Autonomous Navigation for Flying Robots

Lecture 8.1: Visual Navigation with a Parrot Ardrone

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Parrot Ardrone

- Low-cost platform (300 USD)
- Controllable via wifi
- API is open-source
- Many language bindings
  - C/C++
  - Python
  - JavaScript
  - …

Software Architecture for Robotics

- Robots became rather complex systems
- Often, a large set of individual capabilities is needed
- Flexible composition of different capabilities for different tasks

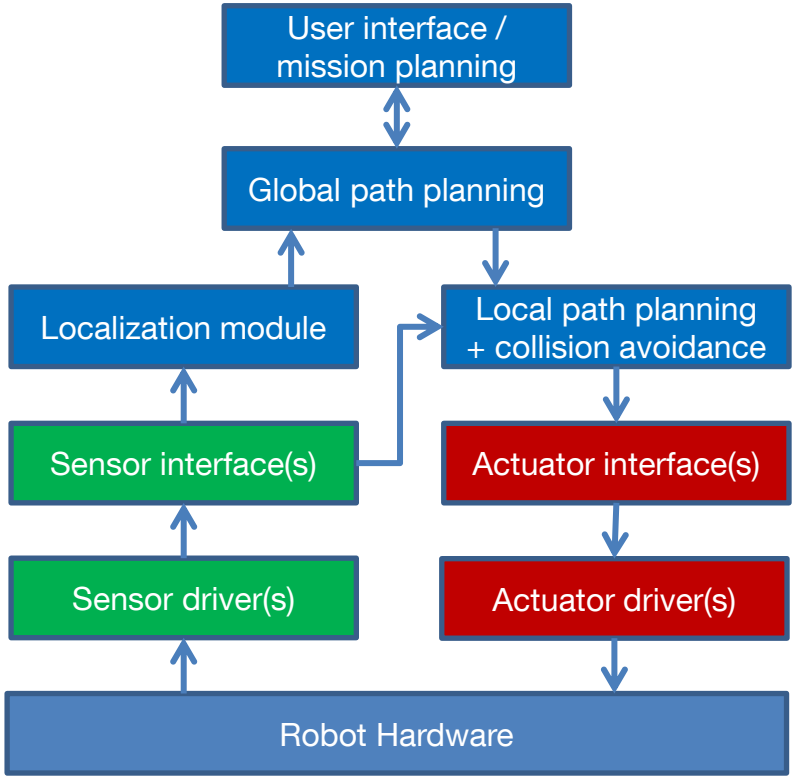
Best Practices for Robot Architectures

- Modular
- Robust
- De-centralized
- Facilitate software re-use
- Hardware and software abstraction
- Provide introspection
- Data logging and playback
- Easy to learn and to extend

Robotic Middleware

- Provides infrastructure
- Communication between modules
- Data logging facilities
- Tools for visualization
- Several systems available
  - Open-source: ROS (Robot Operating System), Player/Stage, CARMEN, YARP, OROCOS
  - Closed-source: Microsoft Robotics Studio

