UAV Navigation within GPS-denied Environments: Dead Reckoning & Computer Vision

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GPS-Denied Environments

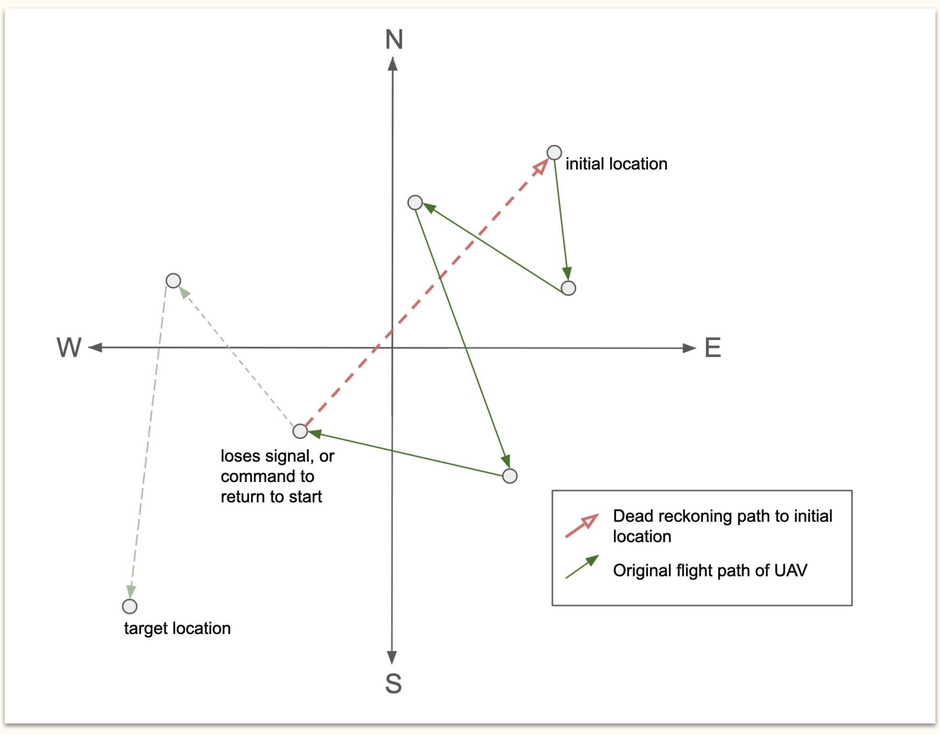
- subject to interference within indoor locations,tree-dense or other barrier-intensive areas, remote locations, GPS-spoofing devices, extraterrestrial environments
- GPS systems currently maintained by U.S. Dept of Defense without guarantee for future

Related Research

- SLAM: Simultaneous Localization and Mapping for constructing and updating map of environment, while tracking current location within map
- Convolutional Neural Networks within pre-trained environments, returning required yaw angle for path-following given curren visual input of path

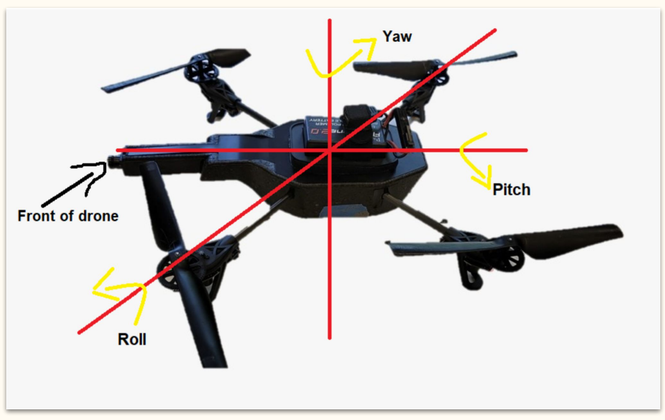
This Approach

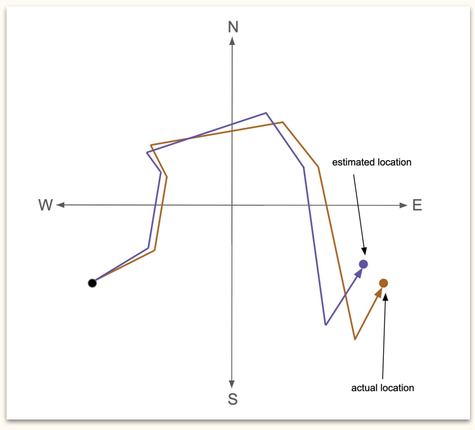
- suitable for foreign environments with minimal processing during original UAV mission - emergency backup
  1. Takes photo of original location
  2. UAV flies to target
  3. Loss of GPS-signal midpath, and calculates emergency return home via dead reckoning
  4. Estimates additional flight data with images instead of GPS
  5. Confirms final location with feature matching, otherwise spirals until location is found



