Detection of fast incoming objects with a moving camera

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We tackle the problem of detecting fast incoming objects from a moving camera (e.g. on a flying robot) before an impact. We detect these objects using the optical flow computed from an uncalibrated camera without extracting any feature points [1].

We calculate (and compensate) the motion induced by the camera and the time-to-contact (TTC) [3] to infer the position and the closeness of the incoming objects, respectively. We divide the optical flow into a grid of $g \times g$ pixel cells and we detect motion that is dissimilar from the one induced by the moving camera. For each cell j we compute

$$\hat{\alpha}_j = \left(1 + e^{-(m_j - M)}\right)^{-1}, \tag{1}$$

where m_j is the compensated motion within the cell and M is the 98% percentile of the overall compensated motion in the frame. We use this motion to adaptively learn the background motion model while reducing background motion noise. Unlike [2], our strategy to adaptively learn the background motion adapts to different camera velocities and scene depths.

We merge the optical flow information and use a Bayesian collision avoidance method to locate object-free regions (whose centre is represented as *safe point*) on the image plane. The flying robot can then use this safe point to infer where to go and avoid the object. The likelihood function used by the Bayesian collision avoidance uses measurements from the compensated motion to fit a Gaussian with an active variance that is inversely proportional to the object closeness, which is measured based on the TTC.

Experiments show that our method to detect incoming objects with a moving camera outperforms baselines and alternative state-of-the-art methods. Moreover, our approach to learn the background motion reduces false positive detections.

Our method can be synergistically used with other features and combined with other collision detection methods.

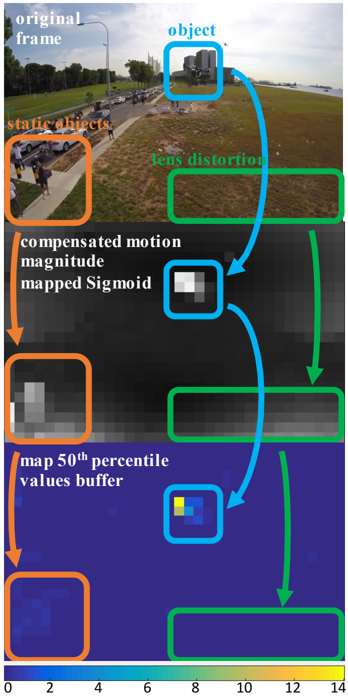

Figure 1: Example of spurious motion removal. (a) Original frame. (b) Magnitude of the compensated motion after mapping via a sigmoid function. (c) Difference from the learnt background indicating the presence of an incoming object.

[1] G. Alenya, A. Negre, and J.L. Crowley. Time to contact for obstacle avoidance. In *European Conference on Mobile Robots*, pages 19–24, Mlini, Croatia, Sep. 2009.

[2] O. Barnich and M. Van Droogenbroeck. ViBE: a universal background subtraction algorithm for video sequences. *Trans. on Image Processing*, 20 (6):1709–1724, Jun. 2011.

[3] Y. Watanabe, F. Sakaue, and J. Sato. Time-to-contact from image intensity. In *Proc. of Computer Vision and Pattern Recognition*, pages 4176–4183, Boston, MA, USA, Jun. 2015.