Multiple-view Geometry 1

Overview, Intro to Visual Odometry, Feature extraction and matching, Motion Estimation

RRC Summer Sessions

Overview

Overview

Multiple-view geometry

The study of geometric relations between multiple views (images) of a 3D scene, that are related to the camera motion and calibration as well as the scene structure.

- Single-view geometry: Camera modeling, camera calibration
- Two-view geometry: Epipolar geometry, projective reconstruction, auto-calibration
- Three-view geometry: Trifocal geometry, transfer of point and line correspondences
- N-view geometry: Quadrifocal geometry, Structure from motion

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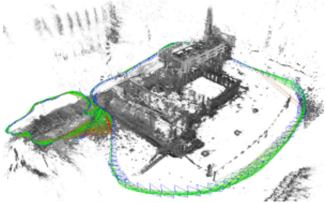
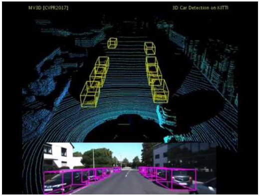
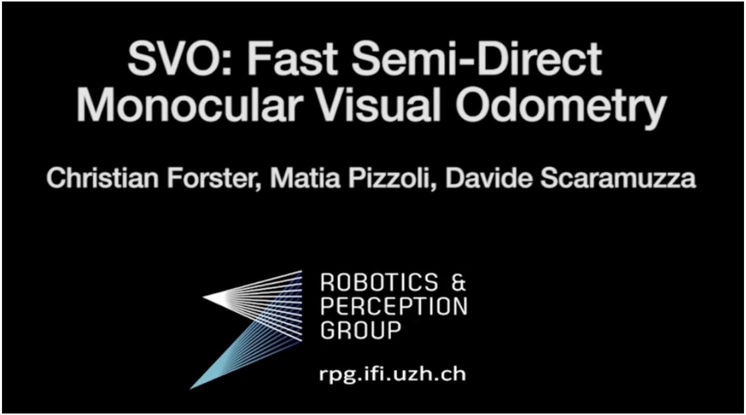
Overview

Applications





Visual Odometry
SVO



Overview

References

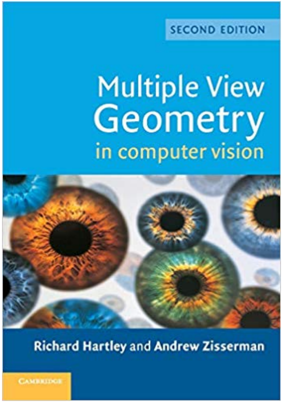


Figure: Multiple-View Geometry - Richard Hartley, Andrew Zisserman

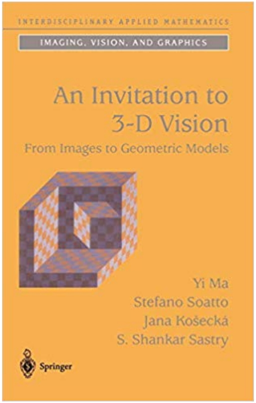


Figure: Invitation to 3D Vision - Yi Ma et al.

Overview

Courses

- Photogrammetry II - Cyril Stachniss
- Multiple-view Geometry - Daniel Cremers
- Vision algorithms for mobile robots - Davide Scaramuzza

Overview

Researchers/Groups to follow

- Robotics and Perception Group, University of Zurich
- Computer Vision Group, TUM
- Autonomous Vision Group, MPI
- Photogrammetry and Robotics Group, UBonn
- Dyson Robotics Lab, Imperial
- Mobile Robotics Group, Oxford

and more..

Visual odometry

Visual Odometry

Definition

The process of estimating the egomotion of an agent using only the input of a single camera or a system of cameras attached to it.

This is done by incrementally estimating the pose of the agent through examination of the changes that motion induces on the images of its onboard cameras.

Key assumptions:

- Static scene
- Sufficient illumination with enough texture in the scene
- Sufficient overlap between consecutive frames

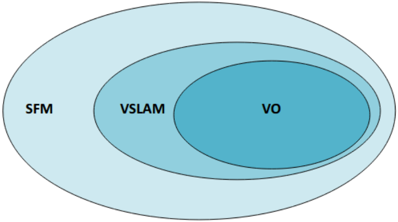
Visual Odometry
History

- Initial work started in the 1980s and was primarily motivated by the Mars exploration program.
- First known implementation real-time implementation was by Hans Moraveck, in his PhD thesis.
- Mars rovers Spirit and Opportunity used VO systems.

Courtesy: Scaramuzza

Visual Odometry

Related problems



Courtesy: Scaramuzza

- Structure from Motion (SfM): The problem of recovering relative camera poses and the 3-D geometry of the scene, from a set of images.
- Simulataneous Localization and Mapping (SLAM): The problem of incrementally building a *globally consistent* map of an environment that an agent perceives while simultaneously localizing the agent relative to the map.

Visual Odometry

Related problems

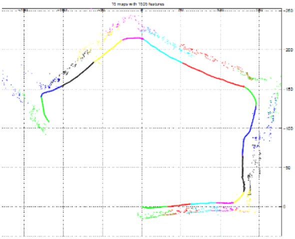


Figure: VO

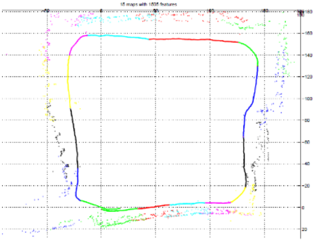
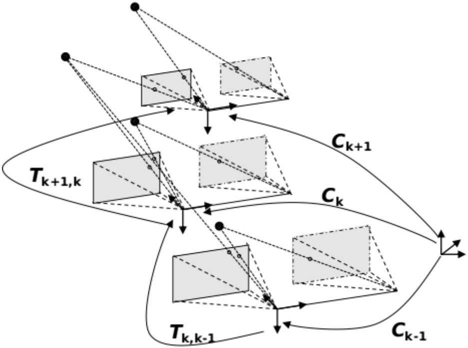


Figure: VSLAM

Courtesy: Scaramuzza

Visual Odometry

Formulation



Courtesy: Scaramuzza

Visual Odometry

Direct vs Feature-based

- Feature-based approach: Extract a sparse set of salient image features in each image and match them in succesive frames to recover the camera motion.
- Direct approach: Motion is estimated directly from the intensity values of all the pixels in the image.

