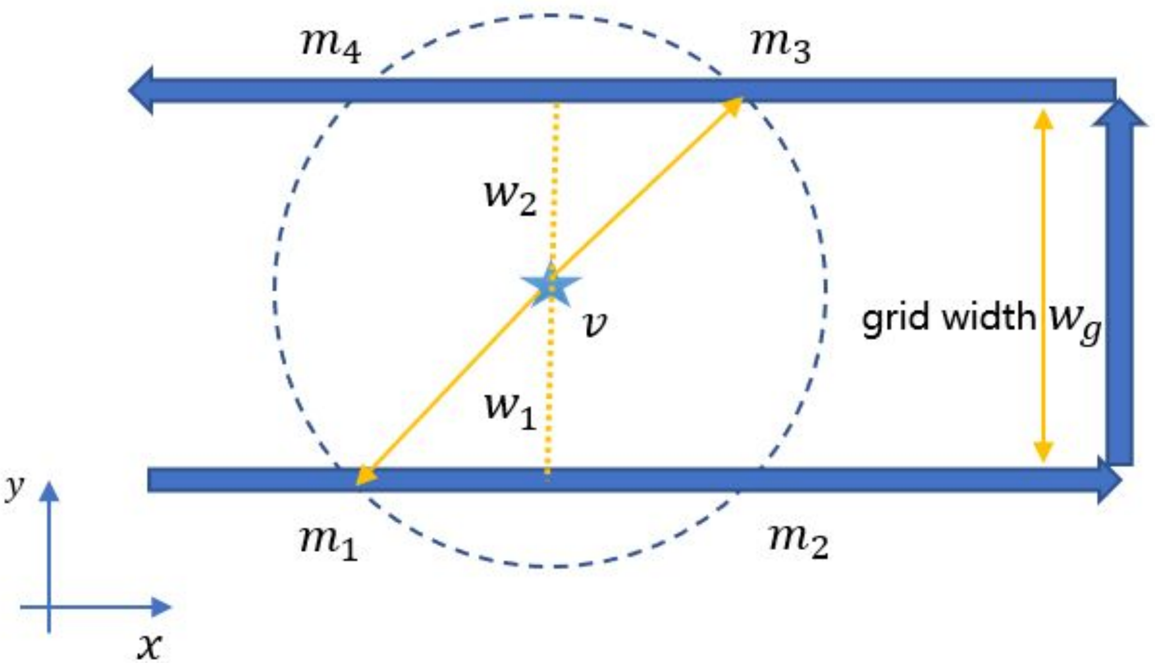


Fig. 7: Triangulation

Signal assignment

$$v_x = \frac{1}{2}(m_{1x} + m_{2x}) = \frac{1}{2}(m_{3x} + m_{4x})$$

Assignment verification

$$(v_x - m_{1x})^2 + {w_1}^2 = (v_x - m_{3x})^2 + {w_2}^2$$

$$w_1 + w_2 = w_g$$

Local Search Method

- Triangulation

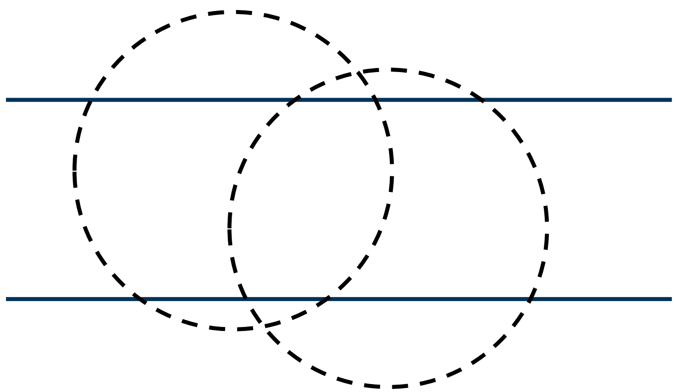


Fig. 8: Overlapping of type 1 handled by signal assignment

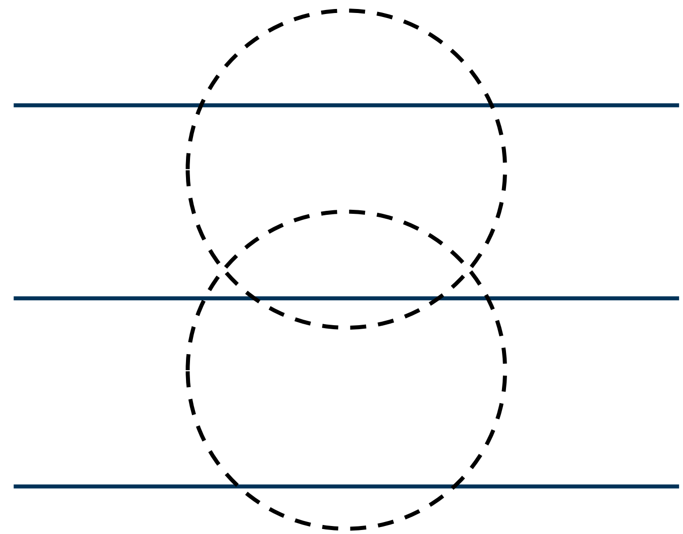


Fig. 9: Overlapping of type 2 handled by assignment verification

Local Search Method

- Triangulation

Fig. 10: Reducing grid width increases marginal points of each victim, which improves quality

Local Search Method

- Iterative Local Search

$$\vec{x}_{t+1} = \vec{x}_t + \alpha * \frac{r_t}{\dot{i}_t} * \hat{d}_t$$

