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Ph.D. DISSERTATION DEFENSE

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Title: Instantaneous Rolling Shutter Camera Localization and General Planar Motion from Point Correspondences

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ABSTRACT

Camera pose estimation aims to localize an observer w.r.t. a known geometric reference and has a range of applications from autonomous navigation to virtual/augmented reality. Motivated by the ubiquity of digital cameras deploying rolling shutter (RS) hardware, pose estimation modules have been extended from the pin-hole camera model to incorporate the dynamic 1D capture characteristics of these sensors. However, absolute pose estimation from single RS scanline inputs has been hitherto ignored in the literature. This omission may be attributed to the limited geometric context available for instantaneous RS capture and stringent latency requirements involved in real-time system operation.

We propose a marker-based geometric framework for the high-frequency absolute 3D pose estimation of a binocular camera system by using the data captured during the exposure of a single rolling shutter scanline. In contrast to existing approaches enforcing temporal or motion models among scanlines, we strive to determine the pose from instantaneous binocular capture. We demonstrate the effectiveness of our proposed approach with an FPGA-based implementation which achieves a localization throughput of 129.6 KHz with a 1.5 us latency. Then, we explore an extended version of our marker-based framework which constitutes a theoretical analysis on the minimum geometric context necessary to solve in closed form for the absolute pose of a single camera by analyzing the 1D observations in a single radially distorted pixel scanline.

Next, we consider the problem of estimating the relative pose of a camera undergoing planar motion from 3D data. We present a novel 2-point method that, unlike prior art, does not assume knowledge of the plane of motion to resolve the under-constrained nature of SE(3) motion estimation in this context. Instead, we enforce geometric constraints identifying, in closed-form, a unique planar motion solution from an orbital set of geometrically consistent SE(3) motion estimates. Finally, we explore the solution space for the general planar motion problem and propose three novel minimal solvers from hybrid point correspondences, as well as a triplet of new non-minimal solvers from 2D-2D point correspondences bridging the theoretical gap from minimal to linear solutions. We integrate our planar solvers within a RANSAC framework and demonstrate robust operation on standard benchmark sequences of real-world imagery.