National Aeronautics and Space Administration

FY23 Innovative Spontaneous Concepts Research and Technology Development (ISC)

Unstructured camera recalibration with mrcal

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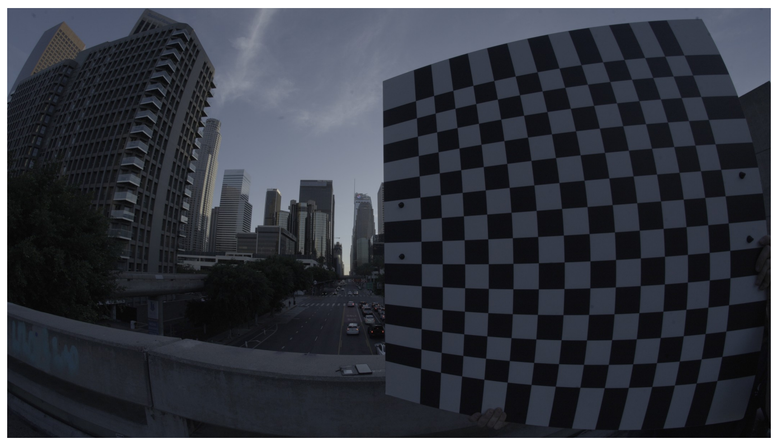
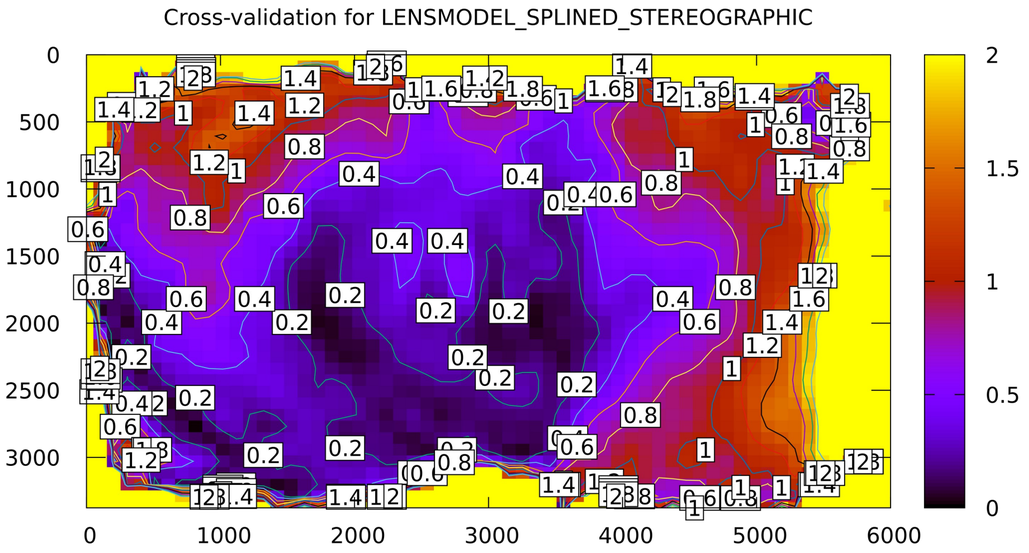
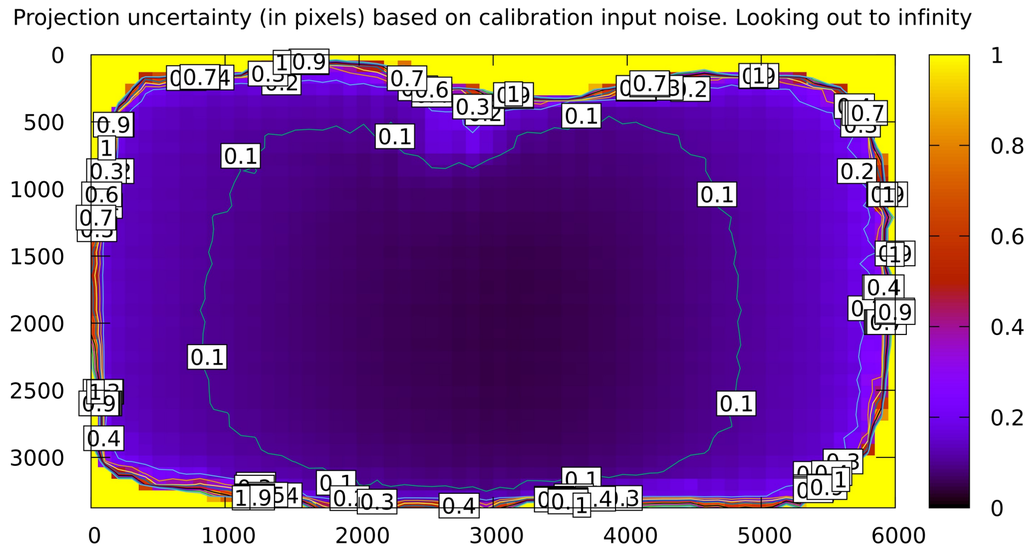
Objective: Develop a camera calibration process that would be functional without a chessboard, while still producing PROVABLY precise and accurate results

