Optimized Snapshot-based Visual Homing for UAVs

Auburn REU 2017
James Brown and Emily Sheetz

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Outline

- Problem
- Background
- Approach
- Results

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The Problem

- Issues with GPS
- Why Use Images for Homing?
- Benefits of Visual Homing

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The Issues With GPS

- GPS jamming
- GPS spoofing
- Loss of GPS signal

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Why Use Images for Homing?

- Cameras are lightweight and can multitask
- Sparse representation of environment
- More reliable than maps or GPS

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Benefits of Visual Homing

- Visual homing: return to starting location
- Practical applications
- Increases safety for users

Background

- Literature review
- Theoretical background
- Motivation of approach

Jamming Research of the UAV GPS/INS Integrated Navigation System Based on Trajectory Cheating

By: Chang Li and Xudong Wang

- Position cheating
- Loss of UAV control
- Velocity cheating

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Biologically Inspired Visual Homing

- *Bio-inspired Visual Guidance: From Insect Homing to UAS Navigation*
    - By: Aymeric Denuelle and Mandyam V. Srinivasan
    - Literature survey of techniques
- *Bee-Inspired Landmark Recognition in Robotic Navigation*
    - By: Kodi Cumbo, Samantha Heck, Ian Tanimoto, Travis DeVault, Robert Heckendorn, and Terence Soule
    - Ground robot learned to use landmarks to navigate to goal

A Sparse Snapshot-based Navigation Strategy for UAS Guidance in Natural Environments

By: Aymeric Denuelle and Mandyam V. Srinivasan

- Finding optimal amount of snapshots
- Navigation with minimal drift
- Path optimization

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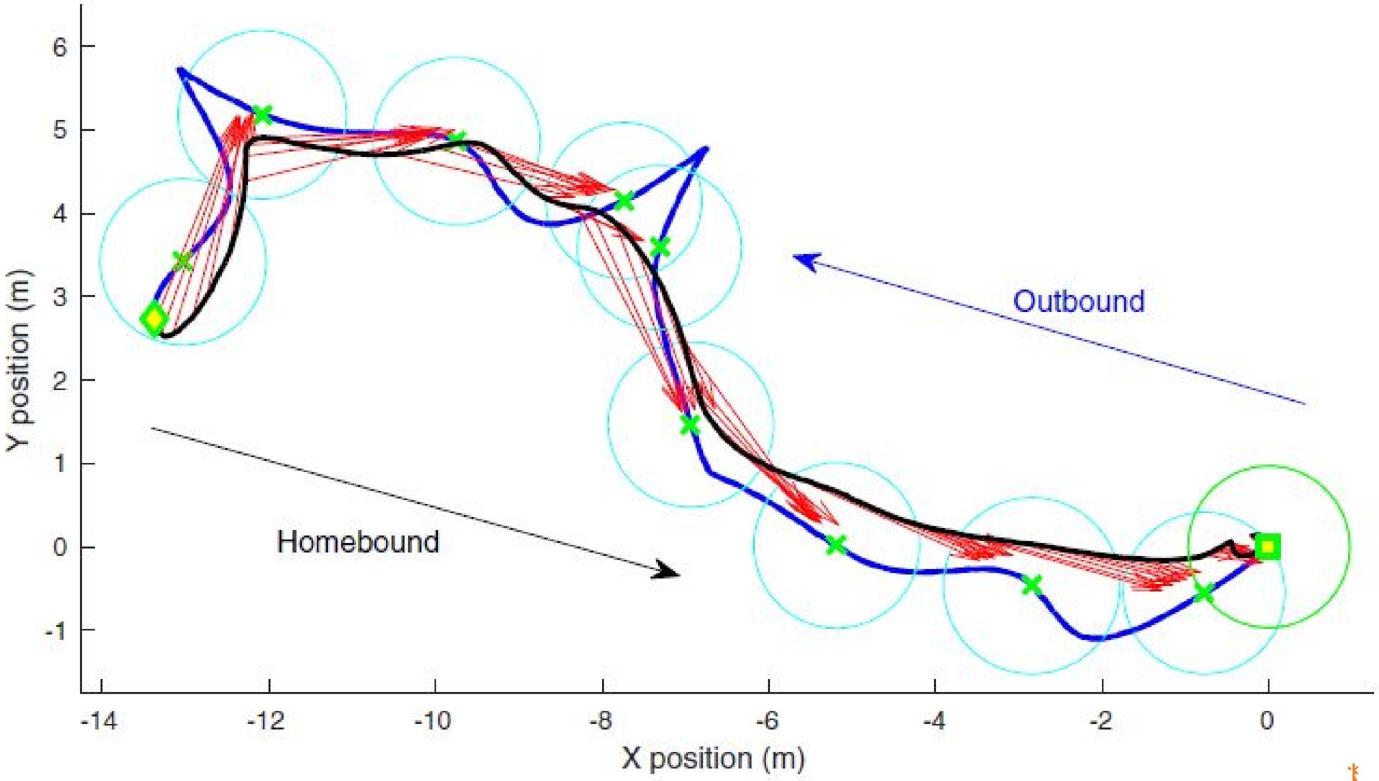

