Stereo and Monocular Vision Guidance for Autonomous Aerial and Ground Vehicles

Centro di Ateneo di Studi ed Attivita' Spaziali Giuseppe Colombo - CISAS

Candidate: Riccardo Giubilato
Supervisor: Prof. Stefano Debei
Co-supervisor: Ing. Marco Pertile
September 22, 2017

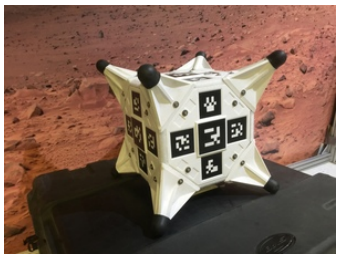
UNIVERSITÀ
DEGLI STUDI
DI PADOVA

Outline

Introduction

Why vision for navigation?

- Estimate vehicle path when other sources of information are absent (GPS) or unreliable (wheel odometry / inertial navigation)
- Build a consistent 3D map of an unknown environment and localize the vehicle inside it (**SLAM**)
- Plan future motions and identify locations of scientific interest
- Cheap hardware and low mass with respect to the quantity of data available



Introduction

Research Objective: Development of monocular and stereo Visual Odometry and SLAM algorithms that allow unmanned vehicles to perform autonomous exploration. Improving reliability and accuracy solving the following issues:

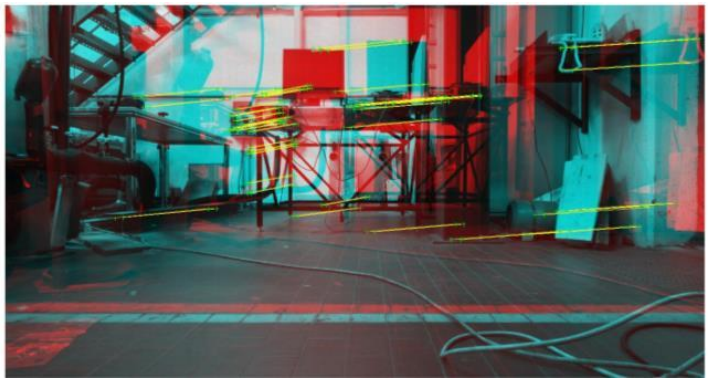
- Stereo Vision:
  - Failures for low stereo correspondences (presence of occlusions, lighting conditions..)
  - Compromise between high stereo baseline (high accuracy) and low reliability (no correspondences for close objects)
- Monocular Vision:
  - No metric scale knowledge
  - Reliability: tracking failures, scale drift

Stereo Vision: failures

Failure mechanisms:

- Excessive proximity of the observed environment
- Obstructions of the FOV of the cameras

