GPS-Less Homing via Neural Net Homography

Auburn REU 2017
James Brown and Emily Sheetz

Outline

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

AUBURN UNIVERSITY

Introduction

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

AUBURN UNIVERSITY

UAVS and The FAA

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

AUBURN UNIVERSITY

Areas Of UAV Research

- Collision Avoidance
- Computer Vision
- GPS-Less Navigation

AUBURN UNIVERSITY

The Problem

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

AUBURN UNIVERSITY

The Issues With GPS

- GPS jamming
- GPS spoofing
- Loss of GPS signal

AUBURN UNIVERSITY

Why Use Images for Homing?

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

AUBURN UNIVERSITY

Benefits of Visual Homing

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

AUBURN UNIVERSITY

Literature Review

- Related and influential works

AUBURN UNIVERSITY

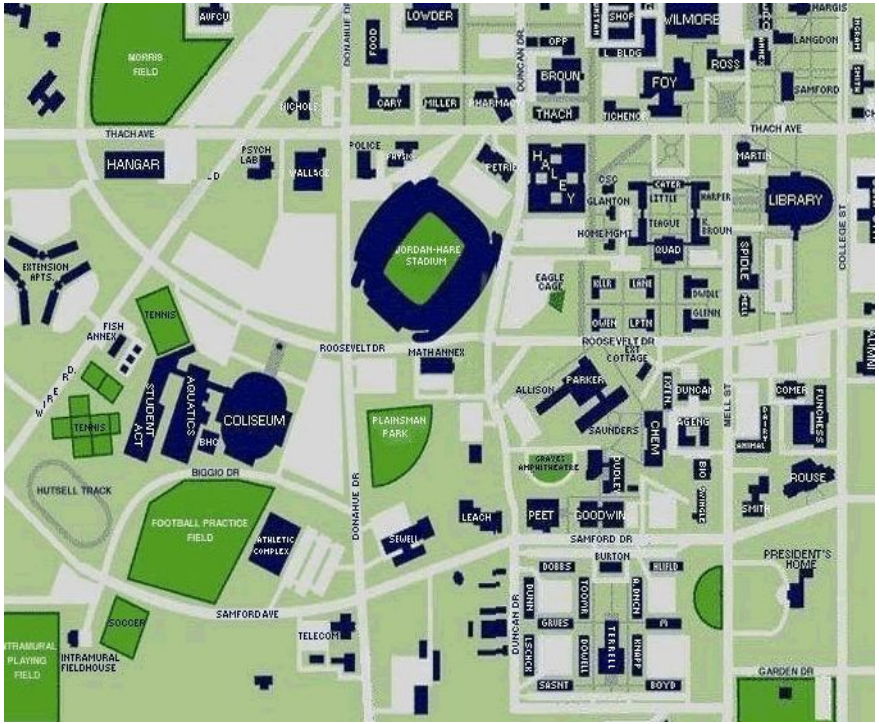
A Framework for Visual Return-to-Home Capability in GPS-denied Environments