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A Framework for Visual Return-to-Home Capability in GPS-denied Environments

By: Benjamin P. Lewis and Randal W. Beard

- Snapshot based homing
- Homography
- Navigation in different environments

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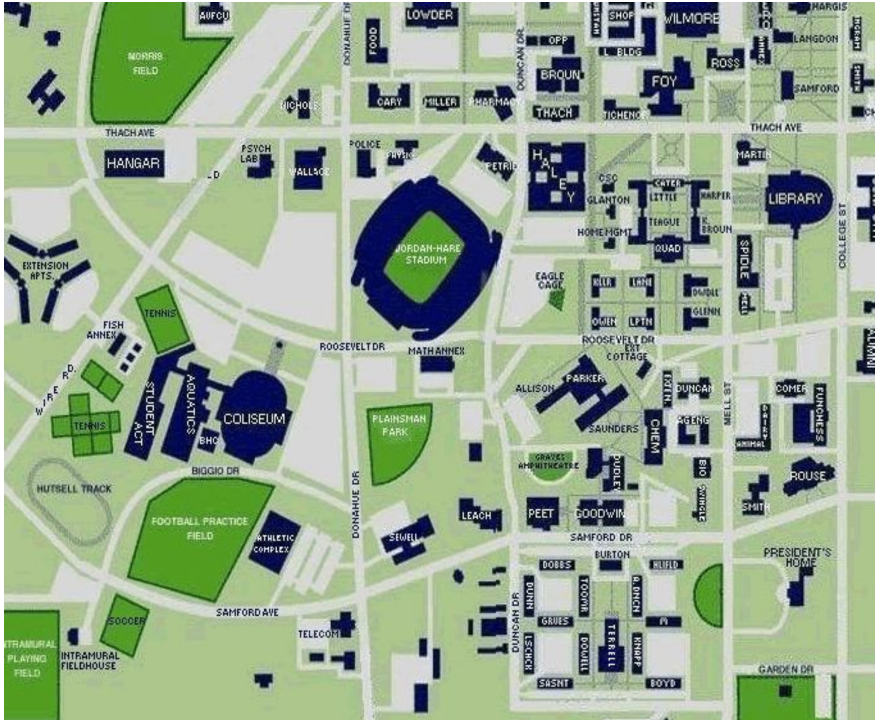
Environment Examples



Homography

- Relates two images using common features viewed from different angles

$$p_r = \boldsymbol{H} p_c$$

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} \sim \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

Homography Control Law

- Compute direction vector to align UAV with reference image
- Based on center of gravity of feature points

$$\vec{v} = \frac{\bar{p}_r{}^T \boldsymbol{H} \bar{p}_c}{\bar{p}_r{}^T \bar{p}_c} \bar{p}_r - \bar{p}_c$$

$$\bar{p}_r = \frac{1}{n} \sum_{i=1}^{n} p_{r_i} \qquad \bar{p}_c = \frac{1}{n} \sum_{i=1}^{n} p_{c_i}$$

