Autonomous Systems Lab

ETH Zürich

Evaluation of Stereo Reconstruction for 3D Mapping

Motivation

Passive stereo vision offers a rich description of the environment in 3 dimensions, but the use of SLAM algorithms developed for laser ranger finder raises several challenges. This evaluation focuses on the application of the Iterative Closest Point (ICP) algorithm to depth images provided by a pair of cameras.

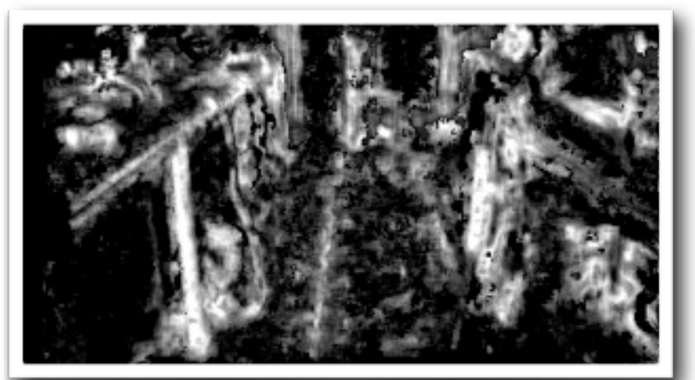


Fig.: Confidence image

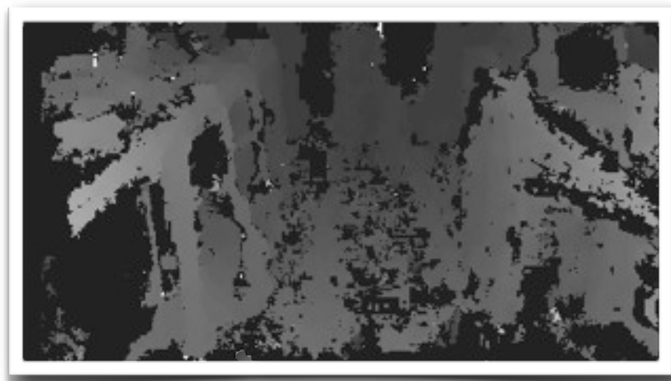


Fig.: Depth image

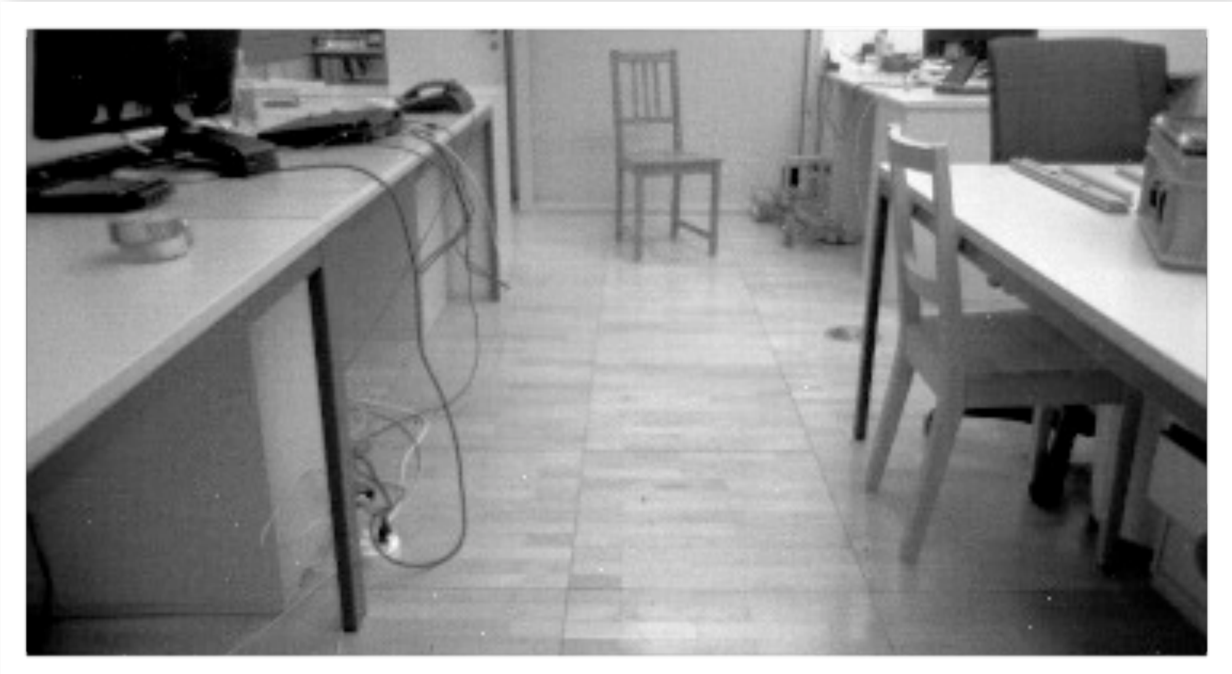


Fig.: Left image from the camera pair

Overview

Within the context of the European project Robots@home (FP6-2006-IST-6-045350), a layered representation of the environment using visual sensors must be demonstrated. The utilization of stereo cameras is explored here as the main sensor for the metric layer.

Preliminary results show that it is possible to realize metric map but sensory noise reduces the sensing range and augments the sensitivity to initial alignment error.

Method

Material

- Stereo camera from Austrian Institute of Technology (AIT) [4]
- 2 Photonfocus greyscale cameras
- Short baseline: 9.32 cm
- Orientation and position optimized for obstacle avoidance

Iterative Closest Point

Specification of the algorithm following the nomenclature of Rusinkiewicz [3]:

1- Selection: Kd-tree construction, plane extraction and noise filtering.

BEGIN loop
2- Matching: Nearest Neighbor search using a kd-tree
3- Rejection: Relative Motion Threshold [1]
4- Weighting: None
5- Error: Point-to-plane [2]
6- Minimization: Cholesky decomposition from the linearized matrix
END

The complexity of ICP:

$$O(n \log m)$$

where n is the number of points in the data point cloud and m is the number of points in the model point cloud.

Reducing the model size (m): Noise Filtering

A target reduction of 50% is realized, based on:
- Range using the depth image
- Texture using the confidence image
- Structure using the curvature space

