A Benchmarking Tool for MAV Visual Pose Estimation

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Introduction

➢ The objective of this work is to create new datasets as benchmarking tool for future works on visual pose estimation for micro-aerial vehicles.
➢ Our sensor suite includes a forward looking and a downward looking camera, a MEMS IMU unit with 3 axis gyroscopes, 3 axis accelerometers and a magnetometer, and a Vicon system for groundtruth.
➢ We show examples of how our datasets could be used for benchmarking visual pose estimation algorithms such as 4 point, 5 point and ARToolKitPlus.

MAV Platform and Environment Setup

![Forward looking camera with 6mm, 80° field of view CS-mount lens](Image1)

![Inbuilt MEMS IMU from the quadrotor](Image2)

![Downward looking camera with 150° field of view lens](Image3)

Fig 1. “Pelican” quadrotor from Ascending Technologies.

➢ Both cameras are point-grey USB-firefly cameras that run at a maximum framerate of 30 fps.
➢ Operating system is Ubuntu 9.10 and ROS (http://www.ros.org/wiki/) is used for data capturing.

![Vicon Markers from the quadrotor](Image4)

Fig 2. Flight environment.

➢ Quadrotor was flown in a 10m x 10m x 10m indoor environment equipped with 8 vicon cameras for groundtruth.
➢ A group of ARToolKitPlus markers is placed on the floor to enhance the image features for the downward looking camera.

![ARToolKitPlus Markers from the quadrotor](Image5)

Data Synchronization

➢ No synchronization issues between the camera and IMU since these data were captured on the same computer evaluating embedded timestamps from the respective hardware.
➢ Synchronization problem between the Vicon system and IMU/camera since these data were collected on different computers.
➢ Data is synchronized by compensating time-shift found from cross-correlation.

![Cross-correlation](Image6)

![Synchronized Body Pitch-Angle Rate](Image7)

Fig 3. (a) Unsynchronized IMU and Vicon data. (b) Cross-correlation factors for the unsynchronized data. Time-shift between the two signals corresponds to the highest positive correlation. (c) Synchronized IMU and Vicon data.

Benchmarking Dataset Package

➢ Five synchronized datasets - 1LoopDown, 2LoopsDown, 3LoopsDown, hoveringDown and randomFront are created from this work.
➢ Datasets are collected from the quadrotor flying 1, 2 and 3 loop sequences, hovering within a space of approximately 1m x 1m x 1m, and flying randomly within the sight of the Vicon system.
➢ Datasets consist of images from the cameras, accelerations, attitude rates, absolute angles and absolute headings from the IMU, and groundtruth from the Vicon system and all the respective timestamps.

Example Usage: Benchmarking Pose Estimation with ARToolKitPlus

➢ We propose to measure the quality of any pose estimation algorithm with cosine similarity:

\[
\alpha = \frac{E \cdot G}{||E|| \cdot ||G||}
\]

➢ E and G are n-dimensional vectors from the measurements of the pose estimation algorithm and groundtruth respectively.

➢ Cosine similarity has a range of [-1 1] where the estimates exactly disagree or match.

Fig 6. Comparison of ARToolKitPlus pose with groundtruth. x, y, z and yaw are very accurate with cosine similarities near to 1.

Fig 7. Global trajectories from 4 point, 5 point and ARToolKitPlus pose estimation algorithms plotted against Vicon groundtruth.

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