Master's Thesis Review

Pablo De Cristóforis

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Title: Keypoint localization and matching in difficult scenes for visual odometry
Student: Jan Vakula
Reviewer: Dr. Pablo De Cristóforis, Laboratory of Robotics and Embedded Systems, Faculty of Natural and Exact Science, University of Buenos Aires.

This review is based on a manuscript of 67 pages corresponding to the Master's thesis of Jan Vakula. The work of this thesis was performed in the Department of Cybernetics, Faculty of Electrical Engineering, Czech Technical University in Prague, under the supervision of Dr. Tomáš Svoboda. The goal of this thesis was to test and improve a visual odometry algorithm developed by Jiri Divis in his Master's thesis. The original and modified version of the odometry algorithm were exhaustive tested and compared in various types of environments and under different conditions.

The main improvement of the algorithm was achieved by the enhancement of the image keypoints management. In order to do that, several issues were faced. First, a Fourier analysis was proposed to detect blurry images and prevent the algorithm use them. Blurry images are problematic since only few keypoints can be extracted from them. Second, for better feature matching the original algorithm was updated so that the closest keypoint is calculated as Manhattan distance instead of Euclidean distance. Third, unlike the original algorithm, the images are not divided into the squares where the nearest point is found, the nearest point is searched in the whole image. Finally, the guide-matching algorithm was changed to establish the correspondences between keypoints from the actual image and keypoints from the previous image, since the translation robot's motion is as little as possible. Using these correspondences and the correspondences between keypoints from the key image and keypoints from the previous image, the correspondences between keypoints from the actual image and keypoints from the key image can be determined very precisely. This last improvement is perhaps the main contribution to the new enhanced version of the visual odometry algorithm proposed by Jiri Divis.

The presented visual odometry algorithm was compared with other types of odometry algorithms (visual compass and ICP) and with ground-truth (obtained from VICON and Leica). The results of the performed experiments show that the implementation of the new enhanced version of the algorithm outperforms the original one. This occurs in all test scenarios, but especially in outdoor

environments like forest area, where the original odometry algorithm totally fails. The new version of the algorithm was implemented as a node within the ROS (Robot Operating System), an omnidirectional camera and a USAR robot were used to do the experiment.

Although the presented work is completed, there are some issues that could be explored. On the one hand, since the focus of the thesis is the use of image keypoints for visual odometry, it would be interesting to test different combination of keypoint detectors and keypoint descriptors. In the presented implementation only one combination was tried: ORB (oriented FAST) keypoint detector and BRIEF keypoint descriptor. However, in last years a number of new keypoint detectors and keypoint descriptors were proposed in the literature. Some works present an evaluation of image keypoint in the context of visual navigation. In my humble opinion, the combination of STAR and BRIEF would be better than the combination of ORB and BRIEF.

On the other hand, a rigid model was used in the presented algorithm for estimating the rotation and translation between poses of the camera. However, this is not entirely correct since the captured images are not planar, they are projections of 3D real world. At least a discussion about this issue should be added in the manuscript.

Despite the aforementioned aspects, the reviewer finds the work performed under this thesis as relevant contribution to guide to future works on visual odometry using omnidirectional cameras. Morevover, the manuscript of the thesis is very well organized, written and can be easily understood. It would be a nice contribution if the ROS node implementation of the algorithm is published together with the manuscript of the thesis.

The presented thesis appears to fulfill the expected goal. Therefore this reviewer considers that it can be defended as-is, and proposes a A (excellent) grade.

Dr. Pablo De Cristóforis