Re-Calibration of Camera Space Manipulation Techniques Accounting For Fisheye Lens Radial Distortion

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We explore the possibility to use Linear Camera Space manipulation (LCSM) algorithm [1] to map a large workspace using cameras equipped with fisheye lenses. We tested how the distortion of the image caused by the lens influences the precision of the LCSM algorithm when used to estimate the positions of visual cues in 3-D space. We used two Hero3 GoPro® (H3GP) cameras as a good compromise between acquisition rate and number of pixel in the image.. We used a previously published correction algorithm to eliminate the fisheye distortion [2] and compare it with standard calibration. The model estimate the radial distortion with a bi-quadratic equation which coefficients K_1 and K_2 To estimate such coefficients a non-linear calibration called Stereo Calibration Method was also used [2]. Stereo calibration uses a pair of images, also known as a stereo pair, to estimate the relative depth of points in the scene. These estimates are represented in a stereo disparity map, which is constructed by matching corresponding points within the stereo pair. These coordinates are used to calculate the distortion factors of each camera lens.

After the theoretical distortion factors values were obtained, a Monte-Carlo analysis was performed correcting each image using a range of coefficients around the theoretical values. Thus, a LCSM recalibration with the corrected images was performed. This comparison tests the robustness of the LCSM calibration algorithm and evaluate if dedicated signal pre-processing are necessary for the camera calibration.

LCSM calibration provide a set of view parameters for each camera that relate the position of a visual cue in the sensor's space with its position in the operational space. The Accuracy of the view parameters directly influences the positional error of the points in the operational space.. Such error can be analyzed via a "leave one out" method [3] and computed as the Euclidian norm between the known position and the estimated position.

Two CODA-motion scanner systems calculated the 3D positions of each calibration point. Two active markers were placed in the plane of the calibration pattern at a known distance. This allowed for the establishment of a framework for each calibration pattern for the two H3GPs consisting of a 13 by 26 checkerboard with 38.1x38.1mm squares. The cameras, calibration pattern, and CODA-Motion scanners' locations were not important when initially positioning the cameras, but had to be maintained in a fixed location for the rest of the experiment for consistency of the data image collection..

A Monte-Carlo analysis was performed creating a range of distortion coefficients (K_1, K_2) containing those suggested by the estimation. As first step, using the distortion model and the different proposed values for the (K_1,K_2) pairs, images were corrected. For each distortion pair the LCSM calibration algorithm was run for 3900 calibration points in a workspace of 0.5x3x1 m. The first linear calibration of the camera space manipulation had an average overall error of 6.87mm, while running the linear method after radial distortion correction provided an overall error average of 6.56mm.. A one-way ANOVA test with $\alpha = 0.95$ was performed between the error distribution of undistorted images and the lowest average calibration error achieved with K_1 = -0.468, K_2 = 0.842 for the left camera, and K_1 = -0.320, K_2 = 1.002 for the right camera.. Even though there was a statistically significant difference between the corrected and un-corrected error distributons($p<0.001$), the results show that the radial distortion does not seem to greatly degrade the accuracy of calibration when LCSM is used. This is particularly true, if the calibration space is conveniently located near to center of image. We found that a non-linear correction of the image does not affect much the calibration of H3GP. Some price advantages include the low camera costs of H3GP compared to specialized computer-vision cameras.

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