Visual Odometry

Drift

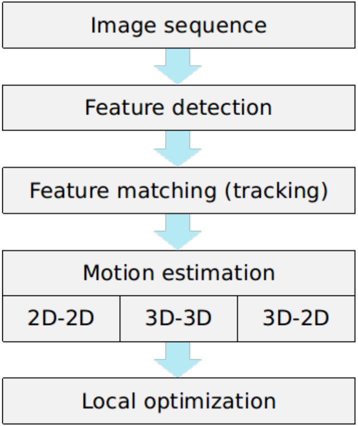
Since VO estimates the camera path incrementally, pose after pose, the errors introduced by each frame-to-frame motion accumulate over time. This causes the estimated path to 'drift' from the real path.

To minimize the drift -

- Local bundle adjustment
- Combine with other sensors such as GPS, LiDAR, or IMU

Visual Odometry

Pipeline

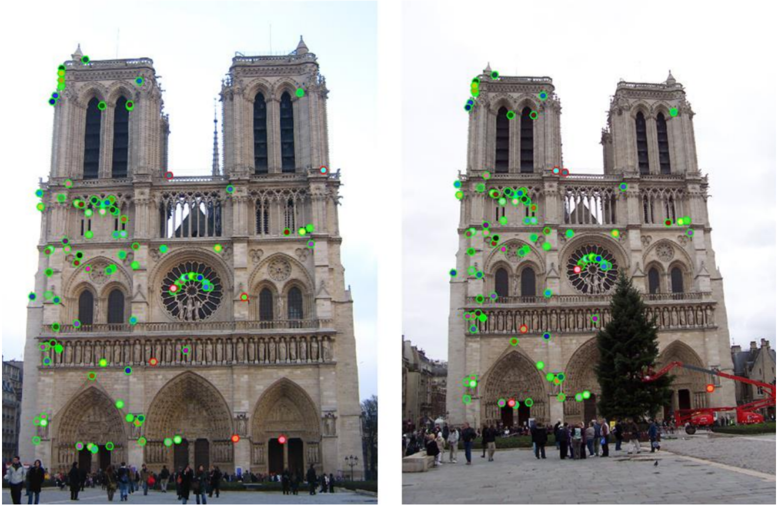


Courtesy: Scaramuzza

Feature extraction and matching

Feature extraction and matching

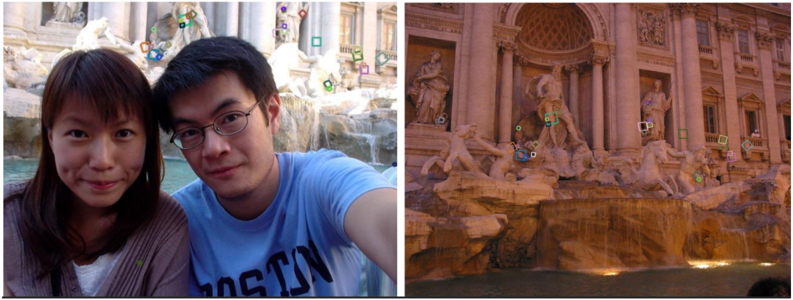
SIFT



Courtesy: Snavely

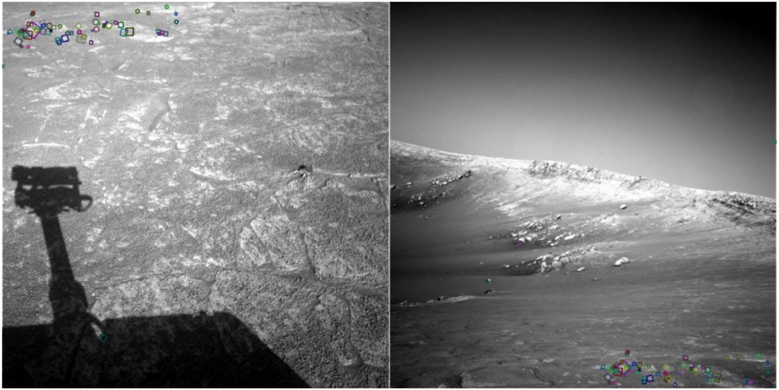
Feature extraction and matching

SIFT



Courtesy: Snavely

Feature extraction and matching
SIFT



Courtesy: Snavely

Motion estimation

Motion estimation

The process of estimating the relative transformation T_k between two frames I_{k-1}, I_k from two sets of corresponding features f_{k-1}, f_k. Depending on the nature of the correspondences, there

are three different categories of methods:

- 2D-to-2D: Both f_{k-1}, f_k are specified in 2D image coordinates.
- 3D-to-3D: Both f_{k-1}, f_k are specified in 3D. The 3D points are obtained using triangulation.
- 3D-to-2D: f_{k-1} are specified in 3D and f_k are the corresponding 2D reprojections on the image I_k.

Motion estimation
2D-to-2D

Continued on board..