Dead Reckoning

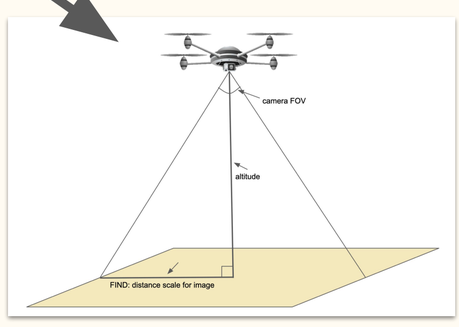
- Upon loss of GPS signal, estimates trajectory with last recorded latitude/longitude data (left photo)
- Uses arctan() function for angle difference between two coordinates
- Over time, larger accumulated error with dead reckoning calculations (bottom right)

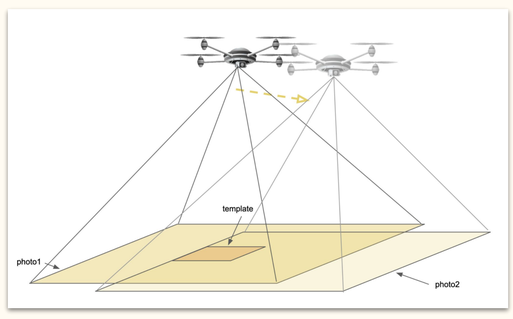


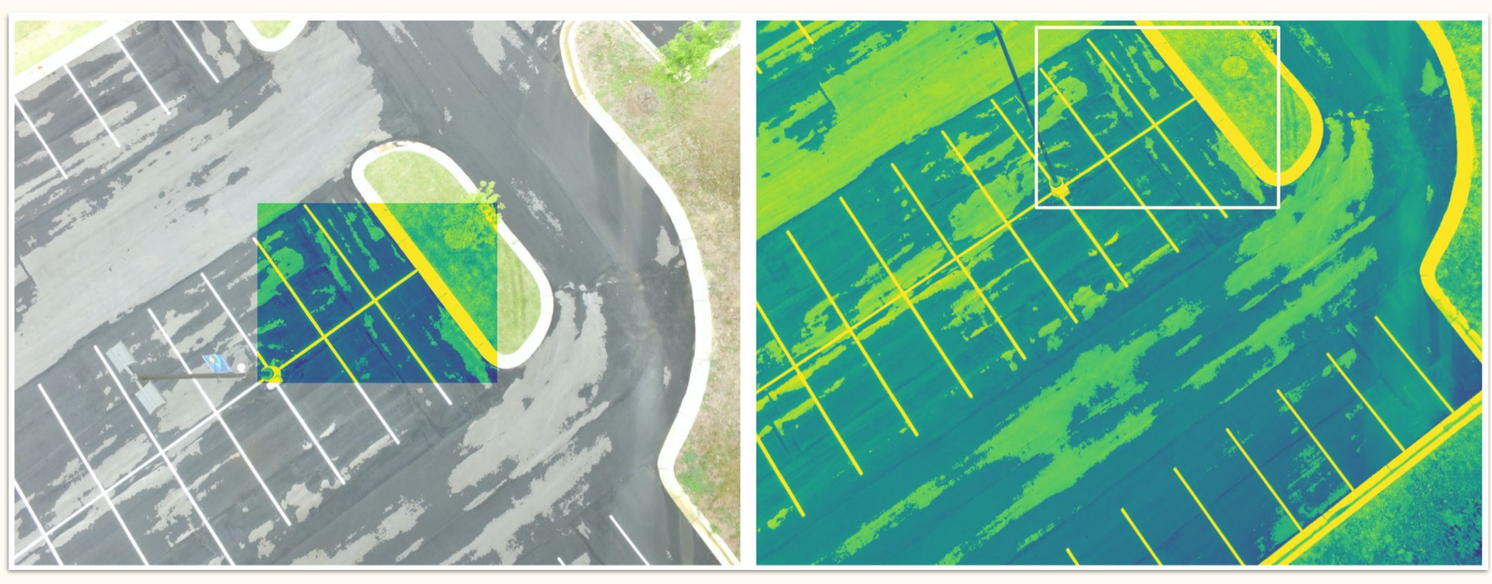


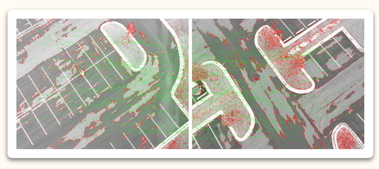
Estimating *Ground Speed* data without GPS for flight navigation