Background: Using cameras for robot navigation is common. This requires a CALIBRATION: a precise description of lens behavior and camera geometry. The calibration must be highly precise for the localization and mapping tasks to work well. During flight the cameras are subjected to mechanical and thermal stresses, which breaks the calibration. Today there are no good methods of restoring it. Common tools use chessboards to compute the calibration, and have to good methods of evaluating the calibration quality, so it's difficult to tell if a calibration is usable. This is a critical problem for marginal calibrations, such as ones that can't use a chessboard.

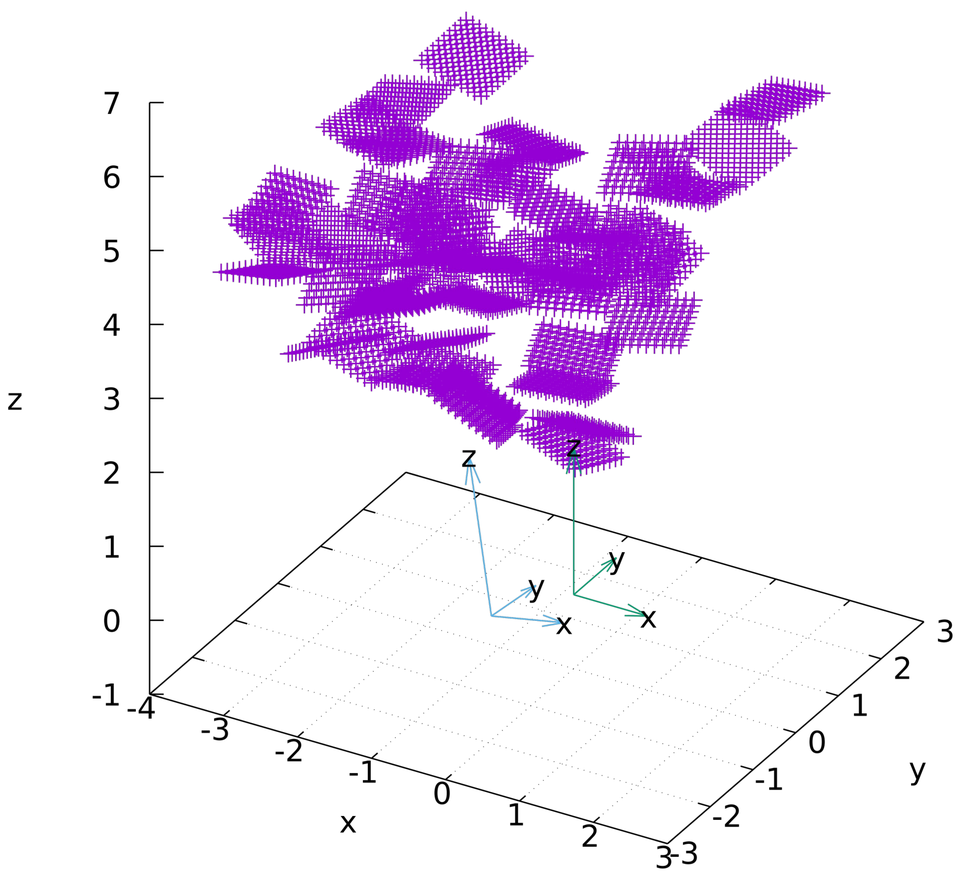


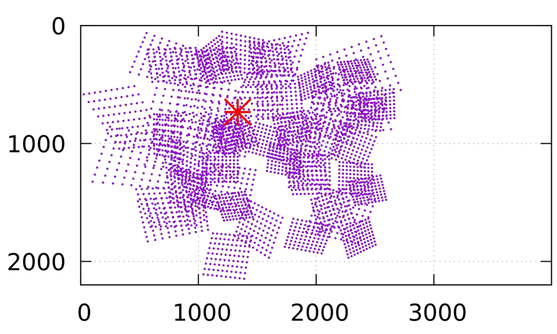
Approach and results: The mrcal project is a novel toolkit developed at JPL and released as open-source software. It provides improved techniques to calibrate cameras and to interpret the quality of the results. It can compute precise calibrations from chessboard images, and to provide actionable quality metrics: projection uncertainty and cross-validation diffs:

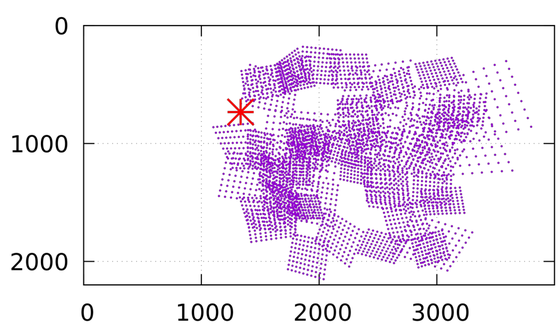


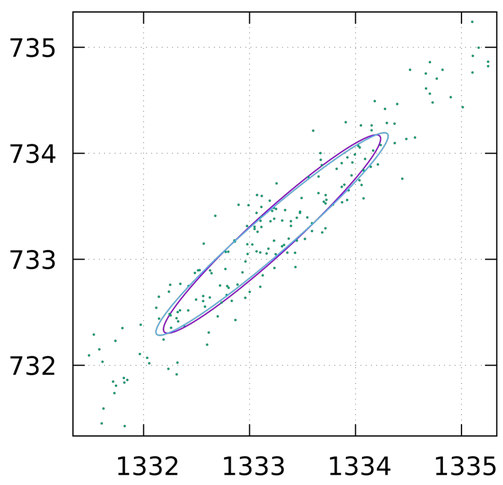


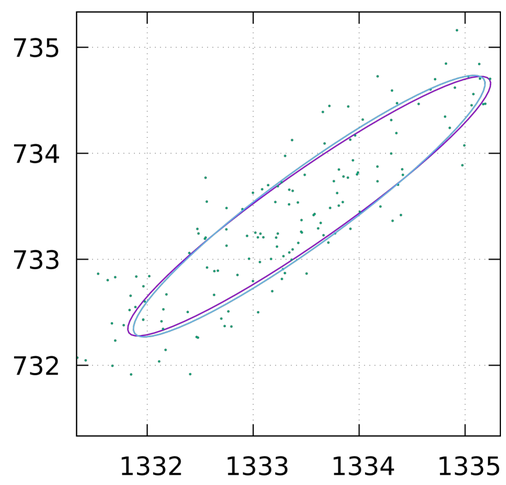
mrcal is also able to calibrate from observations of DISCRETE POINTS in space (no chessboard). However, evaluation of projection uncertainty in this mode was not implemented, which made it impossible to generate reliable calibrations. As part of this effort, a new "cross-reprojection" uncertainty method was designed, implemented and tested. This works without chessboards, and could be used to gauge the quality of a calibration computed off natural images seen by a robot in the field. Simulated calibration showing the predicted and observed 1-sigma uncertainty ellipses:











Significance/benefits to NASA/JPL: NASA routinely sends cameras to space, and degraded calibrations are a major issue for every single project. A reliable chessboard-less calibration method would eliminate a major risk factor, and the robots would be able to see further, make better maps, and move faster and more safely.

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