Example Architecture for Navigation

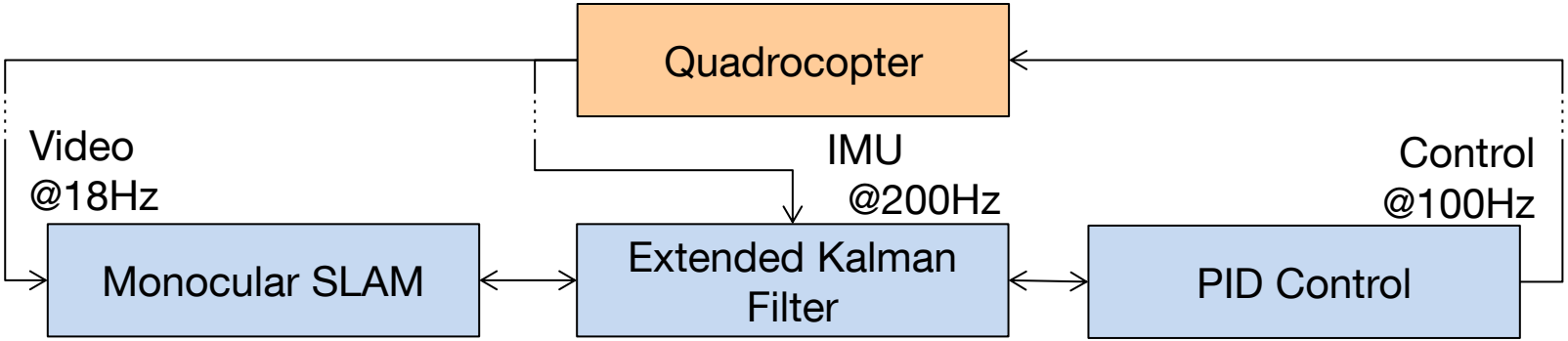


Robot Operating System (ROS)

- http://www.ros.org/
- Installation instructions, tutorials, docs

Camera-based Navigation

[Engel, Sturm, Cremers; IROS 2012; RAS 2014]



Camera-based Navigation

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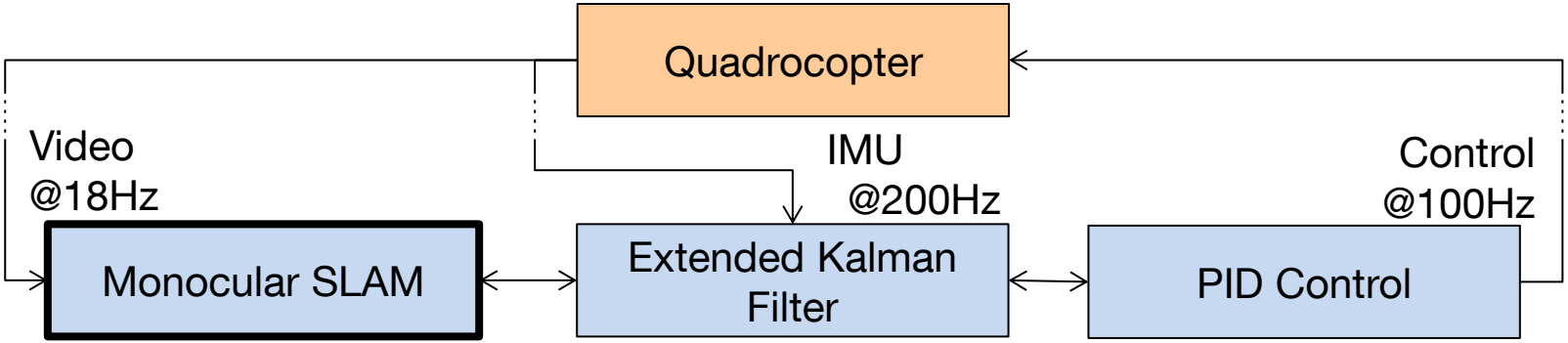
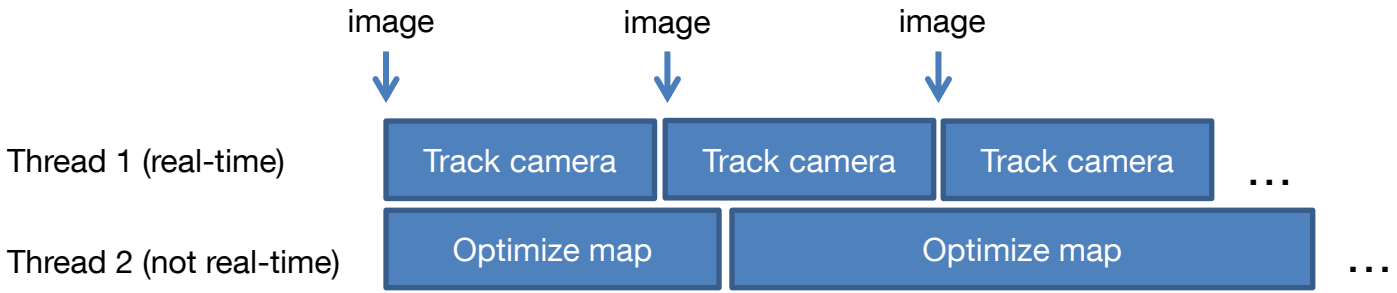


