Indoor Localization and Mapping
Multiple Autonomous Robotic Systems Lab (MARS) Lab

Abstract
Navigating in GPS-denied environments is a prerequisite for robotics’ applications. Vision-aided Inertial Navigation Systems (VINS) have prevailed as a solution to 3D localization, due to the complementary sensing capabilities of cameras and Inertial Measurement Units (IMUs). Lately their unique characteristics allowed for their deployment on portable computers, such as cell phones.

Motivation
• People & robots navigate outdoors using:
  • (i) Global Positioning System (GPS)
  • (ii) Maps (e.g., Google maps)
• Not available
  • Indoors
  • Close to buildings (urban canyon)
  • In outer-space
• GPS-denied navigation, required for:

Technical Overview

Vision-aided Inertial Navigation
• Inertial Navigation
  • Provides noisy estimates of our motion.
• Vision-aided
  • Camera measurements provide corrections

Unique advantages for 3D Localization
• Efficient
  • Low cost / power / weight sensors
  • Computationally efficient
    - 2x real-time utilizing a single CPU core on Samsung S4, or on Google Glass
• Versatile
  • Same device for people, robots, vehicles
  • No prior knowledge of the environments

Problem Description
• Objective: Track the position and orientation (pose) of a sensing platform, comprising a camera and an Inertial Measurement Unit (IMU).
• System state vector: \( x = [q^T_G \quad b^T_I \quad \mathbf{v}_I^T \quad \mathbf{p}_I^T | \ldots] \)

Motion Model
We employ a standard kinematic model of motion,
\[
\dot{q}^T_G(t) = \frac{1}{2} \Omega(\omega(t)) q^T_G(t), \quad \dot{\mathbf{v}}_I(t) = \mathbf{v}_I(t), \quad \dot{\mathbf{p}}_I(t) = \mathbf{p}_I(t)
\]
\[
b_I(t) = n_{\omega I}(t), \quad \dot{n}_{\omega I}(t) = 0, \quad i = 1 \ldots N
\]
where the features are static with respect to time.

Measurement Model
The camera measures the perspective projections of each point onto the image plane:
\[
z_i = 1/x [x \quad y \quad 1] = \hat{x}_i \quad \hat{y}_i = \hat{C} (q^T_G \quad \mathbf{p}_I)
\]

Achievements
• Real-time indoor localization on Samsung S4, Google Glass, Quad-rotors
• Adjustable processing cost

Key Contributions
• Observability analysis for inertial systems aided by camera measurements of points, lines or planes [1, 2, 3]
• Design rules for improving estimators’ consistency [1]
• Computationally efficient algorithms for:
  • Visual-Inertial Odometry [1]
  • Simultaneous Localization & Mapping [4]
  • Bundle Adjustment [5]

Research Goals
• Resource-aware measurement selection and processing
• Robustness to occlusions/ abrupt motions
• Large-scale mapping using multiple mobile devices

References