Optimal Trajectory Generation for Localization of Avalanche Victims

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Motivations and Objectives

• Search and rescue missions are time-critical operations
• Research shows that the chances of survival decrease drastically after 30 minutes [1]
• Robotics agents can cooperatively localize the victims faster, increasing their chances of survival

Figure 1: Three avalanche search and rescue scenarios.

ARTVA System

• The victim is equipped with a transmitter emitting a magnetic field
• Each rescuer is equipped with a receiver
• The data from all the receiver is analyzed by an algorithm, which returns the estimation of the transmitter location
• The accuracy of the estimation improves as the rescuers get closer to the transmitter location

Figure 2: Commercially available avalanche receiver.
Estimation of Transmitter Location

• The performance of the estimator can be quantified in terms of its observability index

• The observability index depends on the level of excitation of the vehicle’s trajectory

Figure 3: The left figure shows minimally-excited trajectory while the right figure shows an exited trajectory.
Problem Formulation

• We consider a search and rescue mission involving $N$ UAVs tasked to locate avalanche victims
• The problem considered is to generate safe and feasible trajectories
• The trajectory generation problem is formulated as an optimal control problem

Figure 4: Possible UAVs trajectories to locate an avalanche victim.
Replanning Strategy

• As the distance between the vehicles and the transmitter decrease, the estimation accuracy increases

• The estimate of the transmitter location is re-evaluated every $\bar{t}$ seconds and conditions for replanning are checked
  
  $\|\hat{p}_t(t) - \hat{p}_t(t - \bar{t})\| < \rho$
  
  $\sigma(s(t), s(t)) > \epsilon$
Implementation

- We simulate a search and rescue mission using MATLAB
  - 5 UAVs
  - $d_{safe} = 3 \, m$
  - $v_{max} = 5 \, m/s$
- The optimization problem is solved using MATLAB fmincon
- Vehicle’s trajectories are approximated by 5th order Bernstein polynomials

![Figure 5: Bernstein polynomials.](image)
Numerical Results

Figure 6: Mission execution at three time instances.
Numerical Results

Figure 7: Inter-vehicle distances.

Figure 8: Velocity profile.
Conclusion

• We developed a framework that generates optimal trajectories to locate avalanche victims

• Future works include
  • Experimental results using UAVs
  • Strategies to decrease computational time for real-time implementation

Figure 9: UAV flying at the CAS lab.