Opposition Report: *Visual Odometry for Autonomous MAV with On-Board Processing* by Jacob Greenberg

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In his project, Jacob deals with the problem of using visual odometry to track the position of an MAV. The reason for using visual odometry is that there are some environments in which the standard method of GPS cannot be used, such as inside buildings. Specifically, he evaluates the efficacy of a particular algorithm, AICK, for this purpose. The aims of the project are well explained, both in the abstract and the introduction sections. The title is a good reflection of these aims, but perhaps including that the work is for GPS-denied environments would be good. Justification for the method of tackling the problem is also given in the introduction, and while it is not particularly detailed, given that the project aims to investigate the method, the explanation given is sufficient. Additional reasons for investigating AICK are given in the related work section.

The ideas behind the project are adequately explained, with the background section giving information about how MAVs work, and hints at why visual odometry may be needed, as well as some information about the RGB-D camera, registration and visual odometry. This covers all of the major parts of the project. The related work section explains in more detail the ideas behind visual odometry and specific approaches to the problem. Some approaches to RGB-D SLAM are also mentioned, which is relevant as position tracking forms a major part of SLAM algorithms.

Chapter 4 describes in detail the ORB and AICK methods, explaining how features are extracted from point cloud frames and then matched between frames. Each part is explained with all the important details, and one can understand the logic behind the method well from reading the chapter. It also discusses some different approaches for the registration in terms of which frames are used, which forms an important component of the experimental results.

The implementation chapter seems a little out of place in its current position in the report. While hardware details and things relating to the implementation should be mentioned in the report, the flow is broken slightly by this chapter, and I feel it would be better as an appendix.

The experimental evaluation is well done. Several trials are performed with characteristics for the motion of the MAV to investigate registration quality. These include two trials where the performance of the system is not satisfactory. The inclusion of these trials is good, as it acknowledges the existence of environments in which the system does not perform well, and examines the problems in more depth. Each trial has a detailed written evaluation along with figures showing registration results and information about the keypoints extracted. Although the purpose of these trials was to test the registration, it would have been good to see the tracking error for the trajectories, but this is not something that is easy to gather, so its omission is not a serious problem given the scope of the project.

Trials are also performed to compare the tracking error on the ORB-SLAM and AICK methods. It is acknowledged that the experimental setup for these trials was not ideal and might affect the results to some degree. However, the trials are still useful to see the performance of the system, and are the only realistic way to evaluate the tracking error. The plots shown give a good idea of how the tracking drifts for the two methods.

One potential issue with the layout of the experimental evaluation is that some techniques for solving problems with the system are proposed there, rather than in the method section. While they are quite small, since they are part of how the final system works perhaps it would be better to move the explanation of those modifications. At the same time, the flow of the experiments section might be broken by the removal of the explanations.

The final section of the chapter mentions autonomous station-keeping experiments, but data from these experiments is not shown — it would be nice to see this as well.

Since there was only one type of keypoint selection method and descriptor used, it might have been instructive to see how different selection methods or descriptors would affect the system.

To summarise, the experimental evaluation acknowledges the limitations of the system, and proposes solutions to certain problems encountered during testing, some of which are implemented. This is good as it indicates that solutions to these problems were considered.

The conclusion briefly explains what was achieved in the project, and mentions some of the issues that were encountered. The future work section mentions some specific improvements that could be made to improve the system, and also suggests some other sensor setups that could be used to navigate GPS-denied environments.

The bibliography contains papers which are very relevant to the work. Some landmark papers on the SIFT and SURF features are included, as well as some papers describing corner detection methods. Papers for the ORB and AICK methods are also present. ICP and visual odometry literature are also included. Some papers on benchmarking and evaluating SLAM are mentioned, as well as some work specifically on MAVs with constrained computational power. All of these inclusions mean that there are no glaring omissions in the bibiliography.

There was one section of the report which was difficult to understand. On page 45 there is a discussion of how monocular SLAM is unable to compute the scales, which I could not grasp very well. Other than that, beyond minor spelling and grammatical mistakes there are no issues, particularly in the sections which are important for understanding. Page 42, with the explanation of parts of the scene with large numbers of keypoints exiting the image is also not very easy to follow.

Overall, I think the project is good, and has achieved quite good results. A number of different scenarios were examined, showing the strengths and weaknesses of the approach. Some solutions to problems encountered were proposed, and some of them made a big difference to the end result. All but a few small parts of the report were easy to understand.

Questions

- Advantages/disadvantages of visual odometry over e.g. laser sensors
- Different keypoint algorithm could help with the problem of low keypoint numbers?
- Why is rotation more difficult to handle (6.2.2)
- How could you test the station keeping of (6.4)
- Could visual odometry also be useful outside of GPS-denied environments?