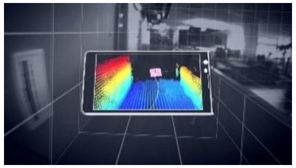
# Direct Visual-Inertial Navigation with Analytical Preintegration

**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

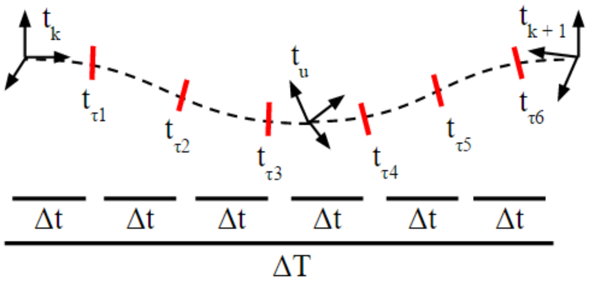
- Potential applications:
  - Unmanned Autonomous Vehicles
  - Mobile phones



https://i.ytimg.com/vi/Qe10ExwzCqk/maxresdefault.jpg

# 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:

$$ {}^{G}\mathbf{p}_{k+1} = {}^{G}\mathbf{p}_k + {}^{G}\mathbf{v}_k \Delta T - \frac{1}{2}{}^{G}\mathbf{g}\Delta T^2 + {}^{G}_{k}\mathbf{R} \underbrace{\int_{t_k}^{t_{k+1}} \int_{t_k}^{s} {}^{k}_{u}\mathbf{R}\left({}^{u}\mathbf{a}_m - \mathbf{b}_a - \mathbf{n}_a\right) du ds}_{{}^{k}\boldsymbol{\alpha}_{k+1}} $$

$$ =: {}^{G}\mathbf{p}_k + {}^{G}\mathbf{v}_k \Delta T - \frac{1}{2}{}^{G}\mathbf{g}\Delta T^2 + {}^{G}_{k}\mathbf{R}^{k}\boldsymbol{\alpha}_{k+1} \, , $$

velocity:

$$ {}^{G}\mathbf{v}_{k+1} = {}^{G}\mathbf{v}_k - {}^{G}\mathbf{g}\Delta T + {}^{G}_{k}\mathbf{R} \underbrace{\int_{t_k}^{t_{k+1}} {}^{k}_{u}\mathbf{R}\left({}^{u}\mathbf{a}_m - \mathbf{b}_a - \mathbf{n}_a\right) du}_{{}^{k}\boldsymbol{\beta}_{k+1}} $$

$$ =: {}^{G}\mathbf{v}_k - {}^{G}\mathbf{g}\Delta T + {}^{G}_{k}\mathbf{R}^{k}\boldsymbol{\beta}_{k+1} \, , $$

orientation:

$$ {}^{k+1}_{G}\mathbf{R} = {}^{k+1}_{k}\mathbf{R}^{k}_{G}\mathbf{R} \, , $$

# 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

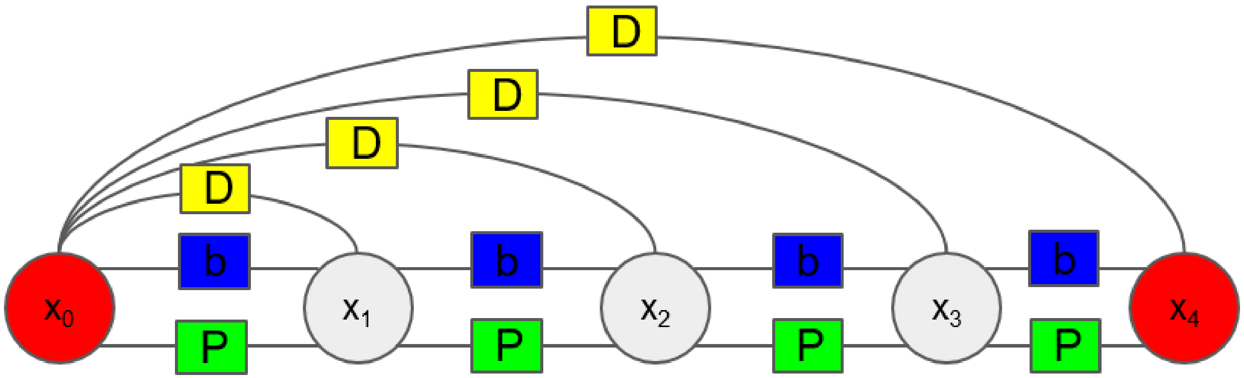
- Provides constraints between nodes over an interval

# 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]