Fachhochschule Nordwestschweiz
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MASTER OF SCIENCE IN ENGINEERING

A novel map matching approach for low-cost mobile mapping systems using 3D cameras and 3D street-level imagery.

The precise location information of road signs can be used to improve the positioning accuracy of a Mobile Mapping System (MMS). Combining pixel and depth information captured by a lowcost RGB-D camera, a 3D coordinate can be determined. The difference vector between a measured point and the position of a sign is used to generate an update coordinate. Using Neural Nets to fully automate the detection of signs and measurement thereof will be able to fully automate the workflow. The approach yields a consistent improvement of reducing the path deviation from several meters to <1m.

From Pixel to 3D Coordinate

Image capturing is done with the Intel RealSense D455 low-cost RGB-D camera, that captures color (RGB) and depth (D) data. The depth information can be used to calculate 3D points in the image relative to the sensor. Coupling the relative positional information from the image with the direct sensor orientation of the system, a 3D coordinate in a global reference frame can be calculated. This measurement and conversion process can be fully automated using the programming language Python. As seen in Figure 1, only two steps (highlighted green) require manual input.

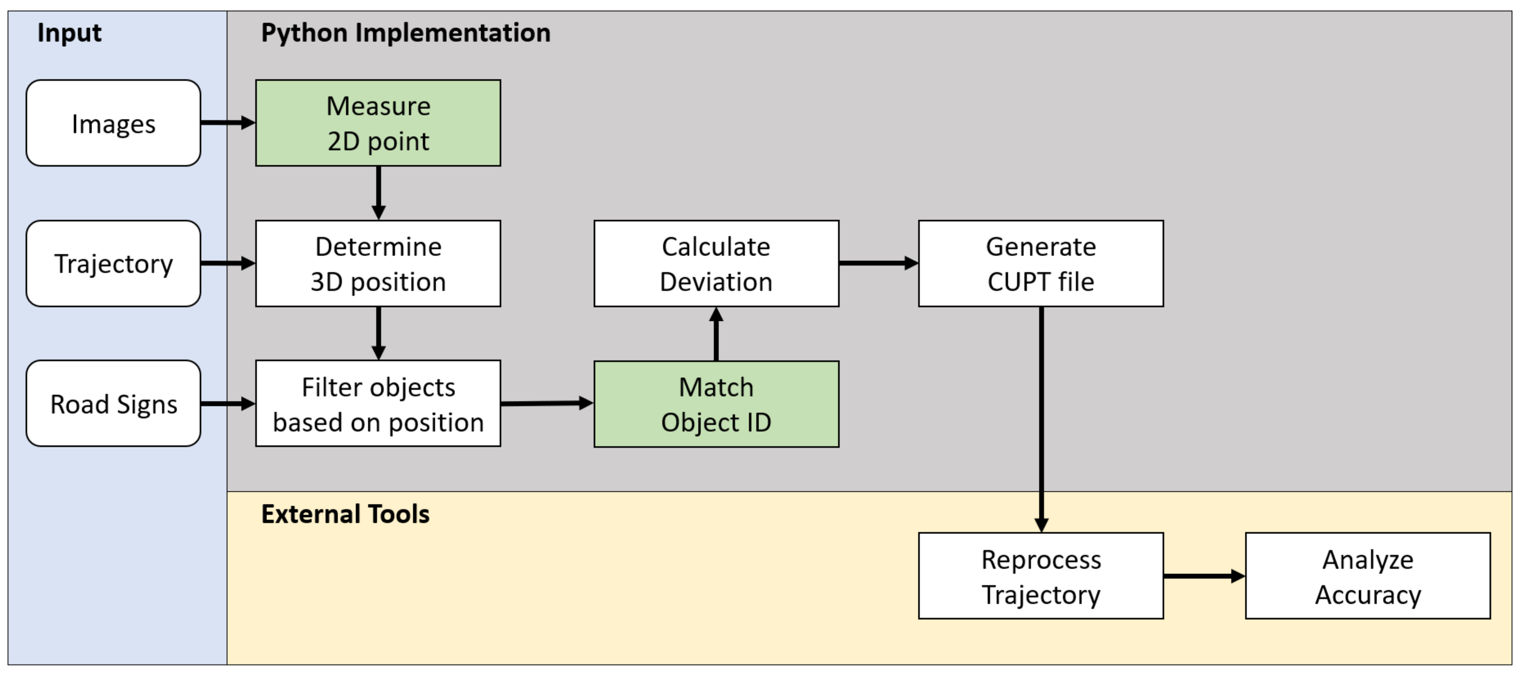

Fig. 1: Image Measurement Tool workflow

Image Quality and Depth Map Disparity