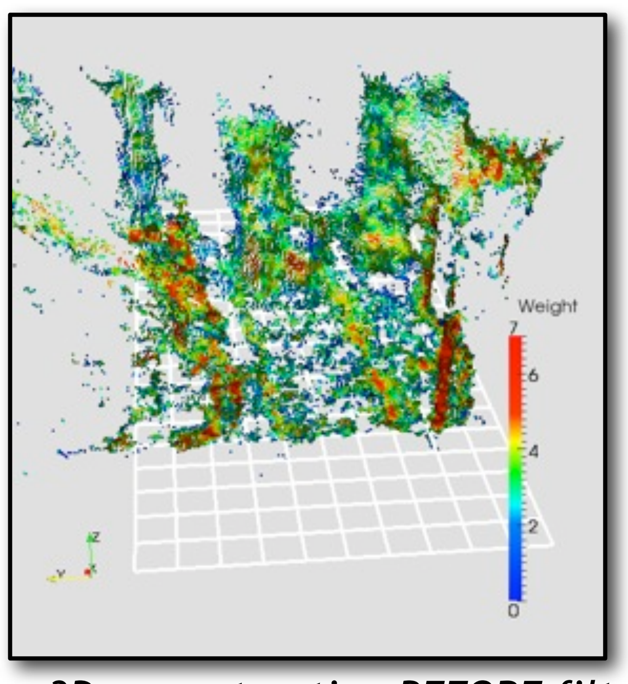


Fig.: 3D reconstruction BEFORE filtering

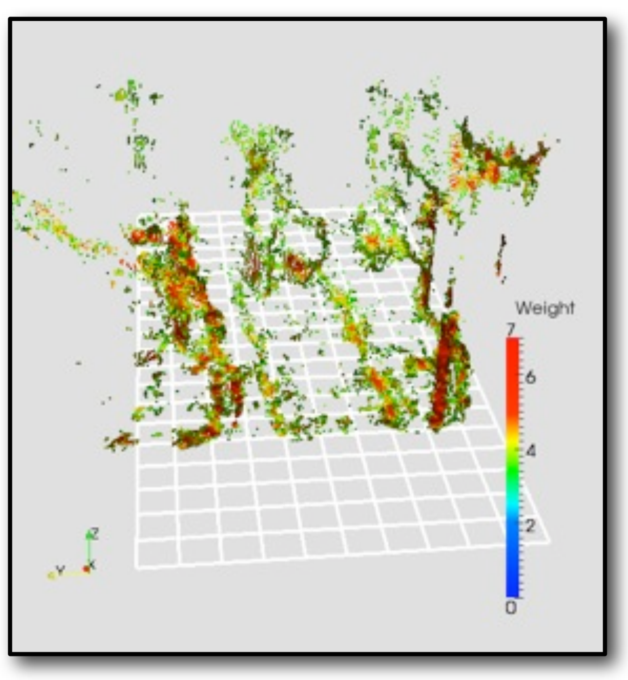


Fig.: 3D reconstruction AFTER filtering

Reducing the data size (n): Random selection

Different starting position (x = [-0.4, 0.6] m, y = [-0.6, 0.6] m) and orientation (θ = [-0.25, 0.25] rad) were forced to observe ICP convergence positions and angles.