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Flight Path Planning for Unmanned Aerial Vehicles with Landmark-Based Visual Navigation

By: Luitpold Babel

- Numerical method for path optimization
- Paths pass through sequence of landmarks
- Optimal path considers total distance and distance between landmarks

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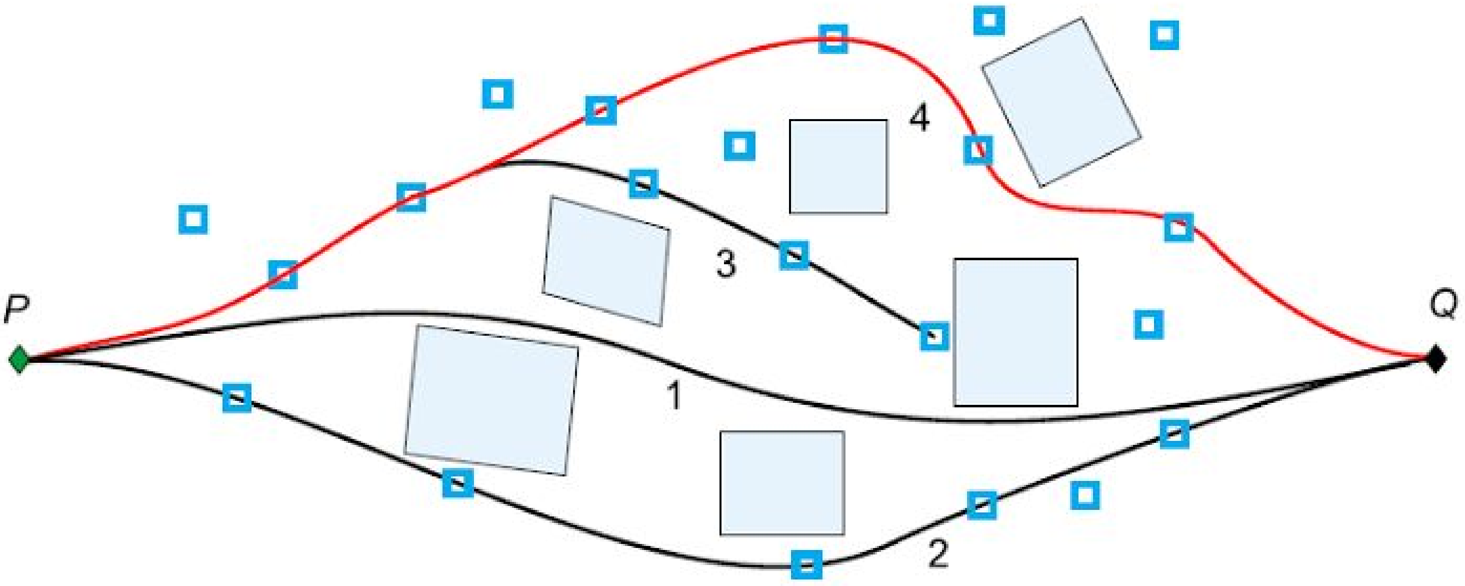

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Approach

- Novel approach to visual homing
- Techniques
- Experiments

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Our Approach

- Combining techniques
- Snapshots to represent environment
- Option for path optimization based on features in snapshots
- Homography control law
- Series of local homing problems, visiting waypoints

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Tools

- MATLAB
  - Simulink
  - Robotics Operating System (ROS)
- Python
- OpenCV

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Simulation Framework

- Random exploratory journey
- Snapshots taken and stored along the way
- On return, periodically computes homography estimation
- Homography control law directs UAV to snapshot
- Normalized direction vectors to navigate
- Option for path optimization

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Experiments

- Visual homing
- Path optimization with visual homing
- Three environments
  - Suburb
  - Desert
  - Forest
- 15 random paths tested across 5 different positions on map

