<u>Department of Electrical and Computer Engineering</u>
<u>University of Rochester, Rochester, NY</u>
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Real-Time Signal Processing Techniques and Hardware Implementation for Optical Metrology

Chen Wang

Supervised by
Professor Jonathan D. Ellis

Optical metrology uses characteristics of light to perform measurements. This could be in the form of calibrating the physical size of an object, measuring the distance between two objects, or measuring the displacement of two objects, to name a few. Typically, optical metrology is characterized for its high resolution and high dynamic range. However, several optical, electrical, and mechanical error sources could impact the accuracy of a given measurement. The following three error sources are studied in this research.

Data age error is the time delay and signal processing-induced phase shift of displacement interferometer measurement results, which means it cannot precisely represent the current position of the target. It becomes significant but often overlooked when there are rapid position changes, whose errors could be up to hundreds of nanometers. This research investigates the causes of this error and reports on a signal processing algorithm and its hardware implementation to compensate the data age error during real-time measurements.

Periodic error is from imperfect optical devices and frequency mixing in traditional displacement interferometer configurations. It is usually on the order of nanometers, which impacts dynamic measurement accuracy. This research presents a signal processing algorithm based on an extended Kalman filter and its FPGA implementation for on-line estimation and real-time correction of periodic error.

Straightness error is a parasitic translation along a direction perpendicular to the primary displacement axis of a linear stage, which could be coupled into other primary displacement directions of a multi-axis platform. This ultimately impacts the precision of multi-axis metrology, calibration, and manufacturing. This research presents configurations based on image registration, and two-dimensional (2D) optical knife-edge sensing to characterize 2D straightness error.