Design and Development of Vision Based Localization Algorithms for Automatic Parking

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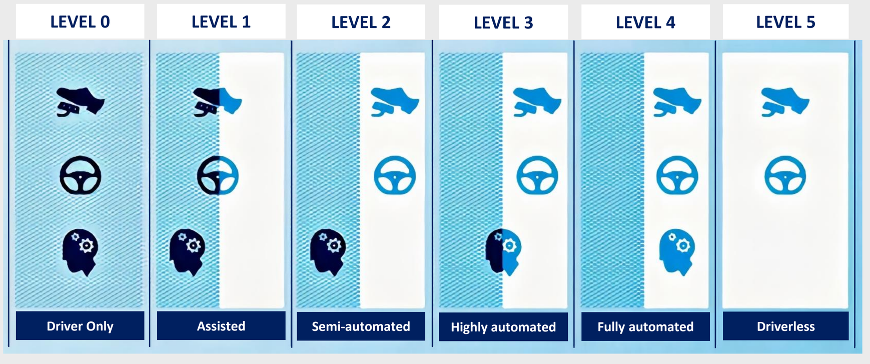
ABSTRACT

The project aims to provide an exciting potential to reduce the workload on the driver and automate the task of parking of long-vehicles. In the scope of this project, we designed and developed an offline mapping pipeline supported by INS/GNSS sensor [5] to create a highly accurate feature-based map. On top of that, we designed and developed a localization pipeline to localize our vehicle precisely in real time in a given map. We implemented our pipelines in Python utilizing OpenCV library where needed. We used KITTI odometry benchmarks [6] to test our system. Our test results show that the system can work up to 3.5 fps and localize the vehicle with an approximately 0.4 m RMSE measured in different environments.

INTRODUCTION

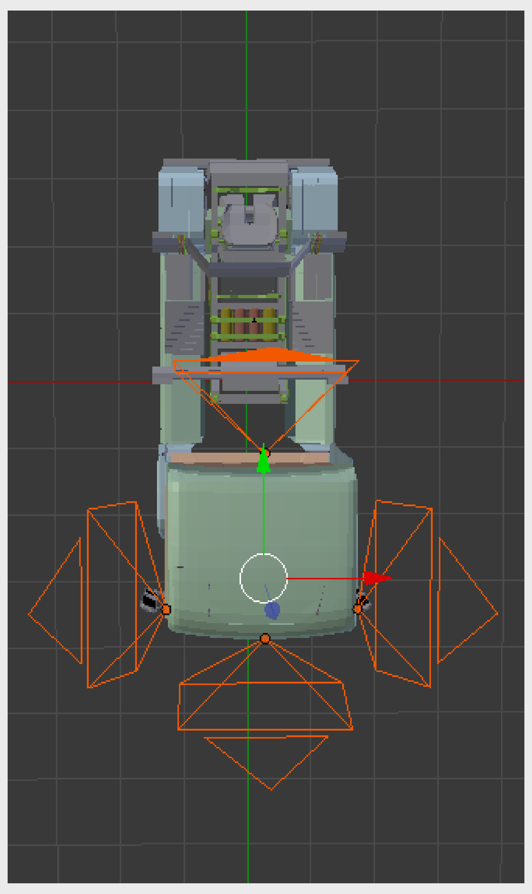
- U.S. Department of Transportation reveals that 94% of the road accidents are caused by the drivers [1].
- Because human drivers experience fatigue, there are strict laws enforcing truck drivers to drive for a limited amount of time in a day which makes the transportation operations inefficient and costly [2].
- Autonomous vehicles are considered as the solution, benefiting from increased safety, increased traffic flow, and reduced mobility and infrastructure cost.
- Autonomous driving is a highly attractive subject for industry and academia as well. Google, GM, Tesla, Ford, BMW and Nissan are some of the leading companies in this multi-billion dollar industry.



