UNIVERSITÀ DEGLI STUDI DI PADOVA

CISAS G. COLOMBO

Stereo and Monocular Vision Applied to Computer Aided Navigation for Aerial and Ground Vehicles

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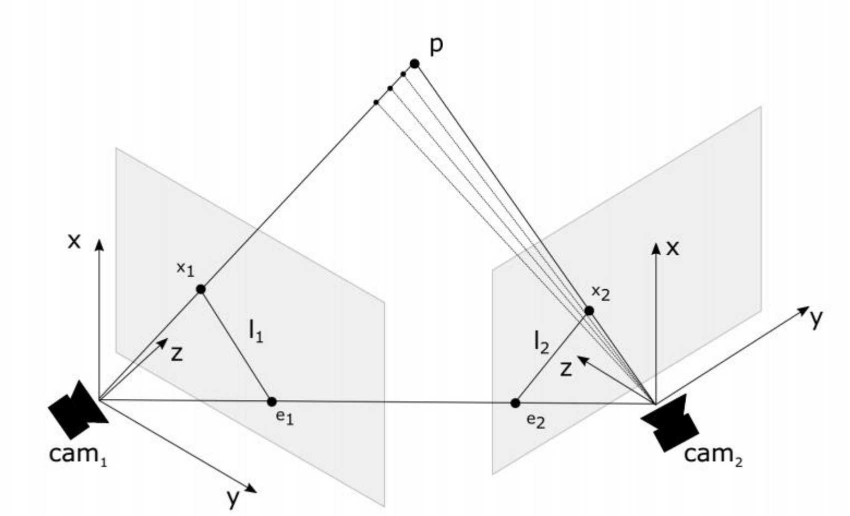
Robot vision:

- Process of extracting visual information about the environment through cameras mounted on the vehicle
- In GPS-denied environments robot vision is the most reliable solution for ego-motion estimation: the process is commonly referred to as *visual odometry*.
- *Stereo Visual Odometry* is implemented in the Curiosity rover for estimating motions through slippery terrains (where wheel odometry fails)
- *Monocular Visual Odometry* is not yet implemented in any active space mission.

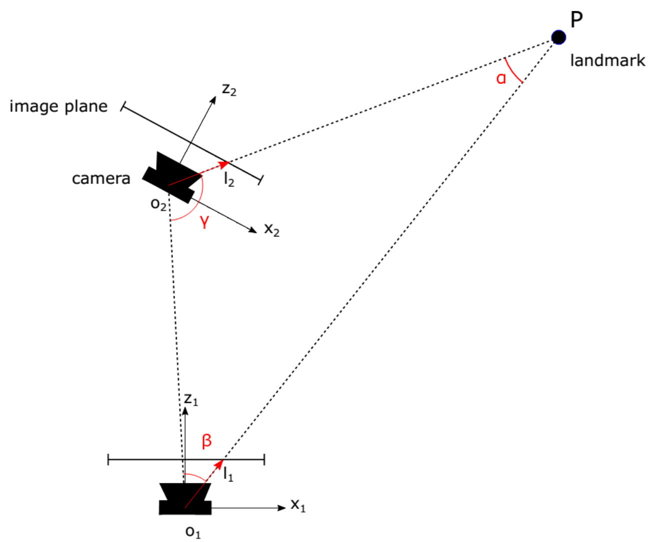
Stereo vision

- 2 images acquired at the same instant -> direct measurement of 3D coordinates of points in the environment
- Visual Odometry -> direct computation (relative motion of the observed map)



Monocular vision

- 1 image -> projection of the environment on a plane, one dimension (depth) is not directly observable
- Visual Odometry -> requires multi-frame integration and depth filters for the tracked features.

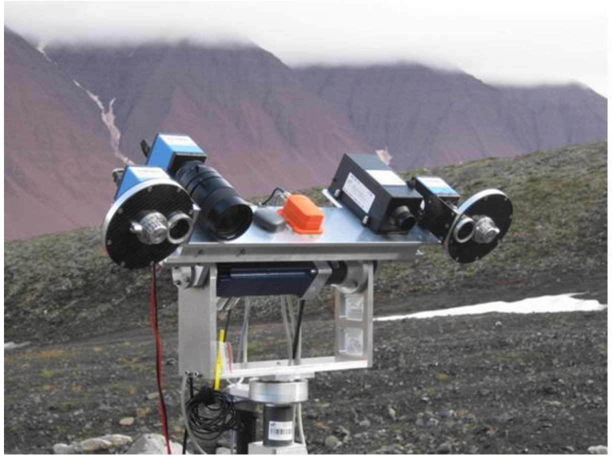


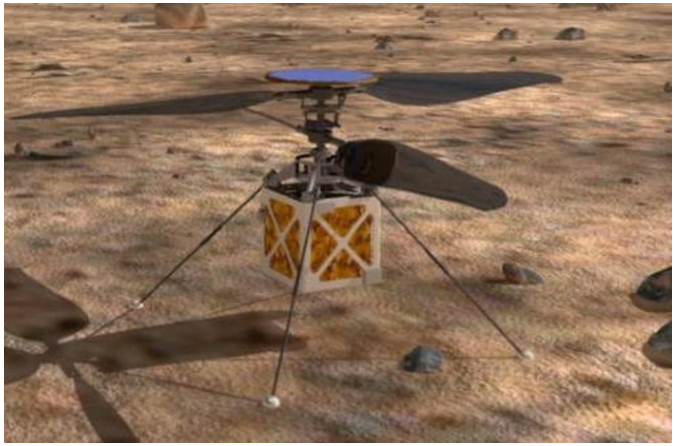
Pros & Cons of Stereo and Monocular Visual Odometry

