Poster Abstract: A Hybrid Control Approach to the Next-Best-View Problem using Stereo Vision*

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ABSTRACT

The increasing capabilities of mobile robots illuminate the need for robotic systems that are able to operate outside the controlled infrastructure of lab environments. Lab environments, equipped with e.g., Vicon systems, provide robots with continuous and precise position and orientation information. This information is not available outside the lab, where the robots should be able to localize themselves using on-board sensors. In this paper we address the problem of optimizing target localization accuracy using mobile stereo vision.

To solve this problem, we consider a single robot equipped with a stereo camera overlooking a group of stationary targets. The advantage of stereo vision, compared to the use of monocular camera systems, is that it provides both depth and bearing measurements of a target from a single pair of simultaneous images (Fig. 1). Differentiation of these measurements provides an estimate for the uncertainty of the target's location. Assuming that noise is dominated by quantization of pixel coordinates and propagating this uncertainty to target coordinates, we obtain highly accurate estimates of the structure of the target location covariance matrix, which captures uncertainty. This is true for both the instantaneous uncertainty of one measurement and for fused uncertainty of the full sequence of measurements. Given such a sequence of measurements, we define the Next-Best-View (NBV) as the position and orientation of the stereo camera from where a new measurement of the targets minimizes their localization uncertainty.

Since controlling the NBV directly in the space of camera positions and orientations involves the solution of highly nonlinear differential equations, we propose a hybrid scheme that decomposes control into the camera-relative and global-world frames. First, we find the NBV in the camera-relative frame using gradient descent in the space of target locations. Then, we design motion potentials in the space of robot positions and orientations $\mathbb{R}^2 \times SO(2)$ that realize the NBV. From this new position, the camera makes a new measurement of the targets that minimizes the fused target uncertainty, and the process is repeated until convergence of the target accuracies. In the proposed hybrid system, consecutive solutions of the NBV problem in the camera-relative frame constitute the switching signal in motion control. As a measure of collective localization accuracy we use either the average uncertainty of the targets corresponding to the centroid of their estimated locations (centroid objective) or the uncertainty of the most poorly localized target (supremum objective). We demonstrate the performance of the integrated hybrid system in Fig. 2.

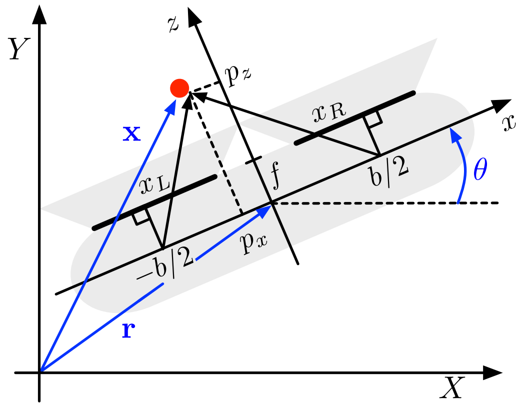

Figure 1: Triangulation of a single target in the relevant coordinate frames for a mobile stereo camera.

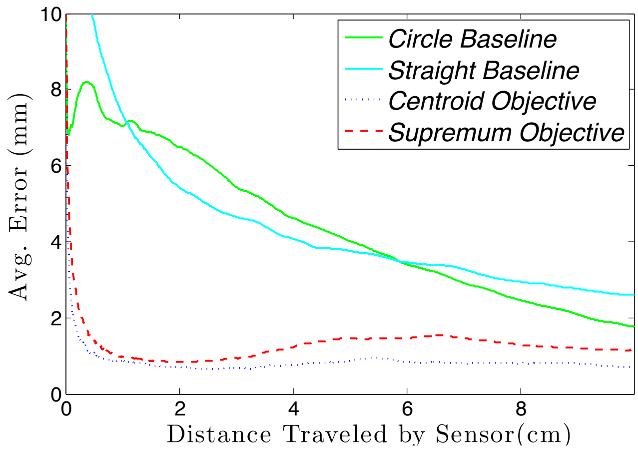

Figure 2: Comparing the localization error of our hybrid control objectives to two heuristic baselines that *circle* around or drive *straight* to the targets.

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