Good case: **44** 3D matches

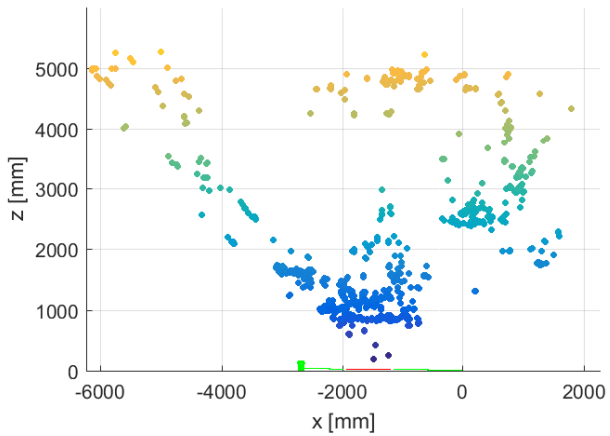


Bad case: **6** 3D matches

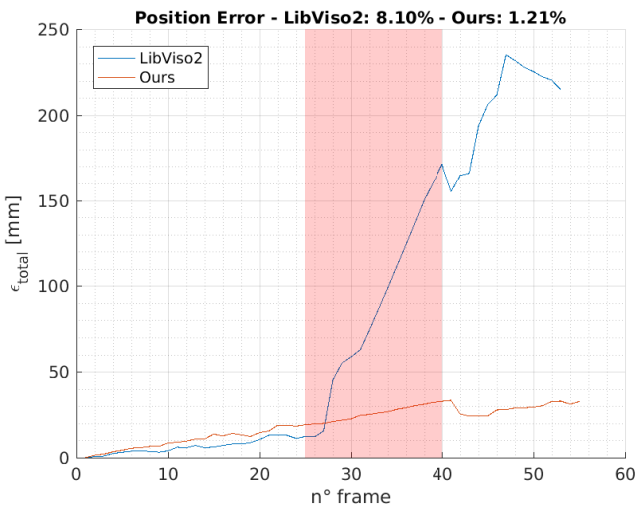
Stereo Vision: dealing with failures

- Heuristic to distinguish *good* and *bad* stereo correlations
- Switch to monocular visual odometry: less baseline between views $\rightarrow$ better performances
- Our algorithm outperforms current state of the art for stereo Visual Odometry (LibVISO2, A. Geiger et al. 2012)
- **Next**: Accurate uncertainty evaluation

Top view of the observed environment



Position estimation error



Monocular Vision

Why monocular vision for UAV exploration?

- Single camera $\rightarrow$ miniaturization: low cost, mass and power requirements
- Improve perception of a ground vehicle by collaborative SLAM

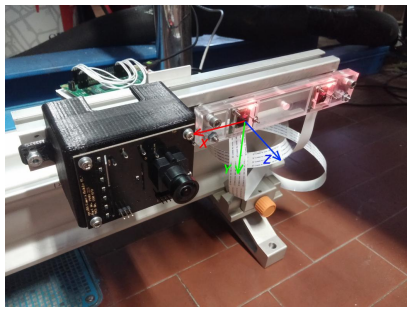
Challenges:

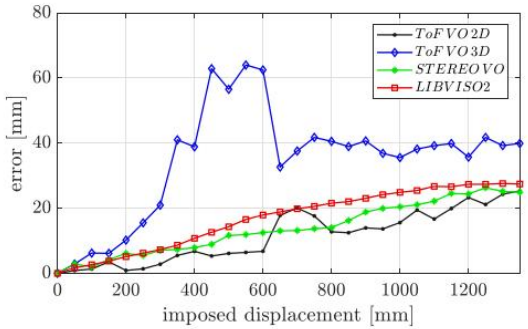
- Monocular vision loses depth information
- 3D reconstruction of environment and ego-motion **up to scale**
- High FPS required to provide localization to an UAV $\rightarrow$ **efficient code**
- No fully working and reliable method in literature up to now

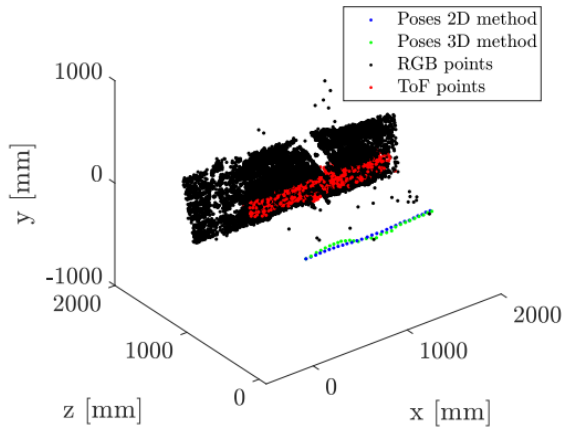
Monocular Vision: Retrieving Scale I

Monocular Visual Odometry aided by a Low Resolution Time of Flight Camera (8x8 pixels @ 20Hz):

- Feasibility study for integrating range measurements in an RGB Visual Odometry algorithm
- Offline Visual Odometry integrating range data in a non-linear optimization of the observed map and camera poses (Local Bundle Adjustment)
- Results show **comparable performances** with a stereo setup







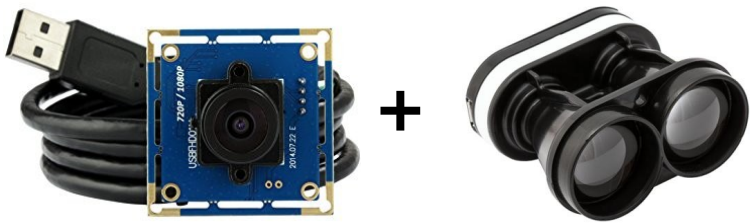
Monocular Vision: Retrieving Scale II

Towards a real time monocular SLAM aided by LiDAR altimeter:

- Real time pose estimation and mapping (>30Hz)
- Low computational power requirements: 1 range measurement

Completed tasks:

- ✓ Real-time Visual Odometry using USB camera
- ✓ C++ drivers for serial communications with the LiDAR altimeter



Monocular SLAM: Video

Conclusions and foreseen activities

In conclusion:

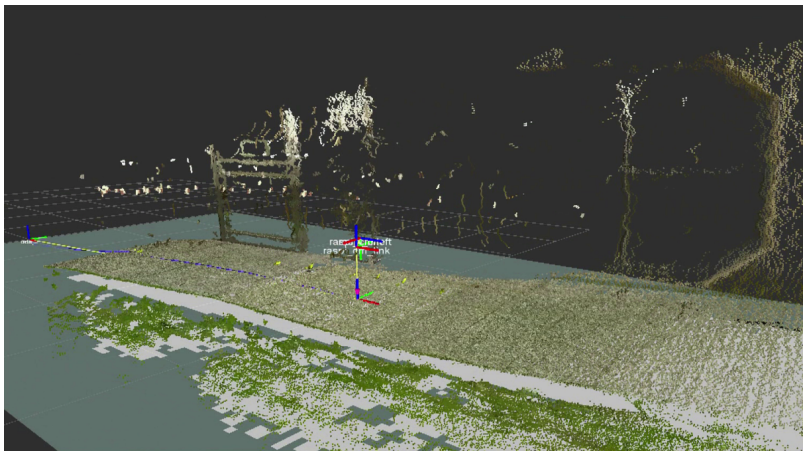
- Monocular vision can be implemented efficiently to recover stereo vision failures
- Scale information can be provided to monocular SLAM using range sensors with a low data volume

Next:

- Uncertainty evaluation of the ego-motion computed by the stereo visual odometry algorithm with recovery
- Implementation of LiDAR altimeter in monocular SLAM
- ROS (Robot Operating System) packages development
- Implementation of the algorithms on real platforms (ground rover and UAV) and testing

MORHPEUS 2.0: Field Robotics Testbed

Mechanical Configuration



Stereo SLAM test

- Mars like rover designed by a team of students
- Testbed for soil sampling and for autonomous navigation in unknown environments

- Training platform for the astronauts during the Pangaea-X extension campaign

Publications

- **Riccardo Giubilato**, Marco Pertile, Stefano Debei: *A comparison of monocular and stereo visual FastSLAM implementations*. Metrology for Aerospace (MetroAeroSpace), 2016 IEEE
- **Riccardo Giubilato**, Sebastiano Chiodini, Marco Pertile, Stefano Debei: *Stereo visual odometry failure recovery using monocular techniques*. 2017 IEEE International Workshop on Metrology for AeroSpace (MetroAeroSpace)
- Sebastiano Chiodini, **Riccardo Giubilato**, Marco Pertile, Stefano Debei: *Monocular visual odometry aided by a low resolution time of flight camera*. 2017 IEEE International Workshop on Metrology for AeroSpace (MetroAeroSpace)
- Sebastiano Chiodini, **Riccardo Giubilato**, Marco Pertile, Stefano Debei: *Experimental evaluation of a monocular visual odometry system aided by a time of flight camera, comparison with a stereo system*. I Forum Nazionale delle Misure, 2017.
- Marco Pertile, Sebastiano Chiodini, **Riccardo Giubilato**, Stefano Debei: *Calibration of extrinsic parameters of a hybrid vision system for navigation comprising a very low resolution Time-of-Flight camera*. 2017 IEEE International Workshop on Metrology for AeroSpace (MetroAeroSpace)
- Marco Pertile, Sebastiano Chiodini, **Riccardo Giubilato**, Stefano Debei: *Effect of rolling shutter on visual odometry systems suitable for planetary exploration*. Metrology for Aerospace (MetroAeroSpace), 2016 IEEE
- Marco Pertile, Mattia Mazzuccato, Guido Pastore, Andrea Valmorbida, Sebastiano Chiodini, **Riccardo Giubilato**, Stefano Debei, Enrico Lorenzini: *Comparison of vision system approaches for distance measurements of a tether tip-mass during deployment on high eccentricity orbit*. I Forum Nazionale delle Misure, 2017.