Monocular SLAM

- Based on PTAM library [Klein and Murray, ISMAR 2007]
- Visual SLAM
  - Match visual features between keyframes
  - Optimize camera poses and 3D feature points
- Optimized for dual cores, highly efficient, open-source



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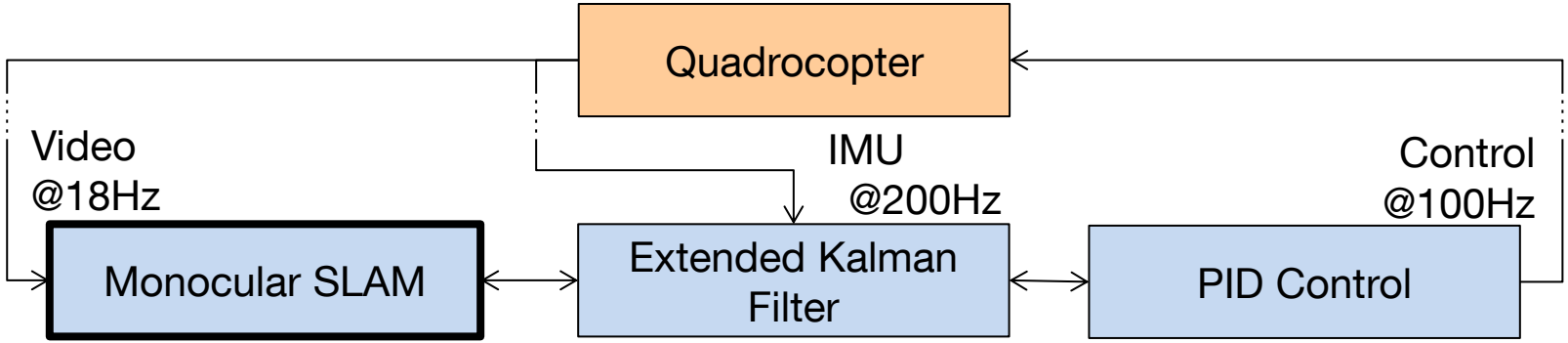

