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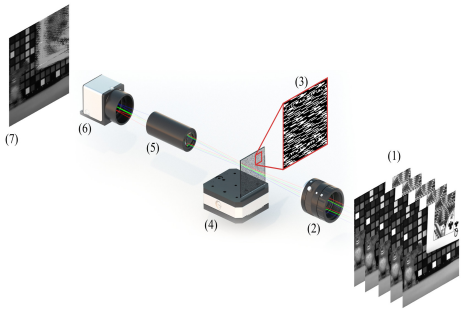
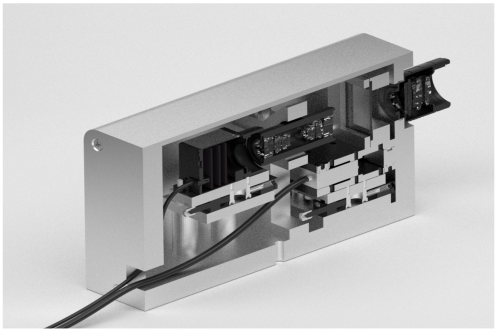
Subject Area	Sensor, Actuator and Communication Systems
Project Partner	Northwestern University, Evanston IL, USA

2 Megapixel Compressive Sensing High-Speed Video Camera

Master Thesis



System overview: 1: scene, 2: lens, 3: binary photo-mask, 4: piezo translation stage, 5: relay lens, 6: sensor, 7: captured image

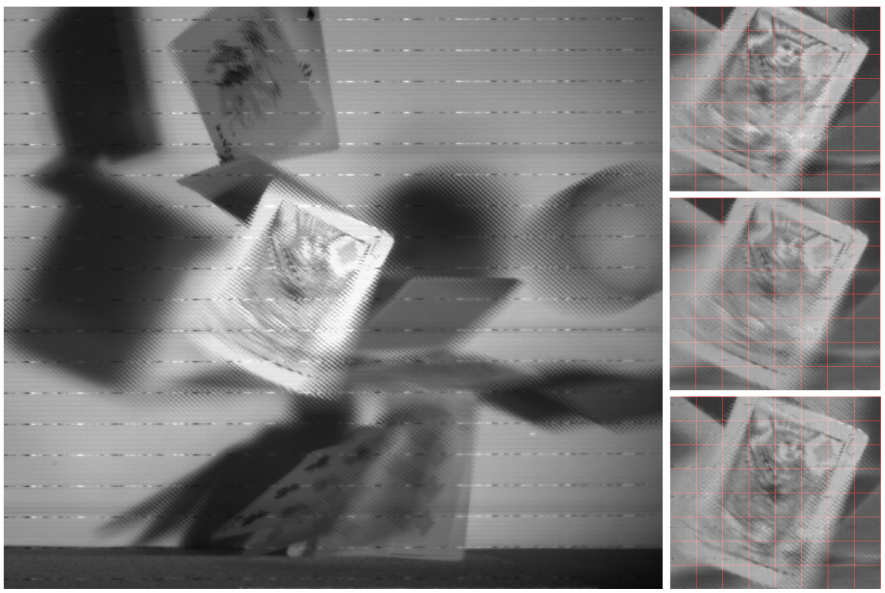


Profile view of the camera prototype

Introduction: A prototype of a new compressive sensing camera takes a single long-exposed image while a binary photo-mask moves in the optical path. From this sensed image and the knowledge of the movement and pattern of the mask, multiple frames can be reconstructed, i.e. a high-speed video can be produced.

Approach/Technologies: This project improves upon the system built by Thomas Niederberger in his Master thesis by implementing hardware and algorithmic changes. First, new mask patterns were evaluated and ordered. They incorporate the property that every spatial pixel is exposed the same amount of time during one exposure. Secondly, since the mask pattern must be known at every time the estimation of the mask was refined and various mechanical uncertainties were investigated. The reconstruction can be mathematically formulated as sparse and least-square optimization problem which requires different solvers such as Orthogonal Matching Pursuit (OMP), L1-Regularized Least-Squares (L1_LS), Fast Iterative Shrinkage-Thresholding Algorithm (FISTA) and Constrained Least-Squares (CLS) which were compared here. It showed that CLS with a high-pass is a computationally efficient procedure which achievessatisfactory results whereas OMP with a dictionary approach performs best but requires so much computation time that it is infeasible. To lower computational effort while improving reconstruction quality a motion detection was introduced which distinguishes between non-moving and moving parts. Different image classification algorithms were tested including filtered and morphologically adjusted features and a Support Vector Machine (SVM). Finally, future work is discussed involving multiple frame reconstructions.

Solution: A comparison between prior work and the improvements leads to the conclusion that the quality was significantly enhanced. However, there is need to improve the design of the whole system since the structural mechanics are not accurate enough, the camera is hardly able to support multiple frames and the stage can not accelerate faster while still being linear.



A sensed image on the left side and a subset of reconstructed and magnified high-speed video frames on the right side