OpenVINS: A Research Platform for Visual-Inertial Estimation

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Motivation

- More systems require autonomy and ability to localize
- Visual-inertial sensors can provide low-cost and light-weight localization
- Research in visual-inertial navigation (VINS) requires large amounts of background and software development

Open Sourced Systems

System	Mono?	Stereo?	EKF?	Geom?	Calib. Spacial?	Calib. Intrinsics?	Calib. Time?
OpenVINS	✓	✓	✓	✓	✓	✓	✓
S-MSCKF	✗	✓	✓	✓	✓	✗	✗
R-VIO	✓	✗	✓	✓	✗	✗	✗
Rovioli	✓	✗	✓	✗	✓	✗	✗
VINS-Fusion	✓	✓	✗	✓	✓	✗	✓
OKVIS	✓	✓	✗	✓	✓	✗	✗
Basalt	✗	✓	✗	✓	✗	✗	✗
ICE-BA	✗	✓	✗	✓	✗	✗	✗

- Wide range of system available for visual-inertial estimation algorithm development.
- Want to provide a feature complete EKF filter system with same level of accuracy as batch-based methods

Key Features

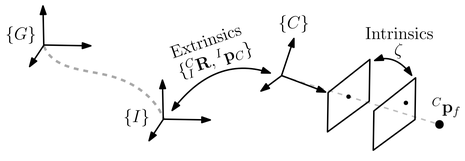
- On manifold sliding window Kalman filter with modular type system for state management
- Online camera intrinsics, extrinsic, and IMU-camera time calibration out of the box
- Temporal SLAM landmarks with First-Estimate Jacobians with five different representations
- Extendable visual-inertial simulator and extensive toolbox for algorithm evaluation and plotting

Type-Based State Management

- Each estimation variable is a type
- Indexes automatically managed during operations
- Pragmatic access to covariance information
- Allows for sparse Jacobians for modularity

```
class Type {
protected:
  // Current best estimate
  Eigen::MatrixXd _value;
  // Index of error state in covariance
  int _id = -1;
  // Dimension of error state
  int _size = -1;
  // Vector correction, how to update
  void update(const Eigen::VectorXd dx);
};
```

Online Calibration



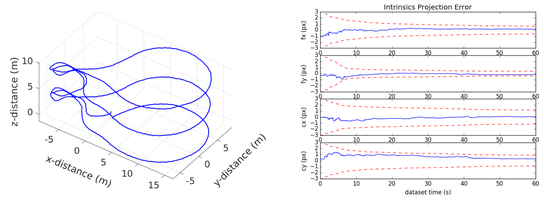
- Calibration of camera intrinsics and extrinsics
- IMU-camera temporal offset ${}^{I}t = {}^{C}t + {}^{C}t_{I}$ modeled

Documentation

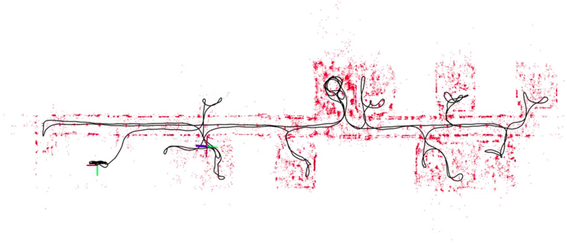
- Documentation and derivations are a key feature of the codebase
- Provide background for those not familiar with estimation

https://docs.openvins.com/

Simulation



- Complete visual-inertial simulation from a given trajectory
- Verified online calibrate ability with consistent estimation



EurocMav Evaluation

Table: Ten run mean absolute trajectory error (ATE) (units of degree/meters).

	V1_01_easy	V1_02_medium	V1_03_difficult	V2_01_easy	V2_02_medium	Average
mono_ov_slam	0.699 / 0.058	1.675 / 0.076	2.542 / 0.063	0.773 / 0.124	1.538 / 0.074	1.445 / 0.079
mono_ov_vio	0.642 / 0.076	1.766 / 0.096	2.391 / 0.344	1.164 / 0.121	1.248 / 0.106	1.442 / 0.148
mono_okvis	0.823 / 0.090	2.082 / 0.146	4.122 / 0.222	0.826 / 0.117	1.704 / 0.197	1.911 / 0.154
mono_rovioli	2.249 / 0.153	1.635 / 0.131	3.253 / 0.158	1.455 / 0.106	1.678 / 0.153	2.054 / 0.140
mono_rvio	0.994 / 0.094	2.288 / 0.129	1.757 / 0.147	1.735 / 0.144	1.690 / 0.233	1.693 / 0.149
mono_vinsfusion_vio	1.199 / 0.064	3.542 / 0.103	5.934 / 0.202	1.585 / 0.073	2.370 / 0.079	2.926 / 0.104
stereo_ov_slam	0.856 / 0.061	1.813 / 0.047	2.764 / 0.059	1.037 / 0.056	1.292 / 0.047	1.552 / 0.054
stereo_ov_vio	0.905 / 0.061	1.767 / 0.056	2.339 / 0.057	1.106 / 0.053	1.151 / 0.048	1.454 / 0.055
stereo_basalt	0.654 / 0.035	2.067 / 0.059	2.017 / 0.085	0.981 / 0.046	0.888 / 0.059	1.321 / 0.057
stereo_iceba	0.909 / 0.059	2.574 / 0.120	3.206 / 0.137	1.819 / 0.128	1.212 / 0.116	1.944 / 0.112
stereo_okvis	0.603 / 0.039	1.963 / 0.079	4.117 / 0.122	0.834 / 0.075	1.201 / 0.092	1.744 / 0.081
stereo_srnsdf	1.108 / 0.086	2.147 / 0.121	3.918 / 0.198	1.181 / 0.083	2.142 / 0.164	2.099 / 0.130
stereo_vinsfusion_vio	1.073 / 0.054	2.695 / 0.089	3.643 / 0.132	2.499 / 0.071	2.006 / 0.074	2.383 / 0.084

- Monocular system with temporal SLAM features able to outperform state-of-the-art open sourced systems
- Out-of-the-box support for EurocMav, TUM-VI, and additional example datasets
- Provide extensive evaluation suite for accuracy comparison and constiency verification

Conclusion

- Introduced a state-of-the-art open platform for visual-inertial estimation research.
- Feature rich: state management, calibration, documentation, simulation, and evaluation.
- Developed to facilitate future estimation research and practical applications of visual-inertial localization

https://github.com/rpng/open_vins/