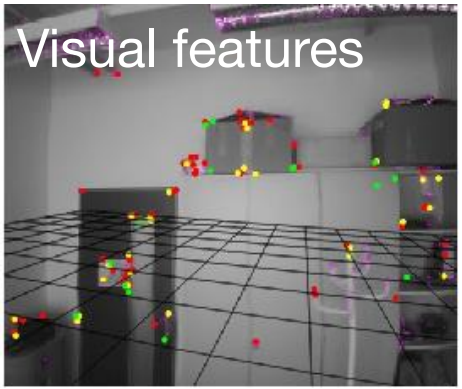

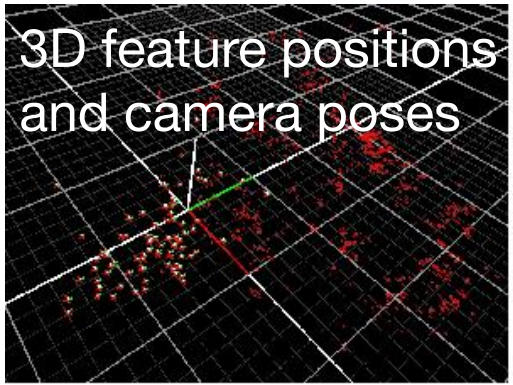

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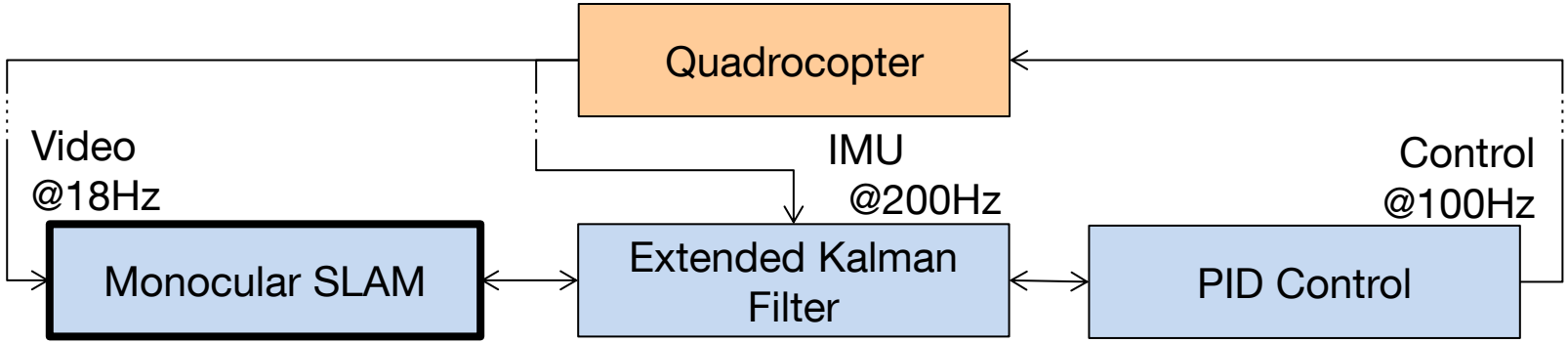
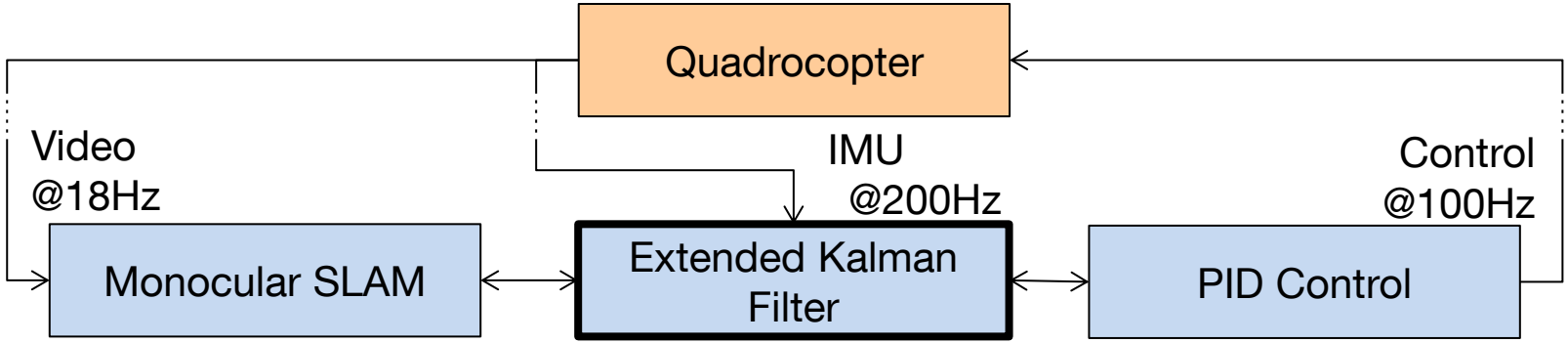


- Based on PTAM
- Our contributions:
  - **Enhanced reliability** by incorporating IMU into PTAM
  - Maximum likelihood **scale estimation** from ultrasound altimeter and IMU