The RealSense D455 has trouble taking color accurate images in outdoor environments (Intel Realsense, 2021), leading to magenta color casts in the image (see Fig. 3). Additionally, due to movement while image capturing, motion blur occurs in areas perpendicular to the direction of movement. These effects impair the ability of artificial intelligence to detect signs when only using RGB data. Due to hardware limitations, the capturing software is unable to capture the RGB and D data synchronously, leading to a disparity, primarily influenced by the position of the object in the Field of View (FoV). Objects in line with the direction of travel have little deviation, while objects perpendicular to the system heading strongly deviate in terms of pixel position between RGB and D (see Fig. 2).

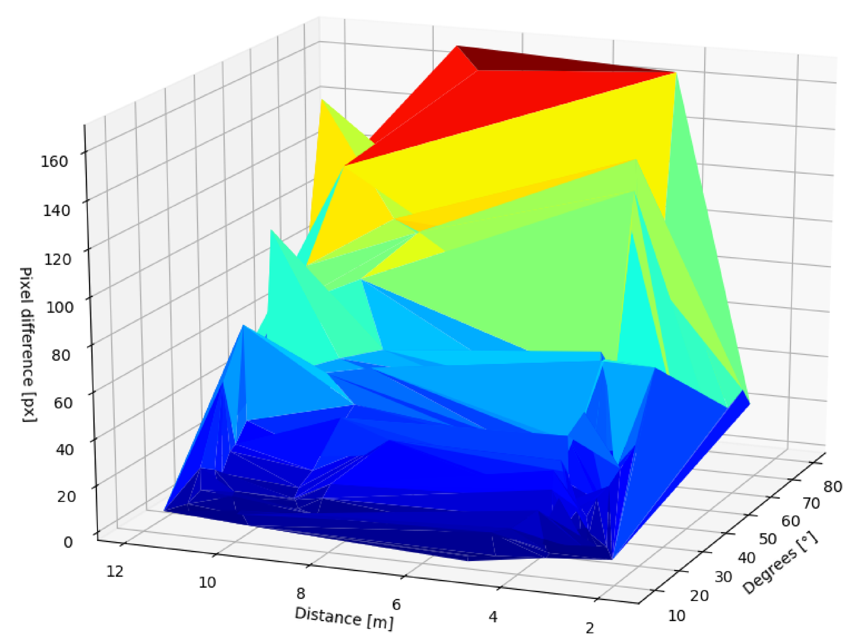

Fig. 2: Pixel deviation between RGB-D images, influenced by distance of object to sensor and position in FoV (0°: heading)

Fig. 3: AI road sign detection
Left: «signfeld», *Right*: «Traffic Sign Detection»

Automatic road sign detection

Road sign detection in images can be automated by applying Neural Nets (NN) designed for object detection on images. Training a NN from scratch was beyond the scope of this thesis, therefore 2 publicly available pre-trained models were used. «Signfeld» was trained purely using synthetic data (Hofmann et al., 2020) whereas «Traffic Sign Detection» was trained on real world data (Arcos-García et al., 2018). Both models are based on the German Traffic Sign Detection Benchmark (GTSDB). The performance of both models on the data used is not reliable enough for full automation. This is in part due to Swiss road signs not being part of the GTSDB, but also due to the quality of the captured images.