Path Planner and Controller

- Potential Field

$$U_t = \frac{1}{2}\zeta(\vec{x}_{goal} - \vec{x}_t)^2 \qquad \vec{x}_{t+1} = \vec{x}_t + \nabla U_t$$

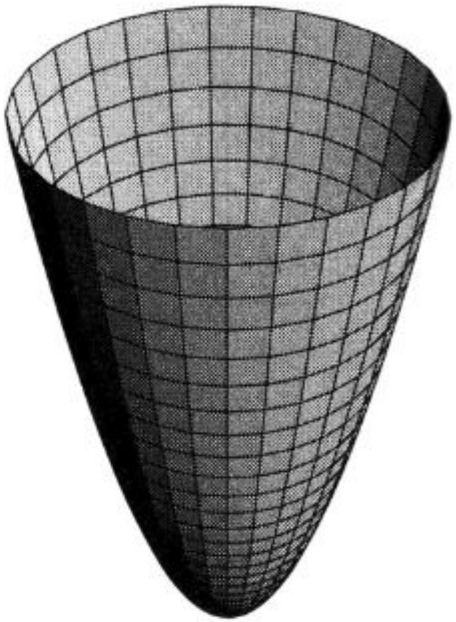


Fig. 11: Potential field

Path Planner and Controller

- Trajectory Generation
  - Straight line
  - Approaching target -> recursive judgment of the distance
  - Distance from target point increases -> replan the trajectory to prevent overshoot.
- Controller

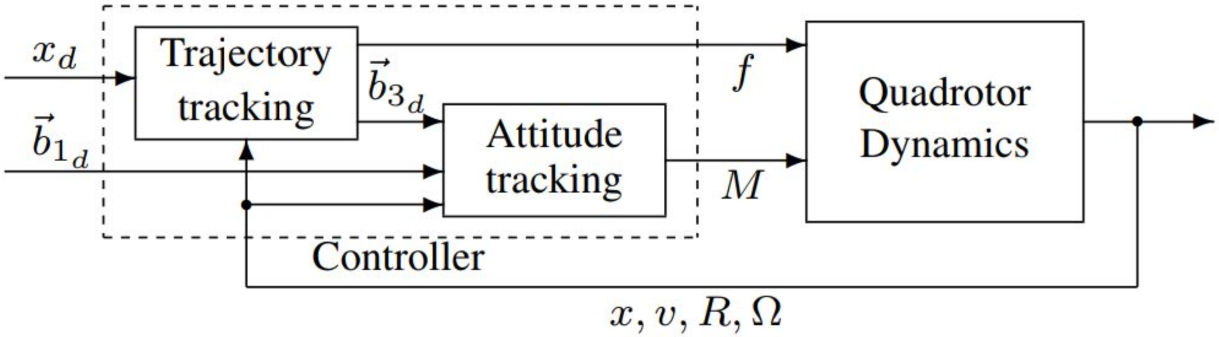


Fig. 12: Controller

Experiment

- Efficiency: covered area per second
  - covered area: $415*300m^2$
  - global search speed: 8m/s
  - local search speed: 5m/s
- Robustness: 10 rescues, 10 victims each rescue
- Accuracy
  - <1m: highly accurate
  - 1-5m: low accurate
  - > 5m: failure

