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Optical Flow Experiments for Small-Body Navigation

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Abstract

Optical Flow algorithms [1, 2] have been successfully used and been robustly implemented in many application domains from motion estimation to video compression. We argue that they also show potential for autonomous spacecraft payload operation around small solar system bodies, such as comets or asteroids.

Operating spacecraft around small bodies in close distance provides numerous challenges, many of which are related to uncertainties in spacecraft position and velocity relative to a body. To make best use of usually scarce resource, it would be good to grant a certain amount of autonomy to a spacecraft, for example, to make time-critical decisions when to operate the payload. The Optical Flow describes is the apparent velocities of common, usually brightness-related features in at least two images. From it, one can make estimates about the spacecraft velocity and direction relative to the last manoeuvre or known state.

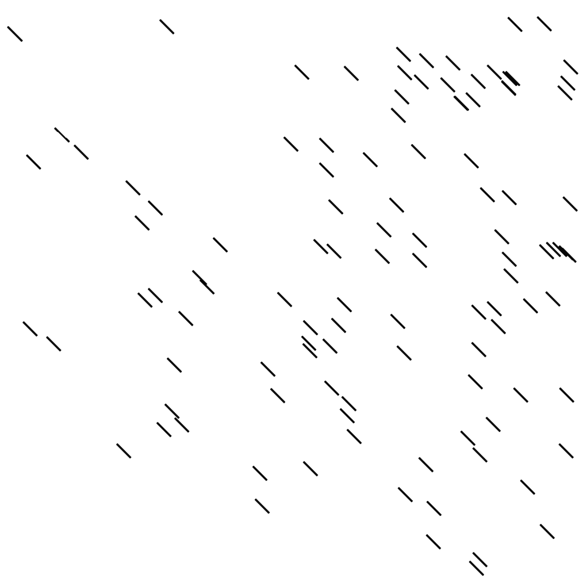

Figure 1: An example of an Optical Flow derived from two subsequent images.

The authors have conducted experiments with readily-available optical imagery using the relatively robust and well-known Lucas-Kanade method [3]; it was found to be applicable in a large number of cases. Since one of the assumptions is that the brightness of corresponding points in subsequent images does not change greatly, it is important that imagery is acquired at sensible intervals, during which illumination conditions can be assumed constant and the spacecraft does not move too far so that there is significant overlap. Full-frame Optical Flow can be computationally more expensive than image compression and usually focuses on movements of regions with significant brightness-gradients. However, given that missions which explore small bodies move at low relative velocities, computation time is not expected to be a limiting resource.

Since there are now several missions which either have flown to small bodies or are planned to visit small bodies and stay there for some time, it shows potential to explore how instrument operations can benefit from the additional knowledge that is gained from analysing readily available data on-board. The algorithms for Optical Flow show the maturity that is necessary to be considered in safety-critical systems; their use can be complemented with shape models, pattern matching, housekeeping data and navigation techniques to obtain even more accurate information.

References

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[3] Lucas, B. and Kanade, T.: An Iterative Image Registration Technique with an Application to Stereo Vision, Proceedings of Imaging Understanding Workshop, pp. 121–130, 1981