- Uses template matching (optical flow) for finding the distance moved within a timeframe
  - Uses overlapping photos taken from underbelly of UAV, with a template from the center of the first image to be matched to a corresponding portion of the second image
- Coverts the ‘pixels moved’ into ‘distance (meters) moved’ by finding scale, and divides by time passed for meters/second of UAV speed
- For testing:
  - DJI Phantom 3 Pro UAV, 94° FOV, 3.1 mph, altitude of 65 m.
  - Optimized algorithm for 6 seconds between photos with a distinct image template, with a final margin of error of approximately 0.01



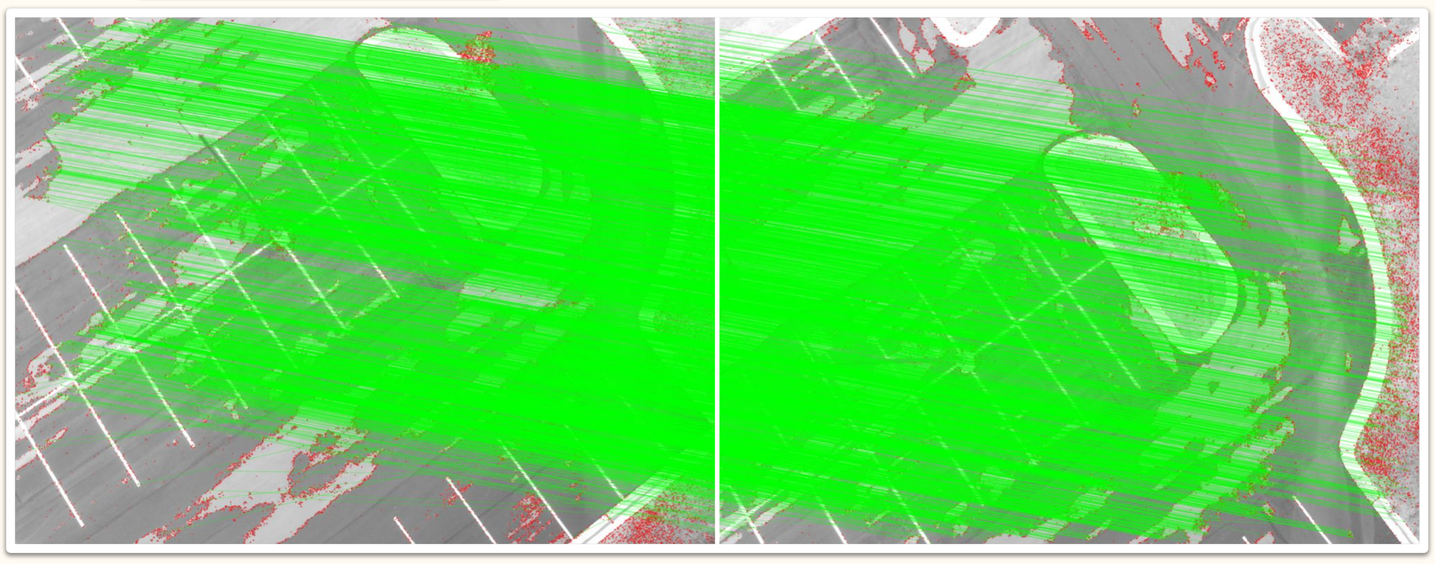






left example: false match
- 198 good matches
- 29,843 features
- 0.0066 ratio

below example: correct match
- 5721 good matches
- 29,842 features
- 0.1917 ratio



Feature Matching for Location Recognition

- Matches current location of UAV with original photo of takeoff
- If the two images are similar, will land, otherwise will spiral until location is found
- Uses SIFT image feature descriptors for image matching, both scale and rotation invariant
- Takes ratio of good matches to number of keypoints within the first image, sets a minimum threshold of 0.15 for binary correct/incorrect location determination