Camera-based Navigation

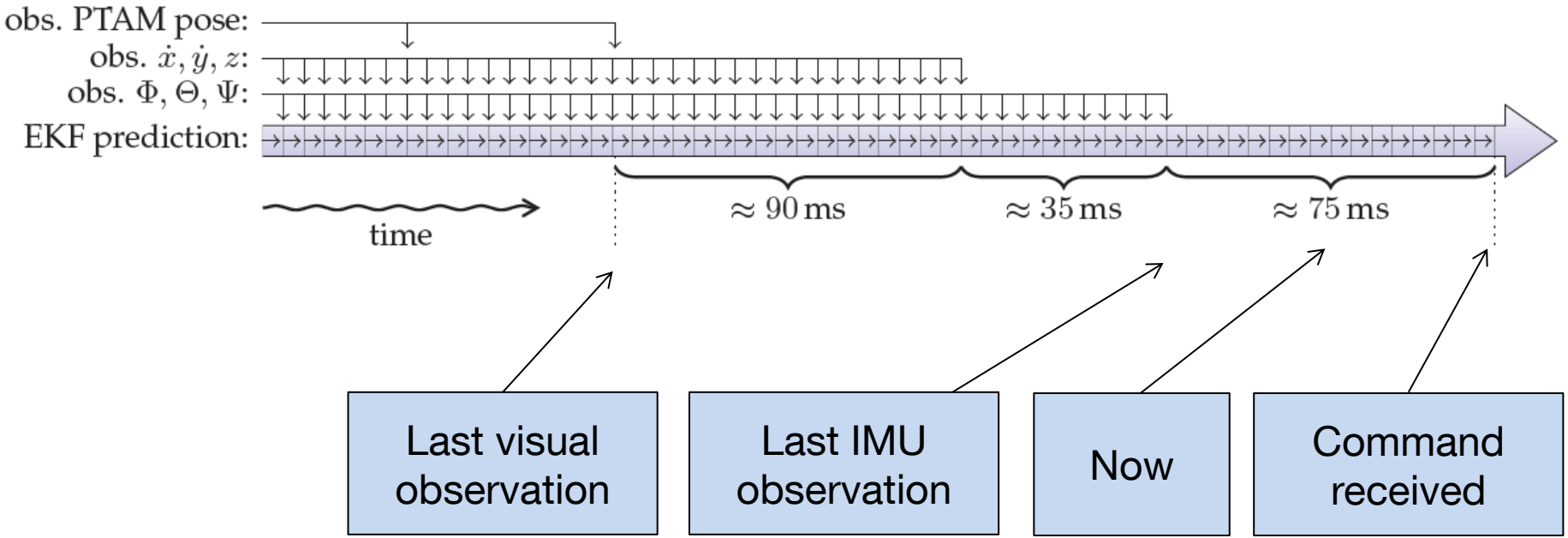
[Engel, Sturm, Cremers; IROS 2012; RAS 2014]



- Input: PTAM estimate, IMU, controls
- Output: pose estimate
- State vector: $(x, y, z, \dot{x}, \dot{y}, \dot{z}, \phi, \theta, \psi, \dot{\psi})^\top$
- Full, calibrated model of the flight dynamics
- Delay compensation (~200ms)

Time Delays

[Engel, Sturm, Cremers; IROS 2012; RAS 2014]



Camera-based Navigation

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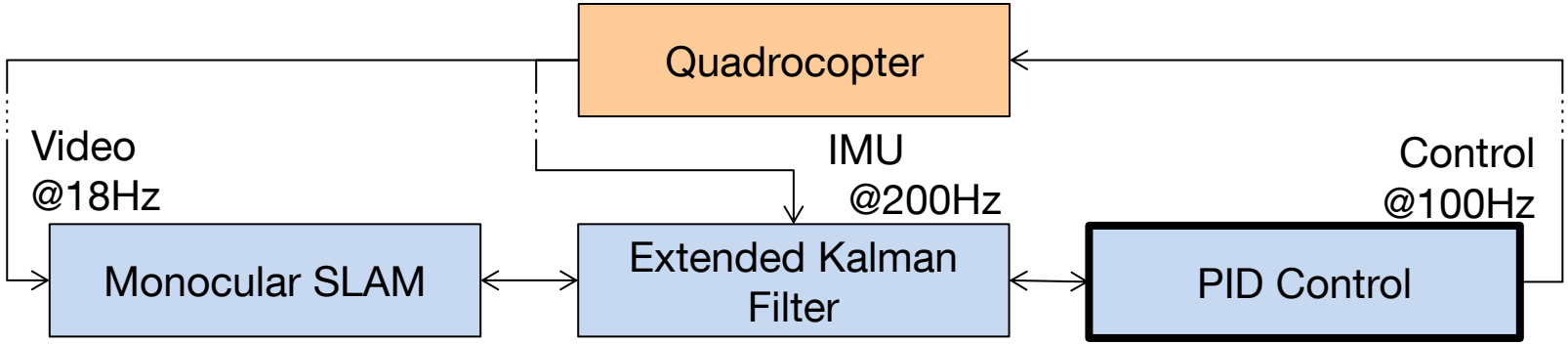