- There are 6 levels of autonomy established by SAE [3] ranging from fully manual to fully autonomous systems.
- Currently, autonomous vehicle industry can provide partial autonomy (Level 2 & 3) and is aiming for full autonomy (Level 4 & 5) in the foreseeable future [4].
- In our project, inline with this vision, we are aiming to design and develop vision based localization algorithms for automatic parking to be implemented on semi-trailer trucks.
- The backbone of a such autonomous system is being able to localize the vehicle accurately at all times during the process. Therefore we designed our system from scratch with the objectives:
  - Design specific camera setup for the automatic parking of semi-trailer trucks
  - Leverage the open-sky operation and the existence of an accurate INS/GNSS module
  - Design and implement stereo vision based offline mapping and online localization algorithms

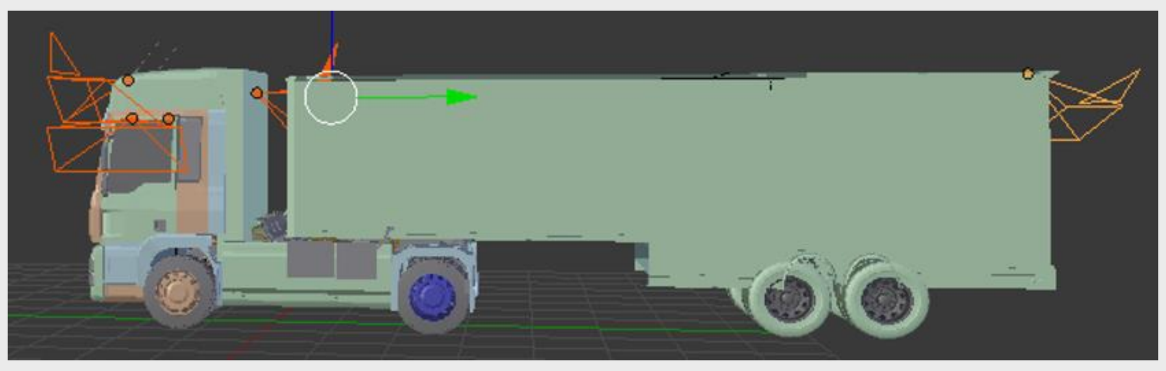
PROJECT DETAILS

Modelling of the Semi-Trailer Truck and Camera Setup

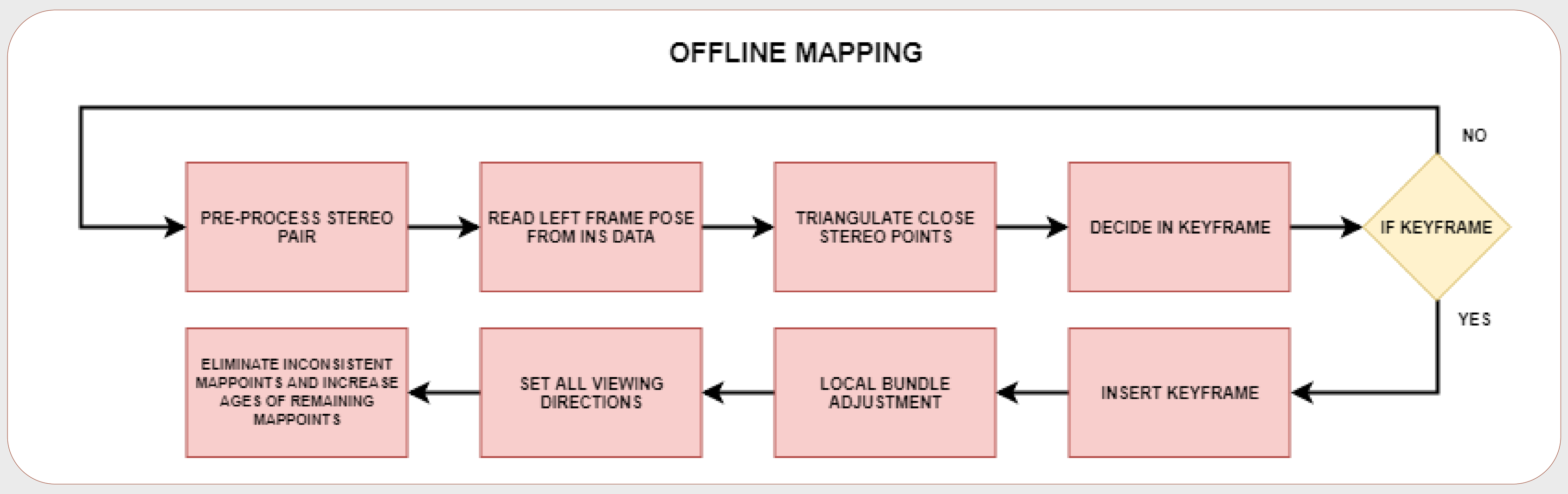


We designed a cost-efficient solution which satisfies the needs of vision-based automatic parking, after modelling and analyzing several different camera setups.

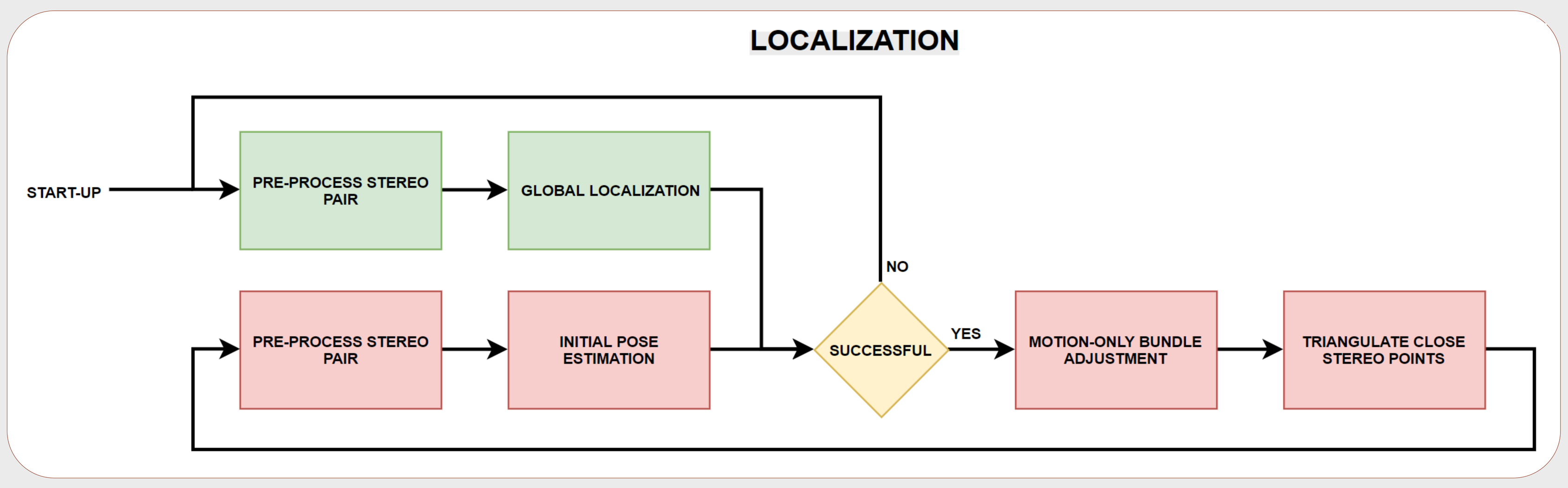
- Stereo camera is used in front of the truck for localization and mapping purposes.
- Two monocular wide-angle cameras are located on the sides of the truck for parking spot detection.
- Two monocular wide-angle cameras at the back of the truck and the trailer are located to observe the back. In the situation where truck is connected to a trailer, the camera at the back of the truck is used to calculate the relative pose of the trailer to the pose of the truck.