Fig.: End positions

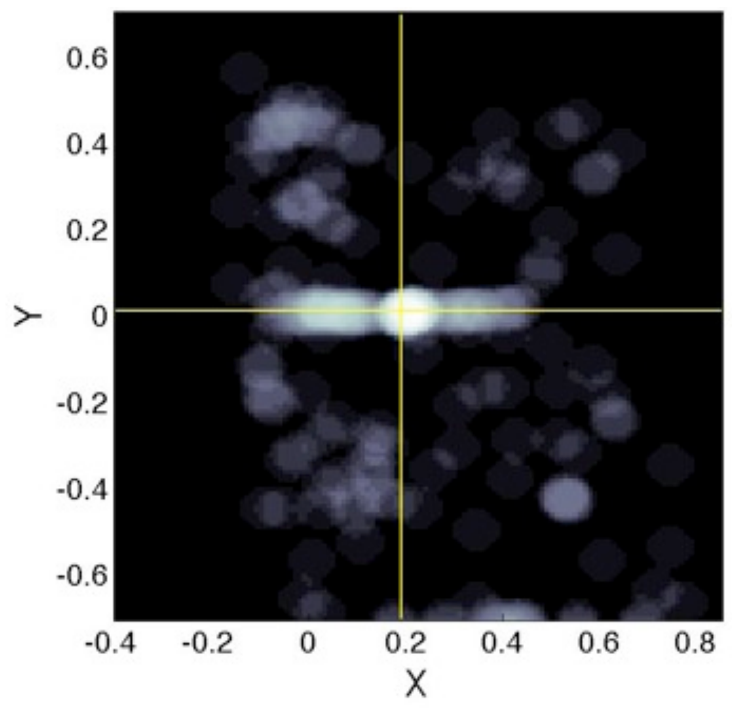
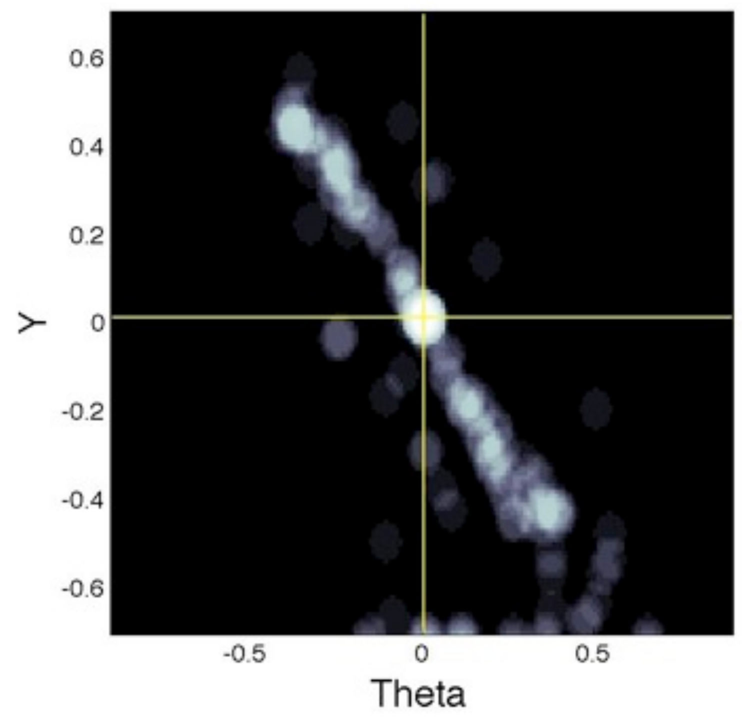
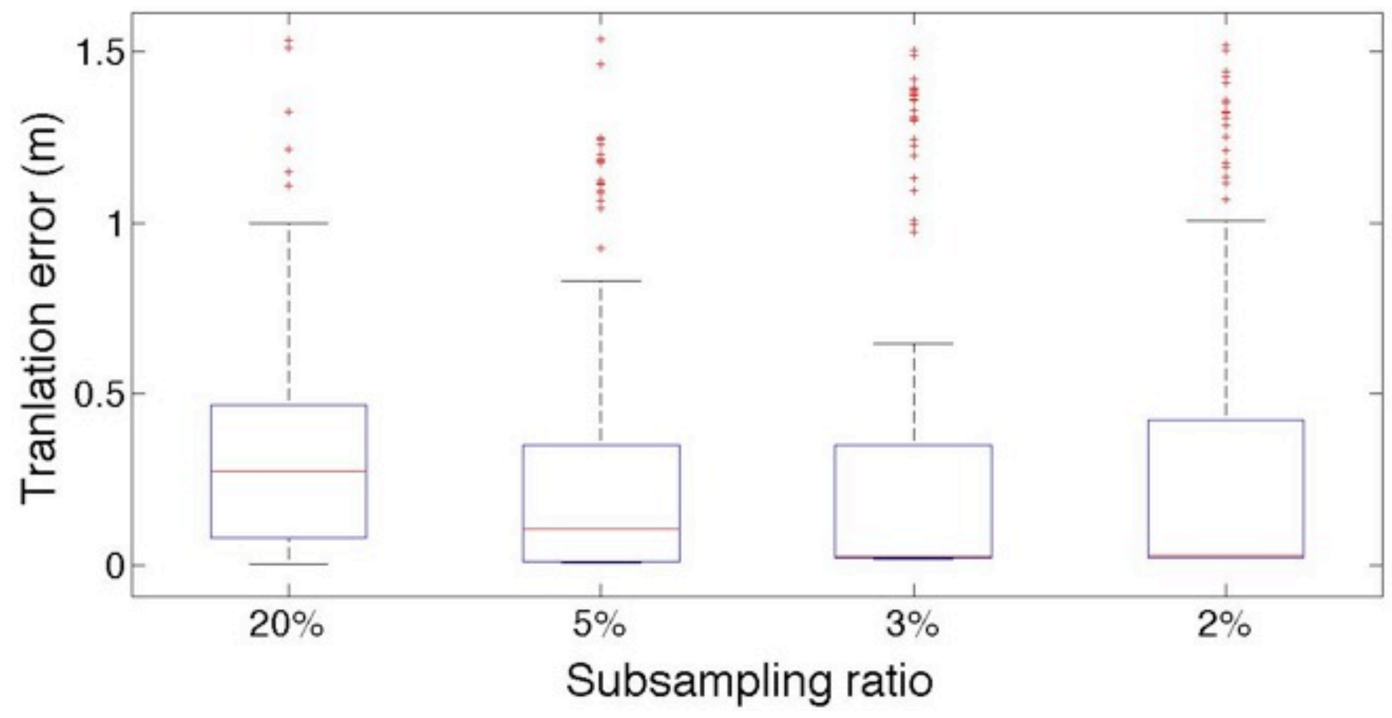


Fig.: End positions/angles



Figures above were obtained with a subsample ration of 20%. The yellow cross marks the *ground truth* and the white level represents the point density. On the xy-plane, final correlation follows the environment configuration. On the θy-plane, final correlation highlights a limitation to resolve alignment due to sensor eccentric position in respect to readings.