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Results

- Results of experiments
- Conclusions
- Future work

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Data Analysis

Test	Successful Homing	Successful Optimized Homing	Average Distance Reduced	Average Time Saved
Suburb	87%	85%	48%	84 seconds
Desert	100%	67%	54%	95 seconds
Forest	93%	50%	59%	104 seconds
Overall	**93%**	**67%**	**53%**	**93 seconds**

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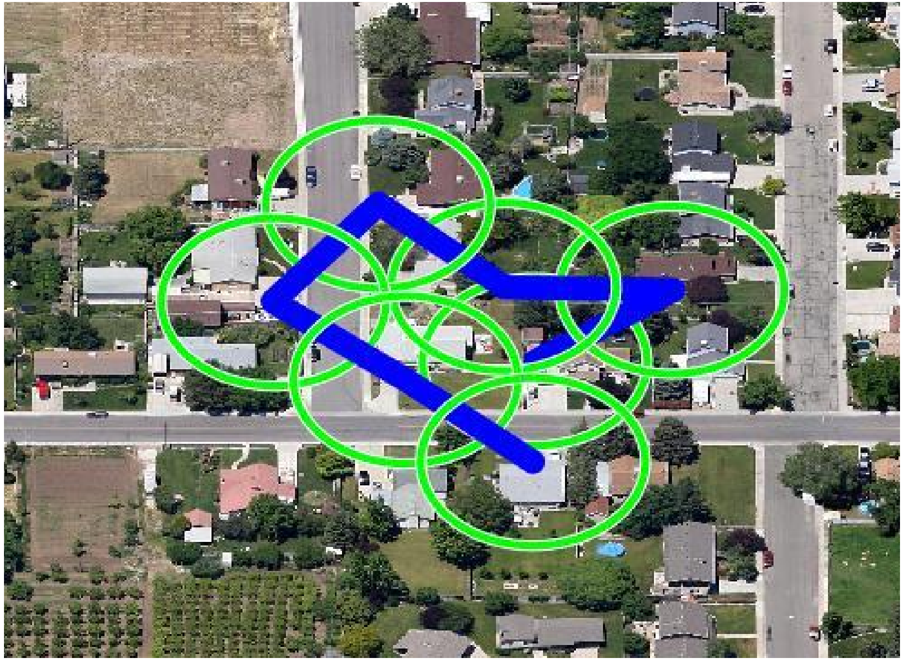
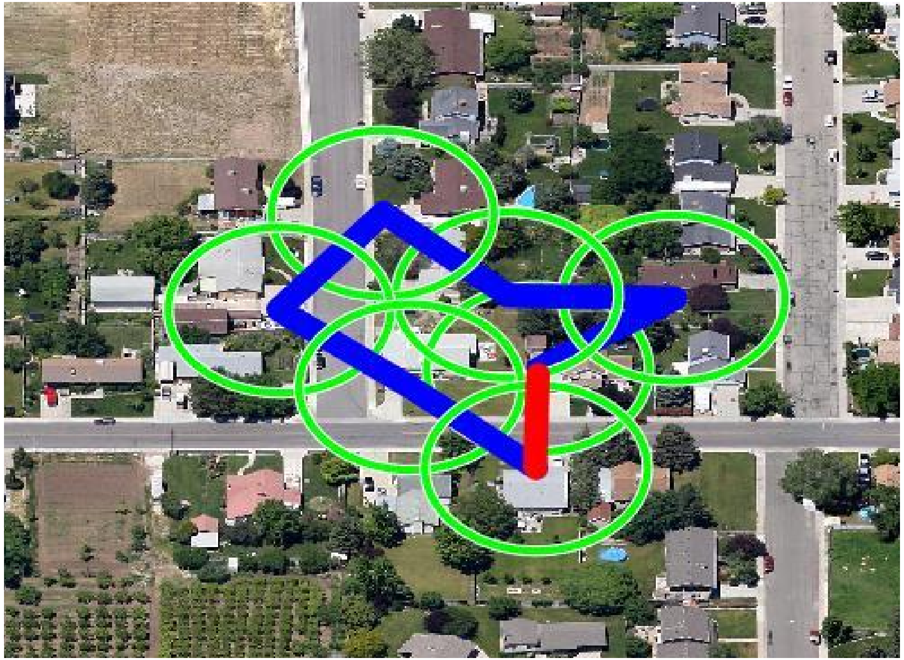
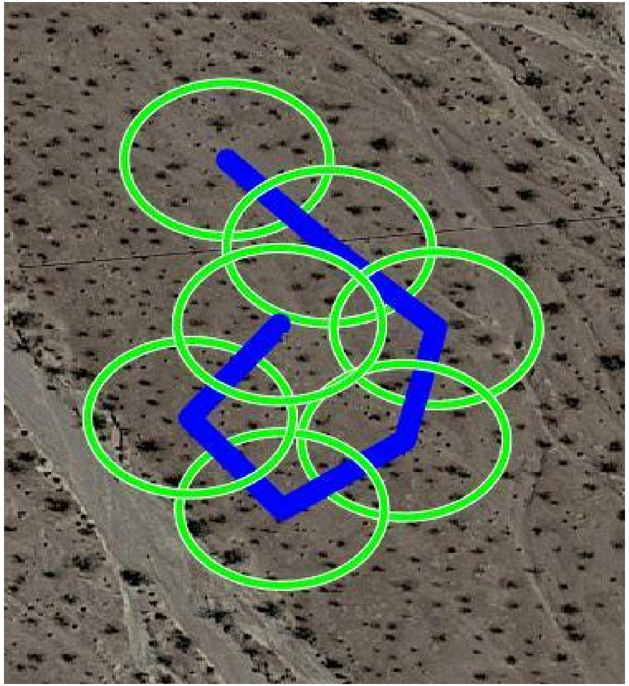
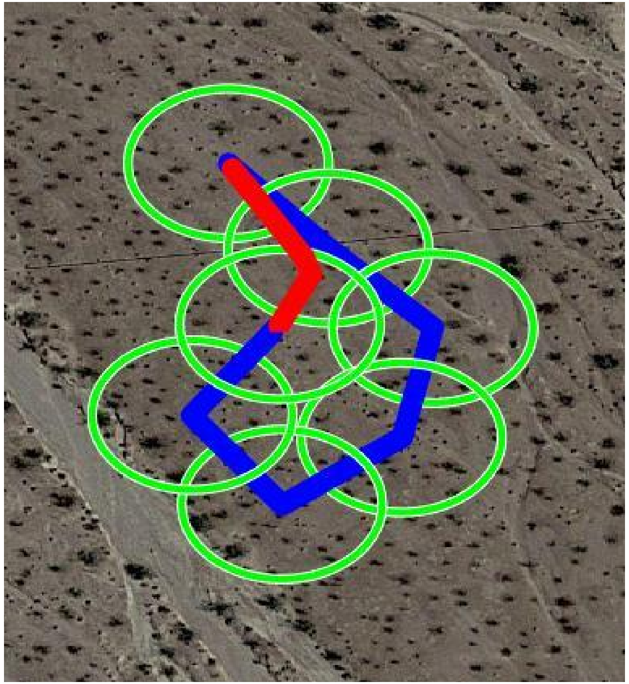
Data Analysis