Experiment

- Methods without direction

method	without direction			with direction
	Cross Flight	Iterative Cross Flight	Triangulation	Directed Iterative Local Search
Error (m)	0.33	**0.22**	0.47	0.36
Covered Area (m^2)	415*300	415*300	415*300	415*300
Time (s)	**733**	796	864	**702**
Covered area per second (m^2/s)	**186**	172	158.5	**195**
Number of high accuracy	94	**99**	92	**100**
Number of low accuracy	5	**0**	8	**0**
Number of Failure	1	1	**0**	**0**

Table 1 Comparison between different local search methods

Experiment

- Cross Flight and Triangulation
  - Triangulation needs smaller grid width and longer flight distance
  - Triangulation is more efficient than Cross Flight as victim number rises

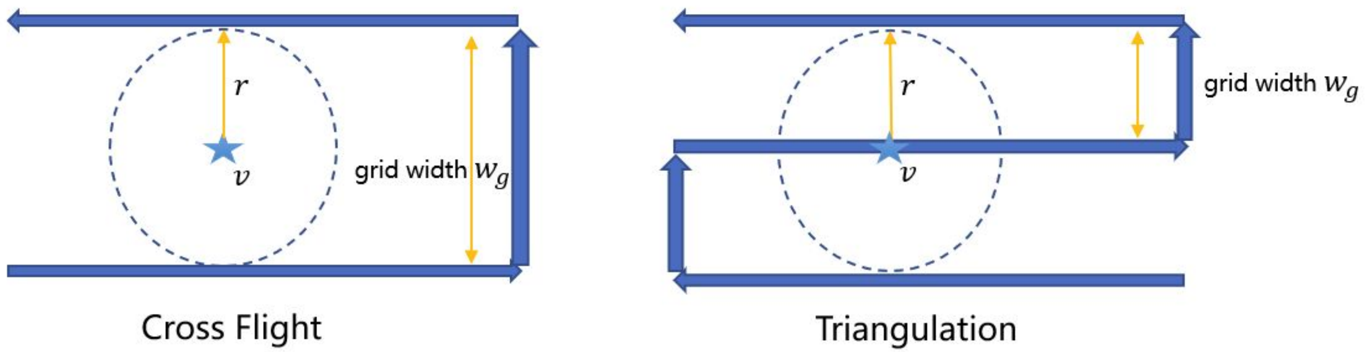


Figure 13 Extreme cases of Cross Flight and Triangulation

	10 victims	15 victims	20 victims	25 victims
Time of Cross Flight [s]	194	307	409	521
Time of triangulation [s]	277	326	380	445

Table 2 Comparison between Cross Flight and Triangulation

Experiment

- Method with direction

method	without direction			with direction
	Cross Flight	Iterative Cross Flight	Triangulation	Directed Iterative Local Search
Error (m)	0.33	**0.22**	0.47	0.36
Covered Area (m^2)	415*300	415*300	415*300	415*300
Time (s)	**733**	796	864	**702**
Covered area per second (m^2/s)	**186**	172	158.5	**195**
Number of high accuracy	94	**99**	92	**100**
Number of low accuracy	5	**0**	8	**0**
Number of Failure	1	1	**0**	**0**

Table 1 Comparison between different local search methods

Conclusion

- Compare different methods to achieve accurate and rapid positioning and rescue of victims in avalanche scenarios
- Prove the high efficiency, high accuracy and high robustness of victim rescue using drones
- Prove the coverage efficiency of drones is much higher than that of humans
- Prove drone has great application potential in avalanche rescue

Contribution

- Dongyue Lu: Sensor model, global search, Cross Flight, potential field, trajectory generation, controller, victim generation, visualization

- Xuhui Zhang: Triangulation: Victim Identification, Localization Verification and Victim Rescuing; Overlapping Handling

- Yamo Akrami: Sensor Models & ILS, potential field

- Yunfeng Kang: Theory of Cross Flight and Iterative Cross Flight, implementation of Iterative Cross Flight

- Yuhang Cai: Read related conference about Cross Flight

Reference

[1] Mario Silvagni, Andrea Tonoli, Enrico Zenerino, and Marcello Chiaberge. Multipurpose uav for search and rescue operations in mountain avalanche events. Geomatics, Natural Hazards and Risk, 8(1):18–33, 2017.

Thank You!