- Based on predicted state from EKF
- Approach and hold target position $(x, y, z, \Psi)^\top$
- High level control:
  Hold position, assisted control,
  follow waypoints

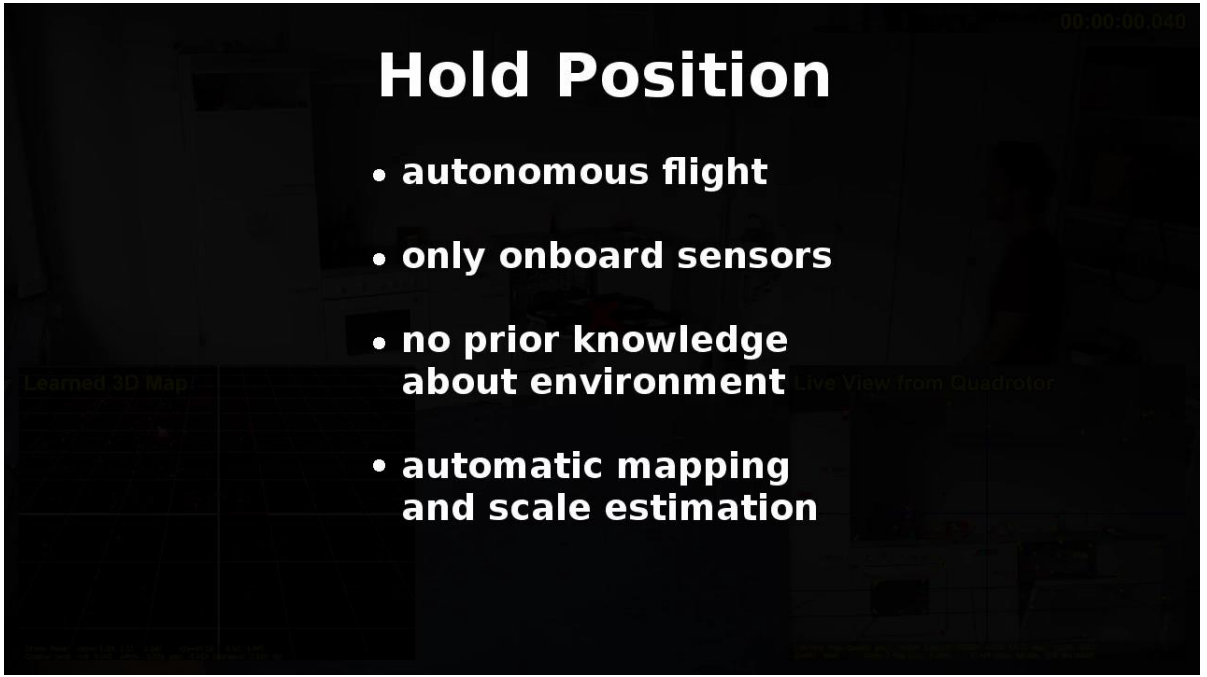
Results

[Engel, Sturm, Cremers; IROS 2012; RAS 2014]

Camera-Based Navigation of a Low-Cost Quadrocopter (J. Engel, J. Sturm, D. Cremers), In Proc. of the International Conference on Intelligent Robot Systems (IROS), 2012. http://youtu.be/tZxIDly7Ino

Results

[Engel, Sturm, Cremers; IROS 2012; RAS 2014]



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Lessons Learned

- Parrot Ardrone
- ROS as a middleware
- Monocular SLAM with PTAM
- Example: Visual navigation with the Parrot Ardrone
  - Fast & accurate navigation (with up to 2 m/s)
  - Source code available on http://www.ros.org/wiki/tum_ardrone