	Stereo	Monocular
Pros	• Accuracy (<1% travelled path) • Direct computation • Permits dense mapping of the environment	• Lower mass, volume and power requirements (UAV applications) • Lighter computational effort for image acquisition and feature extraction • High fps applications
Cons	• Costly feature extraction and matching • System complexity • Blindness to near objects • Degenerates to monocular vision when far objects are observed	• Problem complexity: mapping depends on camera tracking and viceversa. • Requires initialization

Positioning of the research: Active space missions or research projects using vision

- Curiosity (Nasa JPL)
- ExoMars, PanCam (ESA)
- Mars Helicopter Scout (Nasa JPL)

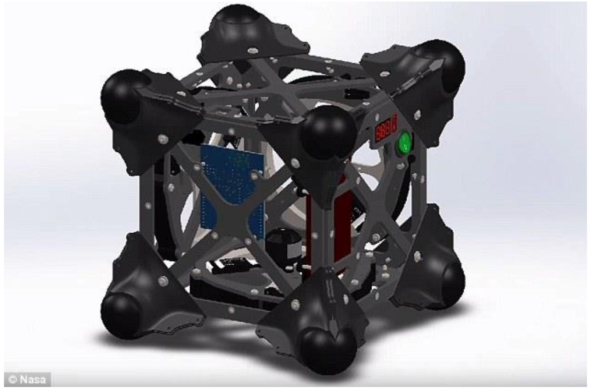




Positioning of the research: Research projects that would benefit from using monocular vision

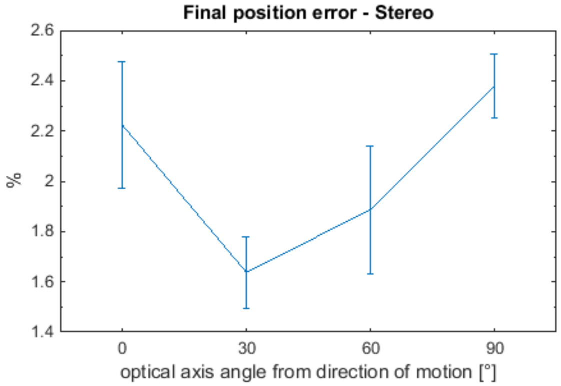
- Extreme Access Flyer (Nasa JPL)
- Hedgehog Hopping Rover (Nasa JPL)

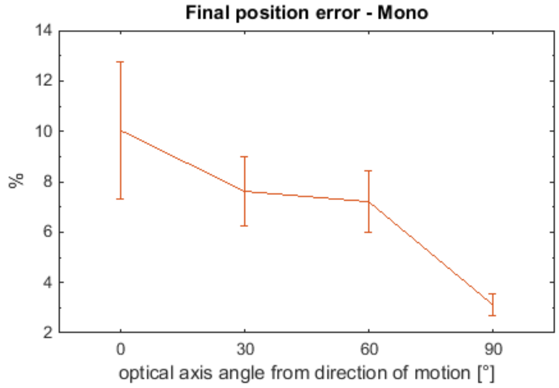
Concepts of UAVs designed for airless and low gravity environment (i.e. asteroid or cometary exploration). Monocular vision would be beneficial in terms of ego-motion estimation capabilities as well as surface mapping and 3D reconstruction.



R.Giubilato, M.Pertile, S.Debei, "*A Comparison of Monocular and Stereo Visual FastSLAM Implementations*", IEEE International Workshop on Metrology for AeroSpace, 2016"

- Offline / Matlab SLAM implementations, mono vs. stereo
- Translational error vs. inclination of the optical axis of the cameras in respect to the direction of motion
- Monocular SLAM/VO more efficient in the case of 90° inclination -> equivalent to downward pointing camera on UAV.
- Stereo SLAM/VO -> issues in the case of 90° related to excessive proximity of the observed environment





Research Objectives

1. Improving the reliability of state of the art stereo visual odometry algorithms:
   - Formulation of novel methods to deal with tracking failures when no correspondence from the stereo frames is found. (Objects too close to the stereo camera, etc..)
   - Accurate performance analysis from a measurement point of view.

2. Development/Improvement of a monocular visual odometry / SLAM (Simultaneous Localization and Mapping) algorithm:
   - Lightweight, low computational effort -> high fps target for real-time application
   - C++ code, investigation of the performance boost gained implementing parallelization / CUDA libraries.
   - Onboard implementation on UAV platform.

Research Methodology. Objective 1 – stereo VO

- Extensive literature review
- Development of the most appropriate method
- Dataset acquisition:
  - Capture of stereo frames
  - Challenging scenario for stereo visual odometry
  - Accurate measurements of the stereo setup position for algorithm performance evaluation
- Matlab implementation of the developed method (offline method)

Research Methodology. Objective 2 – monocular VO / SLAM

- Extensive literature review
- Development/Improvement of the most appropriate method
- Dataset acquisition:
    - Preliminary testing purposes
    - Video feed from a camera
    - 6DOF motion, no restrictions
- Matlab test code development & feasibility evaluation (if necessary)
- C++ code
    - Real time functionality constraint (high fps target)
    - Parallelization / CUDA implementation
- Embedded platform implementation (Raspberry Pi, nVidia Jetson etc..)
- Onboard implementation (drone, if available)

Thank you for your attention