Fig.: Reduction evaluation in function of translation error



The figure above proposes that ICP converges better with a number of points as low as 3%. Further studies will be conducted to understand this observation.

Results

Environment reconstruction

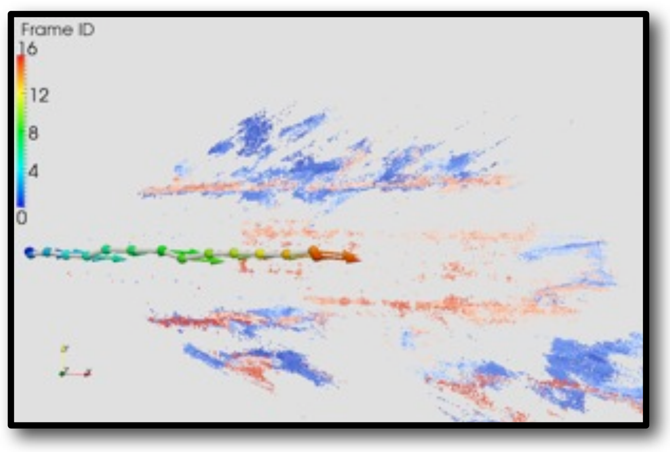


Fig.: Top view with colored spheres representing sensor positions

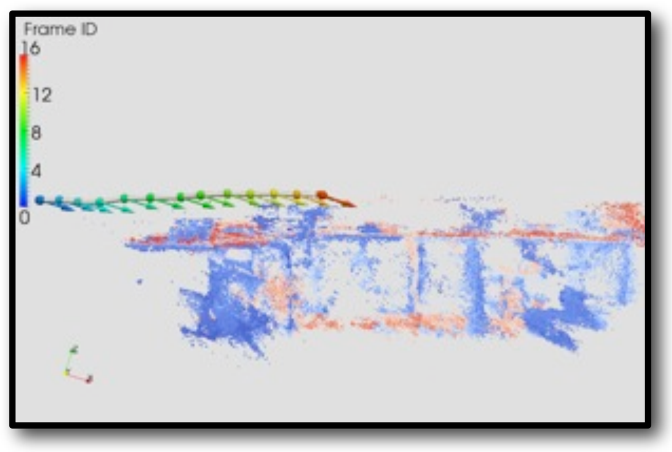


Fig.: Side view with colored spheres representing sensor positions

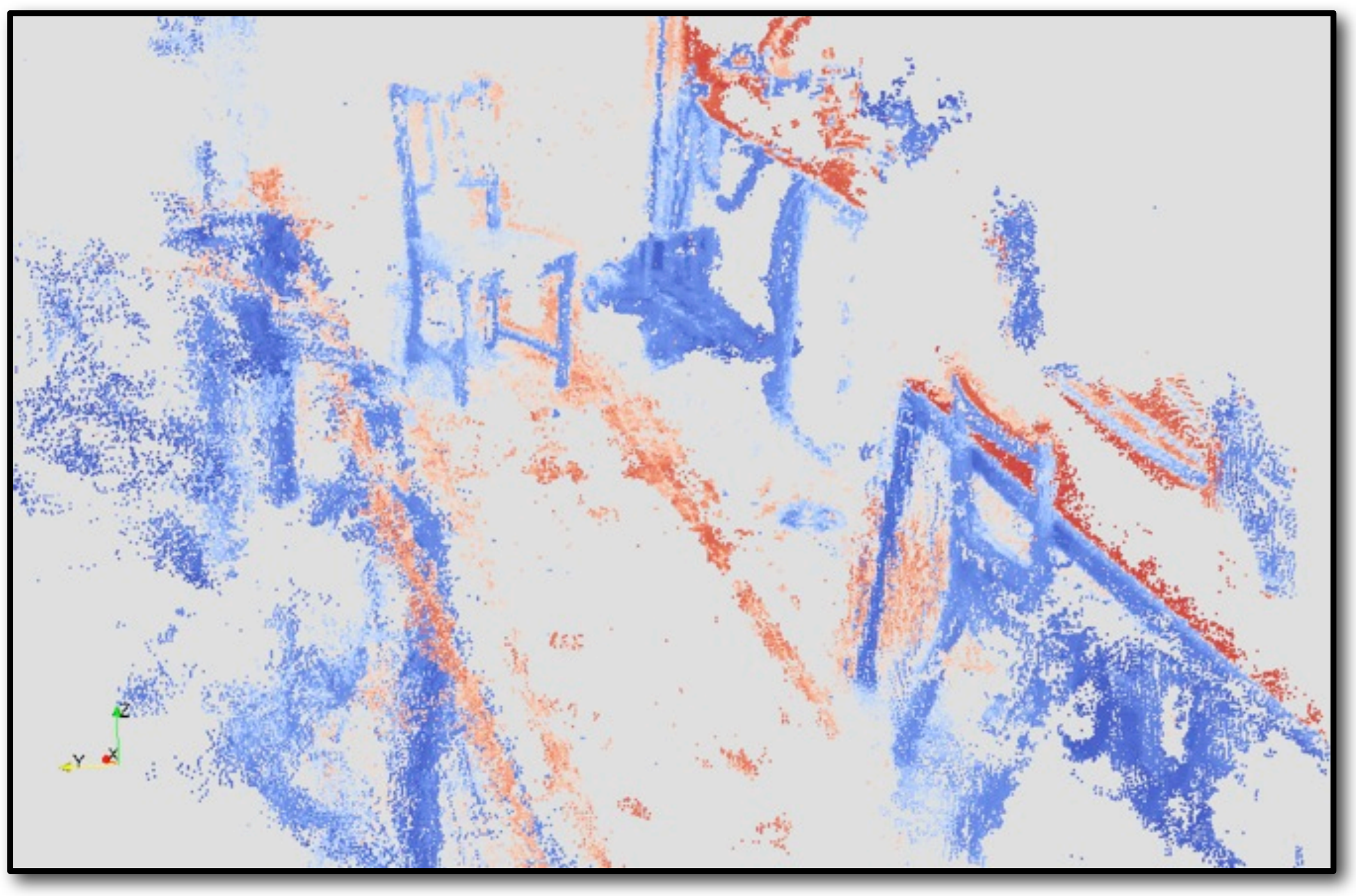


Fig.: Perspective view of the office reconstruction based on 16 frames without odometry information

References

[1] F. Pomerleau, F. Colas, F. Ferland, F. Michaud, *Relative Motion Threshold for Rejection in ICP Registration*, Proc. of The 7th International Conference on Field and Service Robotics (FSR), July 2009.
[2] Chen and Medioni. *Object modeling by registration of multiple range images*. Proc. of the IEEE International Conference on Robotics and Automation, pp. 2724 - 2729 vol.3, 1991.
[3] Rusinkiewicz and Levoy. Efficient variants of the ICP algorithm. 3-D Digital Imaging and Modeling, 2001. Proceedings. Third International Conference on (2001) pp. 145 - 152
[4] M. Humenberger, C. Zinner, W. Kubinger, Performance Evaluation of a Census-Based Stereo Matching Algorithm on Embedded and Multi-Core Hardware, 6th International Symposium on Image and Signal Processing and Analysis ISPA, Salzburg, Austria, 2009

François Pomerleau, Francis Colas {francois.pomerleau, francis.colas}@mavt.ethz.ch   http://www.asl.ethz.ch/people/pomerlef