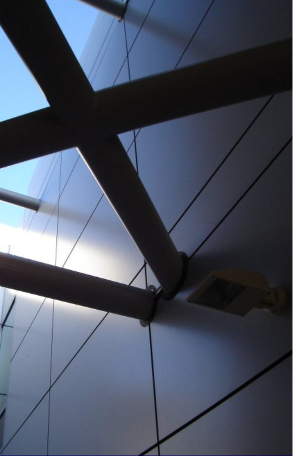

MECHANICAL ENGINEERING
DISSERTATION DEFENSE

The Department of Mechanical Engineering presents:

The Ph.D. Dissertation Defense of

Baurzhan Muminov

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8AM Pacific time

Optical Preprocessing for Low-latency Machine Vision

Doctor of Philosophy, Graduate Program in Mechanical Engineering
University of California, Riverside, July 2022
Dr. Luat Vuong, Chairperson

In recent years there has been an increased interest towards edge computing, *i.e.*, computing performed on distributed devices as opposed to centralized high-power hubs. Examples of edge computing would be the local image processing performed on Unmanned Autonomous Vehicles (UAV's) or the specialized machine vision systems on drones. These edge computing applications require schemes that are efficient with power and memory and typically must operate real-time. Many state-of-the-art image processing solutions that employ advanced optimization and deep neural networks (NNs) achieve impressive benchmark results, but are computationally demanding and thus on many occasions, impractical. The additional requirement for a range of applications is noise robustness or the ability to work in (extreme) low-light conditions; reasonable quality image or accurate object classification may be critical when there is low light flux or when the environment is over-saturated with other signals.

Here, we approach edge computing with a combination of optical preprocessing and shallow NN and we show that this hybrid approach greatly reduces the computational requirements. For low-SNR imaging, we develop a technique that reconstructs objects and scenes from their Fourier-plane images. The optical preprocessing is performed via encoded diffraction with optical vortex singularities. The optical vortex encoder achieves differentiation of the already-compressed Fourier-plane patterns and enables facile inverse inference of the original object scene. We demonstrate that our method is robust to noise. And for a simple NN architecture (one or two layers), leads to generalization, *i.e.*, reconstruction of objects from classes that are greatly different from the ones the NN was trained on. In the discussion, we briefly explore one of the “image complexity” metrics via Singular Value Decomposition. Our research identifies strong potential for swift hybrid imaging systems with edge computing applications and highlights the valuable function of the vortex encoder for spectral differentiation.