GPS-Less Homing via Neural Net Homography

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Outline

- Introduction
- The Problem
- Literature Review and Background
- Our Project

Introduction

- UAV use is rapidly expanding
- UAVs play a large role in military operations
- Autonomous UAVs need development

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UAVS and The FAA

- Federal Aviation Administration (FAA)
- Military, civil, commercial use of UAVs
- Pilots must “see and avoid” obstacles

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Areas Of UAV Research

- Collision Avoidance
- Computer Vision
- GPS-Less Navigation

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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

Literature Review

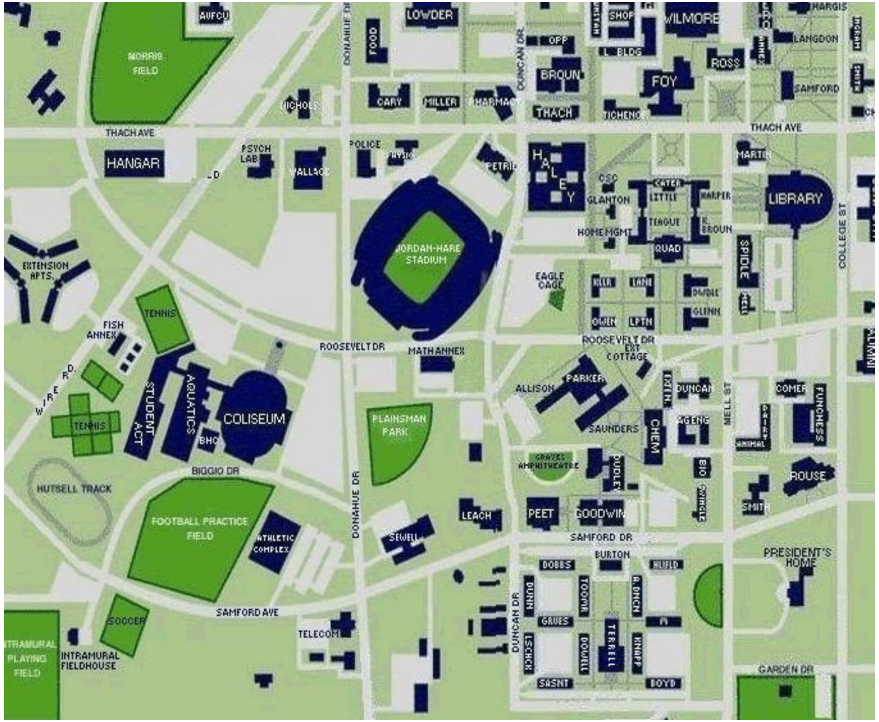
- Related and influential works

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

Environment Examples



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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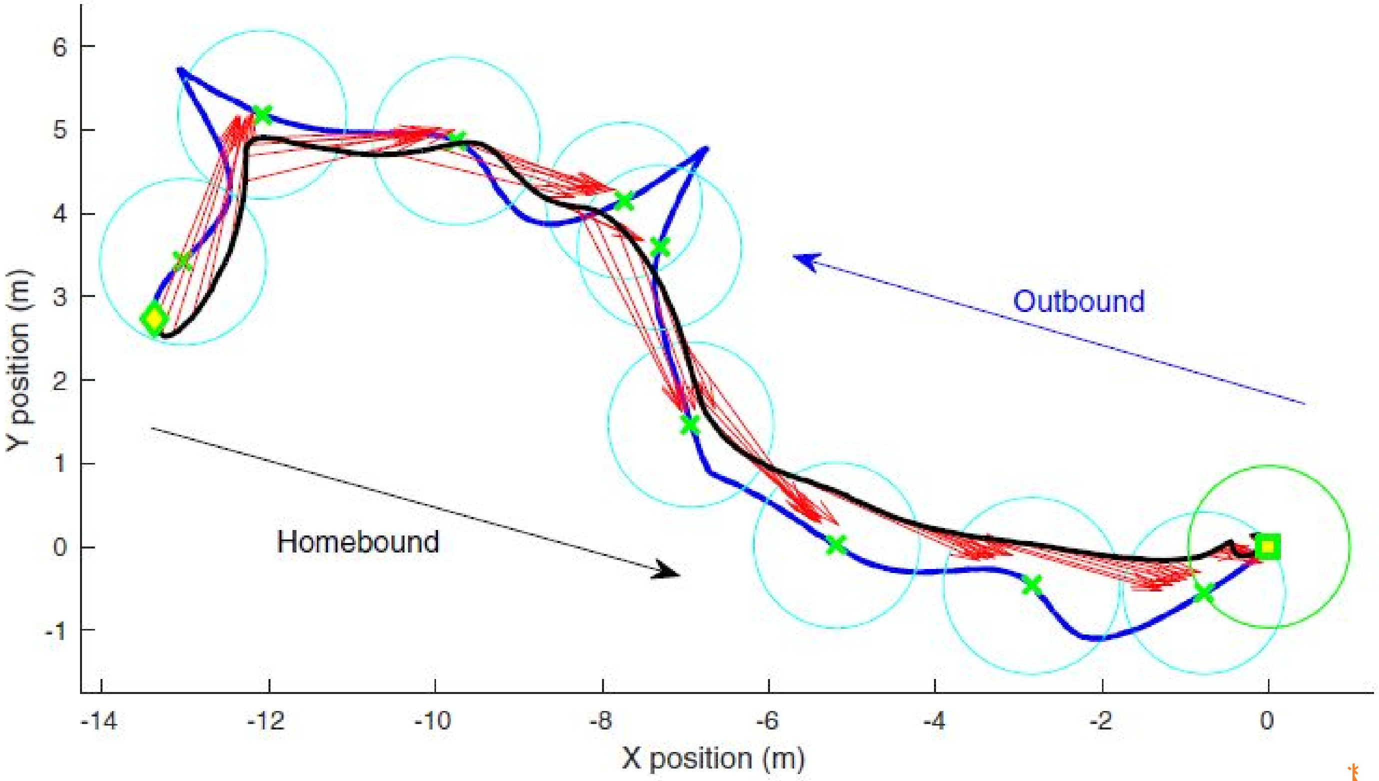