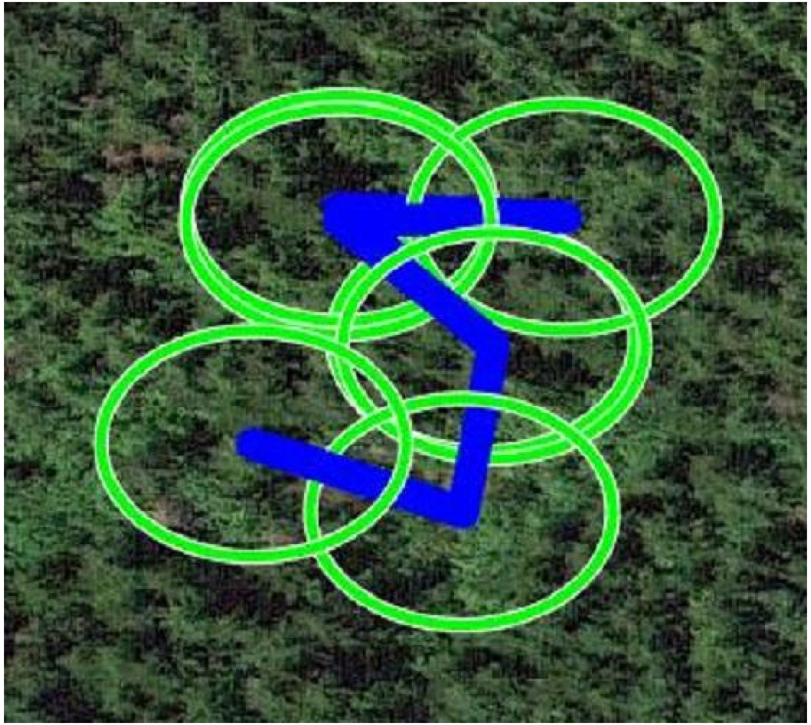


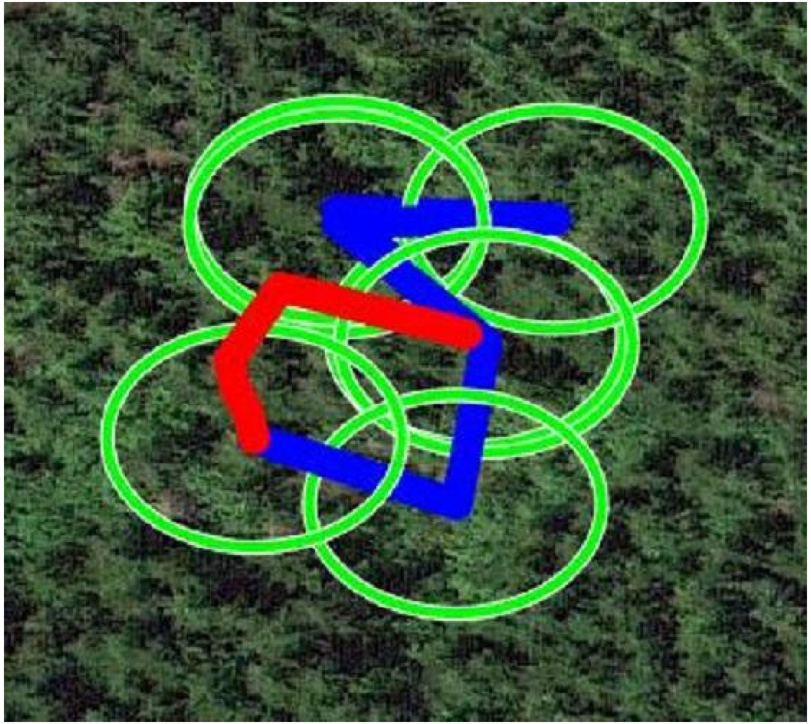
Data Analysis





Data Analysis





Conclusions

- Proof of concept
  - Sparse representation
  - Success in environments with uniform features
  - Path optimization using visual techniques
- Optimization is possible
  - Significantly reduced travel distance and time
  - More efficient visual homing

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Future Work

- Neural network for homography estimation
- More robust solution for regions with poor features
- More realistic simulations
- Implementation on physical drone
- Path optimization:
  - Switching between optimized snapshots
  - Fine tuning thresholds

Summary

- Problem
- Background
- Key Literature
  - Jamming Research of the UAV GPS
  - Sparse Snapshot-based Navigation
  - Homography control law
  - Optimizing UAV paths
- Approach
- Results
- Successful visual homing

Any Questions?

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