Algorithms



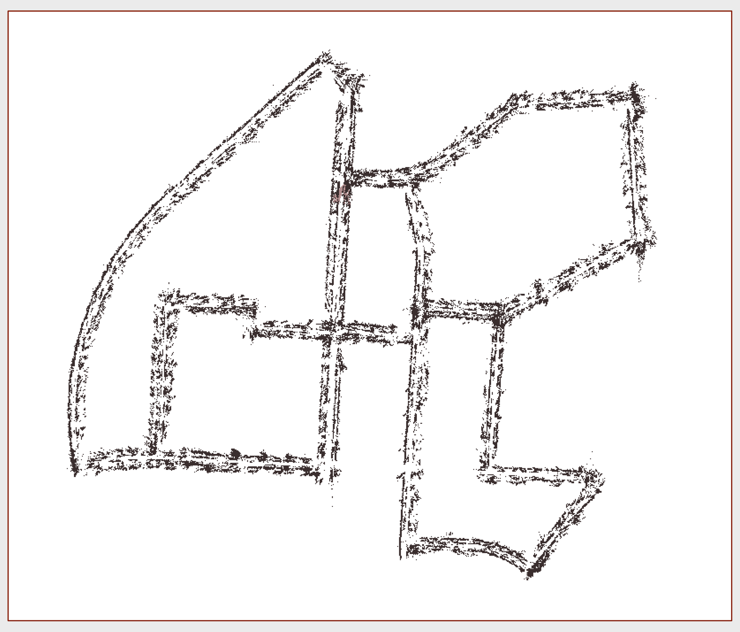
- During offline mapping, the system acquires the pose of the vehicle precisely from INS/GNSS sensors [5] and decides whether the current frame should be added to the map as a keyframe.
- The system performs bundle adjustment optimizations regularly to place mappoints optimally and to find outlier observations.
- The system eliminates inconsistent mappoints and keeps only strong, easily trackable ones in the map.



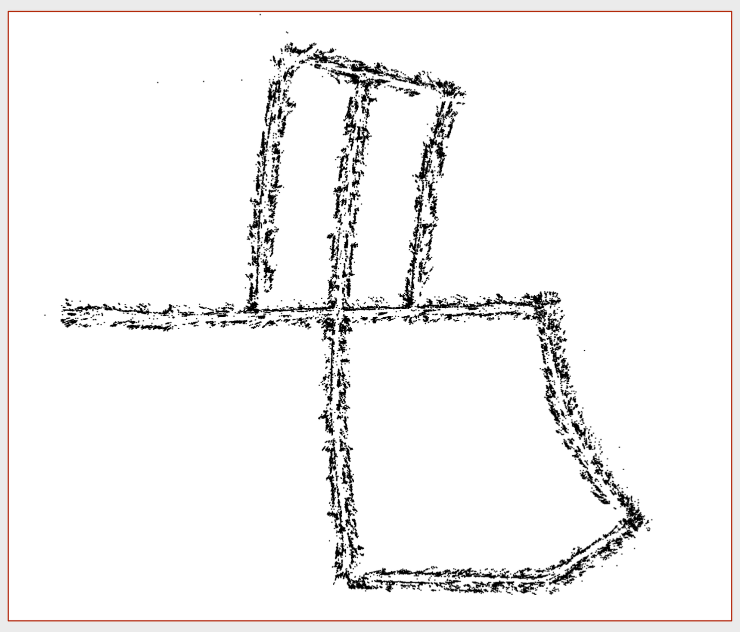
- At the start-up, the algorithm performs a global localization to find the best possible location of the vehicle in the entire map (green loop).
- The algorithm continuously estimates the new location of the vehicle by predicting vehicle's motion and by tracking previous frame.
- Estimations are improved by tracking the offline map during motion-only bundle adjustment.
- In the situations where the vehicle moves with an unpredictable behavior and tracking is lost, the system tries to localize itself globally like at the start-up.
- To increase the fps rate, modules of localization pipeline are reordered and divided into two pieces and we process these pieces in parallel in two processor.