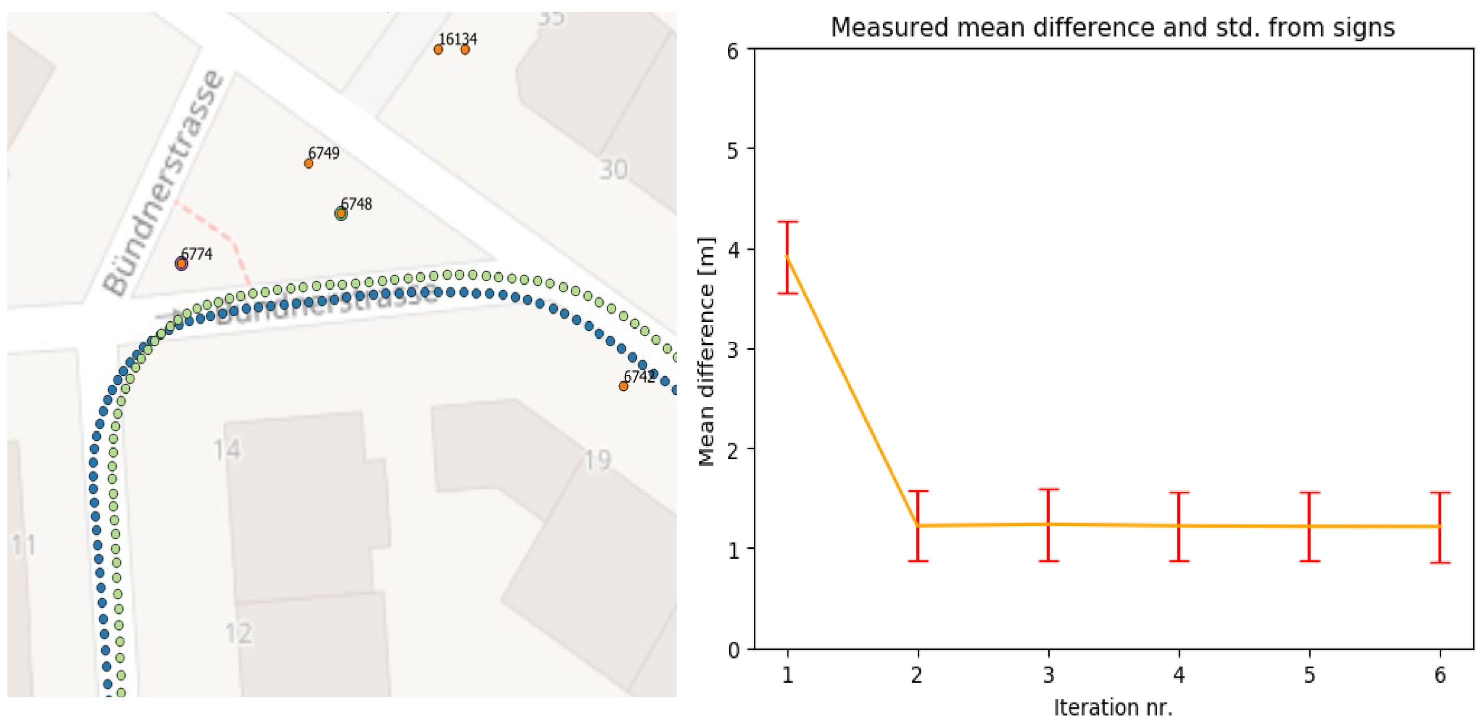

Fig. 4: Iterative trajectory refinement. *Left*: blue original path, green 3. iteration. *Right*: Iterative mean deviation to control points

Iterative Trajectory Refinement

With a clear GNSS signal, the MMS achieves a mean accuracy of <0.9m (Nebiker et al., 2021). However when obstructed, the deviation can be up to several meters. Multiple iterations of path refinement converge. The approach developed in this thesis can be used to achieve a consistent mean accuracy of <1m, including in areas with poor GNSS reception. There is potential for further improvement with more accurate reference data and better RGB-D synchronization.

References: Arcos-García, Á., Álvarez-García, J. A., & Soria-Morillo, L. M. (2018). Evaluation of deep neural networks for traffic sign detection systems. Neurocomputing, 316, 332–344. https://doi.org/10.1016/J.NEUCOM.2018.08.009
Hofmann, D., Wojke, N., & Sandhawalia, H. (2020). GitHub - moabitcoin/signfeld: Synthetic traffic sign detectron. https://github.com/moabitcoin/signfeld
Intel Realsense. (2021). Intel RealSense D400 Series Spec Clarification May 2021.
Nebiker, S., Meyer, J., Blaser, S., Ammann, M., & Rhyner, S. (2021). Outdoor mobile mapping and ai-based 3d object detection with low-cost rgb-d cameras: The use case of on-street parking statistics. Remote Sensing, 13(16). https://doi.org/10.3390/rs13163099

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