Outbound
Homebound
Y position (m)
X position (m)
6
5
4
3
2
1
0
-1
-14
-12
-10
-8
-6
-4
-2
0

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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Other Influential Work

- Biology-inspired approaches to visual homing
  - *Bee-Inspired Landmark Recognition in Robotic Navigation*
    - By: Kodi Cumbo, Samantha Heck, Ian Tanimoto, Travis DeVault, Robert Heckendorn, and Terence Soule
  - *A Bee-Inspired Robot Visual Homing Method*
    - By: G. Bianco, R. Cassinis, A. Rizzi, N. Adami, and P. Mosna
  - *Bio-inspired Visual Guidance: From Insect Homing to UAS Navigation*
    - By: Aymeric Denuelle and Mandyam V. Srinivasan

Theoretical Background

- Homography
- Homography Control Law

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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Deep Image Homography Estimation

By: Daniel DeTone, Tomasz Malisiewicz, and Andrew Rabinovich

- Convolutional neural network (CNN) to estimate homography
- Two grayscale images (reference and camera)
- Feature extraction achieved by CNN

Homography: Four-Point Parameterization

- Better for homography estimation
- Based on offsets of features/corners

$$\Delta x = x_1' - x_1$$

$$H_{4point} = \begin{bmatrix} \Delta x_1 & \Delta y_1 \\ \Delta x_2 & \Delta y_2 \\ \Delta x_3 & \Delta y_3 \\ \Delta x_4 & \Delta y_4 \end{bmatrix}$$

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Homography: Four-Point Parameterization

- Map four-point homography to matrix homography

$$H_{4point} = \begin{bmatrix} \Delta x_1 & \Delta y_1 \\ \Delta x_2 & \Delta y_2 \\ \Delta x_3 & \Delta y_3 \\ \Delta x_4 & \Delta y_4 \end{bmatrix} \qquad H_{matrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix}$$

Our Project

- Our Approach
- Our Contributions
- Our Progress

Our Approach

- Snapshots to represent environment
- Convolutional neural network to estimate homography
- Compute direction vector
- Series of local homing problems, visiting waypoints
- Could be extended for path optimization

Our Contributions

- Combining techniques
  - Biologically inspired
  - Snapshots
  - CNN homography estimation
  - Homography control law

Our Progress

- Simulation framework in MATLAB
- Started coding neural network in MATLAB
- Methods for data acquisition

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Next Steps

- Training and testing of convolutional neural network
- Simulations
- If time allows, path optimization

Summary

- Rise of UAVS
- Flaws of GPS
- Importance of GPS-Less Homing
- Key Literature
    - Visual Return-to-Home
    - Sparse Snapshot-based Navigation
    - Jamming Research of the UAV GPS
- Our Project

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Any Questions?

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