RESULTS & DISCUSSION

Offline Mapping



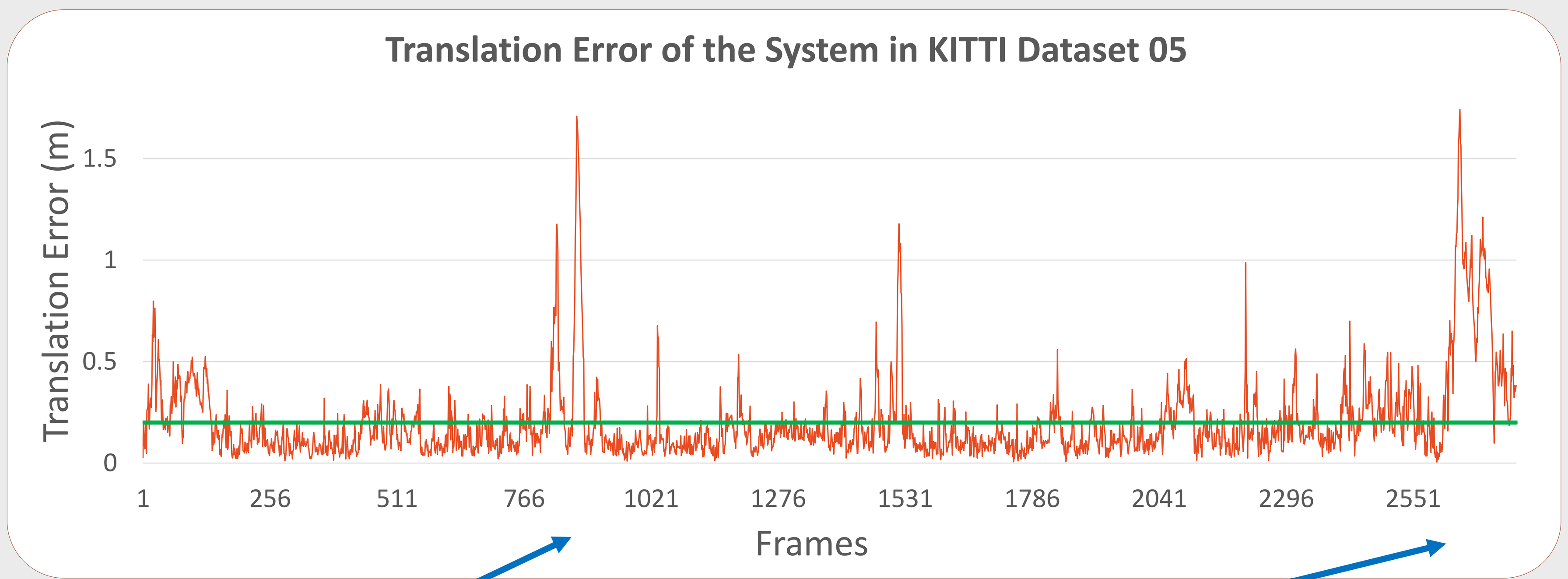
KITTI Odometry Dataset 00
2889 keyframes – 433,435 mappoints

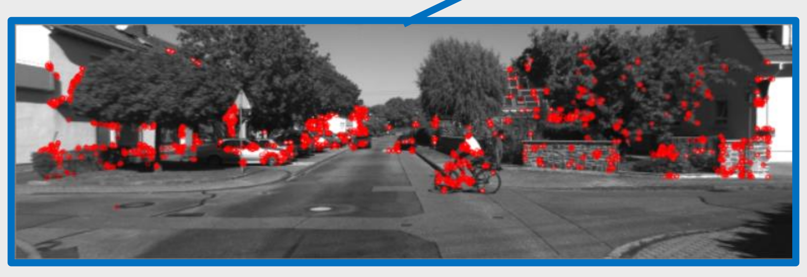


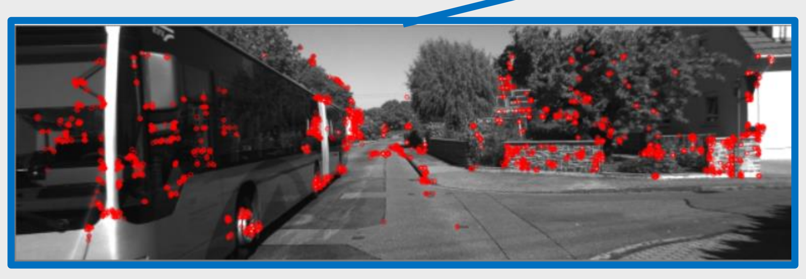
KITTI Odometry Dataset 05
1672 keyframes – 235,013 mappoints

