Direct Visual-Inertial Navigation with Analytical Preintegration

Kevin Eckenhoff, Patrick Geneva, Guoquan Huang
University of Delaware
Background

- Visual-Inertial Navigation- using cameras and inertial measurement units (IMU), track motion of moving sensor platform

- Potential applications:
  - Unmanned Autonomous Vehicles
  - Mobile phones
Preintegration (I)

- IMU measurements provide information on the underlying continuous evolution of the state dynamics

- Preintegration: integrate IMU measurements in local frame of reference to connect start and end poses across a window [Lupton ‘12]
Preintegration (II)

position:
\[
G_p^{k+1} = G_p^k + G_v^k \Delta T - \frac{1}{2} Gg \Delta T^2 + G_R \left[ k \int_{t_k}^{t_{k+1}} \int_{t_k}^s \left( u a_m - b_a - n_a \right) du ds \right]^{k+1} =: G_p^k + G_v^k \Delta T - \frac{1}{2} Gg \Delta T^2 + G_R^k \alpha_{k+1} ,
\]

velocity:
\[
G_v^{k+1} = G_v^k - Gg \Delta T + G_R \left[ k \int_{t_k}^{t_{k+1}} \int_{t_k}^s \left( u a_m - b_a - n_a \right) du \right]^{k+1} =: G_v^k - Gg \Delta T + G_R^k \beta_{k+1} ,
\]

orientation:
\[
k+1 \quad G_R = k+1 R_k R_G R .
\]
Preintegration (III)

- Standard preintegration: **discrete** integration of measurement dynamics

- In previous work [Eckenhoff ‘16]:
  - Introduced preintegration based on **closed-form** solutions of the **continuous** dynamics
  - Offers higher accuracy than comparable discrete preintegration methods

- Provides constraints between nodes over an interval
Direct Image Alignment

- Relative pose between images found through direct visual-odometry [Engel ‘14]
- Minimizes photometric error: intensity difference between candidate pixels and their corresponding pixels in the second image
- Uses a much higher percentage of visual information than feature-based methods
- GPU accelerated for real-time performance
Graph Optimization

- Constraints fused through iSAM2, providing a smooth trajectory estimate
Results

- System tested on publicly available datasets [Burri ‘16]