By: Benjamin P. Lewis and Randal W. Beard

- Snapshot based homing
- Homography
- Navigation in different environments

AUBURN UNIVERSITY

Environment Examples

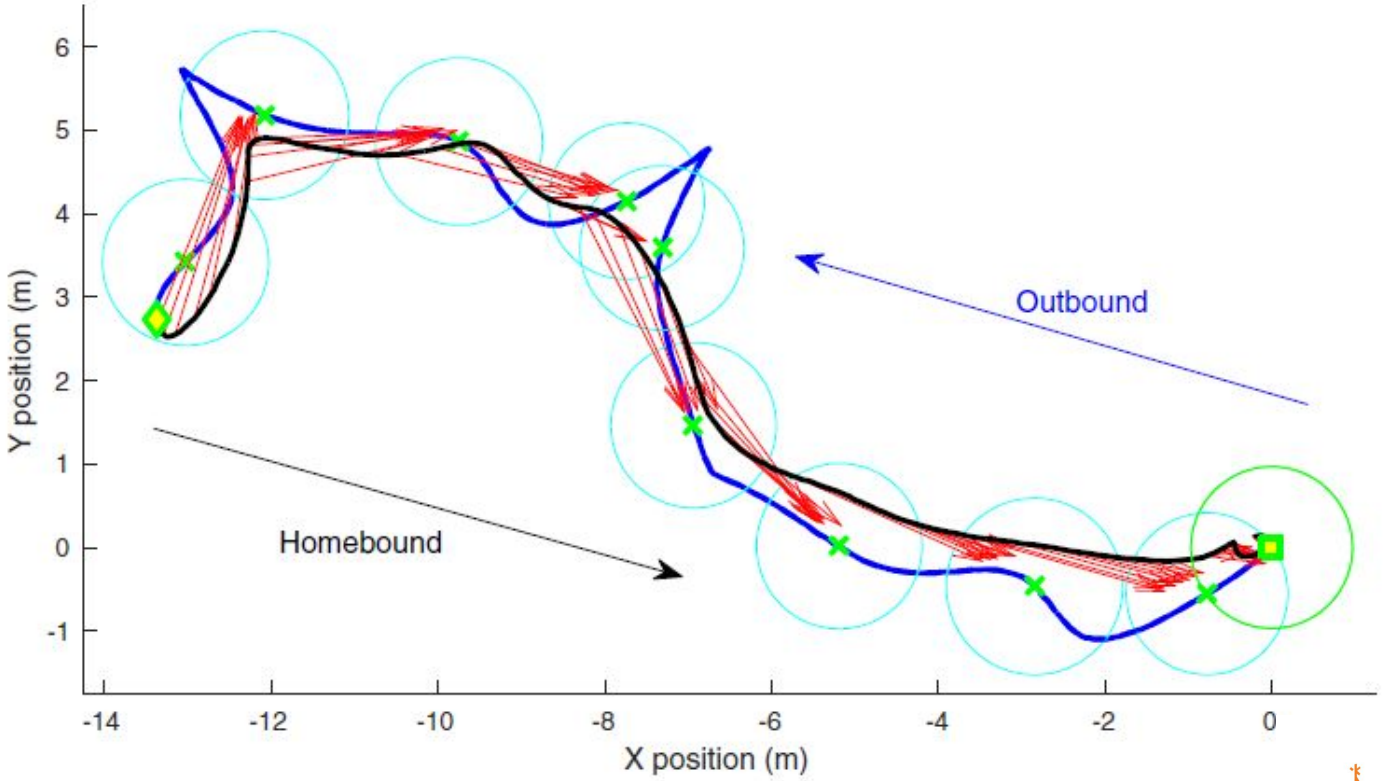


A Sparse Snapshot-based Navigation Strategy for UAS Guidance in Natural Environments

By: Aymeric Denuelle and Mandyam V. Srinivasan

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

AUBURN UNIVERSITY



AUBURN UNIVERSITY

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

AUBURN UNIVERSITY

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

AUBURN UNIVERSITY

Theoretical Background

- Homography
- Homography Control Law

AUBURN UNIVERSITY

Homography

- Relates two images using common features viewed from different angles

$$p_r = H p_c$$

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

AUBURN UNIVERSITY

Homography Control Law

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

$$e_v = \frac{\bar{p}_r{}^T H \bar{p}_c}{\bar{p}_r{}^T \bar{p}_c} \bar{p}_r - \bar{p}_c$$

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

AUBURN UNIVERSITY

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

AUBURN UNIVERSITY

Homography: Four-Point Parameterization

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

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

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

AUBURN UNIVERSITY

Homography: Four-Point Parameterization

- Map four-point homography to matrix homography

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

AUBURN UNIVERSITY

Our Project

- Our Approach
- Our Contributions
- Our Progress

AUBURN UNIVERSITY

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

AUBURN UNIVERSITY

Our Contributions

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

AUBURN UNIVERSITY

Our Progress

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

AUBURN UNIVERSITY

Next Steps

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

AUBURN UNIVERSITY

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

AUBURN UNIVERSITY

Any Questions?

AUBURN UNIVERSITY