- Two examples of maps from the KITTI Datasets are provided above.
- All the datasets that we mapped are recorded in urban areas of Karlsruhe, Germany. Datasets include crooked roads, loops, pedestrians, and moving bikers and vehicles.
- Offline maps are successfully created with strong and plentiful mappoints and keyframes and hardly trackable, weak mappoints are successfully ruled out from the map during the process.

Localization







- In the KITTI Dataset 05, we localize our vehicle with an 0.20-meter mean error and 0.04 variance.
- We failed to keep error under 1 meter in certain situations:
  - There are other vehicles that are moving and occupying substantial portion of the images. This scenario results as an illusion of displacement even though our vehicle is not moving.
  - Certain frames does not have close objects to the camera.
- Although the system obtains inaccurate results in these situations, it successfully manages to recover its position as the localization goes on.

KITTI Dataset [6]	Our Results (m)	ORB-SLAM2 (m) [7]
00	0.4	1.3
05	0.3	0.8
07	0.5	0.5

- There is a lack of past literature work on a complete system similar to ours which we can compare with.
- We achieved less translation RMSE compared to state-of-the-art ORB-SLAM2, although comparison is not fair since SLAM is a harder problem to solve.
- We managed to perform localization up to 3.5 fps.

CONCLUSION & FUTURE WORK

- We designed a cost-efficient camera setup for the purpose of automatic parking of semi-trailer trucks.
- We successfully mapped large datasets from urban areas.
- We obtained 0.4 m RMS translation errors during of localization of in created maps.
- Our system works in real-time with 3.5 fps where the car can travel with a speed up to 15 km/h.
- Future works of this project can be stated as:
  - Park spot detection using two monocular wide-angle cameras are located on the sides of the truck
  - Obstacle detection using all cameras to make the truck aware of its environment at all times
  - Motion planning to decide necessary maneuvers to park the semi-trailer truck
  - Performance improvements to increase localization accuracy and frame rate

REFERENCES

[1] U.S. Department of Transportation, “Critical Reasons for Crashes Investigated in the National Motor Vehicle Crash Causation Survey”, 2015. Available: https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812115. [Accessed 2018]

[2] Traffic Safety Store, “Why Is The Trucking Industry Excited About Autonomous Technology?”, 2017. Available: https://www.trafficsafetystore.com/blog/autonomous-trucks-future-shipping-technology. [Accessed 2018]

[3] Society of Automotive Engineers (SAE), “Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles”, 2016. Available: www.sae.org/standards/content/j3016_201609. [Accessed 2018]

[4] Car And Driver, “Path to Autonomy: Self-Driving Car Levels 0 to 5 Explained”, 2017. Available: https://www.caranddriver.com/features/path-to-autonomy-self-driving-car-levels-0-to-5-explained-feature. [Accessed 2018]

[5] OXTS RT3003, "www.oxts.com," [Online]. Available: https://www.oxts.com/app/uploads/2017/07/RT3000-brochure-170606.pdf. [Accessed 2018]

[6] Geiger, P. Lenz and R. Urtasun, "Are we ready for Autonomous Driving? The KITTI Vision Benchmark Suite," in Conference on Computer Vision and Pattern Recognition (CVPR), 2012.

[7] R. Mur-Artal and J. Tardos, "ORB-SLAM2: an Open-Source SLAM System for Monocular, Stereo and RGB-D Cameras.," IEEE Transactions on Robotics, vol. 33, pp. 1255-1261, 2017.