Application of Signal Tracking Methods for Fringe Analysis

A thesis submitted
in partial fulfillment for the degree of

Doctor of Philosophy

by

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January 2017

ABSTRACT

Simultaneous estimation of phase and its derivatives from a single record of interference field gives significant insights about properties of an object in terms of deformation, strain, curvature and twists. Current state-of-the-art methods provide either phase or phase derivatives from the fringe pattern; moreover their performance is greatly influenced by noise in the fringe pattern and the dynamic range of the phase. Thus, there exist a strong need for development of a phase estimation approach that can handle severely noisy fringe patterns and yet capable of estimating rapidly varying phase even when the phase is having larger dynamic range. This serves us a motivation for our current research work. The main objective of this thesis is to develop the unified, simple yet effective approach for simultaneous estimation of phase and phase derivatives from single record of reconstructed interference field that can handle different conditions present in the interference field like rapidly varying phase, larger dynamic range of the phase and extreme noise in the interference field.

This thesis proposes a novel approach, namely, signal tracking approach as an elegant solution for the phase estimation from reconstructed interference fringes. Signal tracking approach involves two important parts: state space model and tracking algorithm. In this work, state space model for signal tracking approach is derived using Taylor series approximation of the phase map as state model and Polar to Cartesian conversion as measurement model. We have proposed, tested and demonstrated the significance of our work through tracking algorithms that use this state space model such as extended Kalman filter (EKF), unscented Kalman filter (UKF), Particle filter (PF) and wrapped statistics based algorithm (WKF) as tracking algorithms. In order to demonstrate the utility of proposed algorithms, we performed different real-time experiments including digital holographic Interferometry (DHI) and fringe projection profilometry to measure out-off plane displacement and 3D reconstruction of an object, respectively.

It was observed that the wrapped statistics based algorithm satisfies all of our

goals providing the efficient solution of phase estimation problem when the interference fringes are extremely noisy and when underlying phase map has larger dynamic range and can be considered as better alternative for simultaneous estimation of phase and phase derivatives.

Finally, we conclude our work by showing different applications of the proposed signal tracking approach such as multi-component phase estimation in holographic moiré, 3D reconstruction of an object using fringe projection methods. Moreover, we also demonstrate that the proposed method is a suitable fringe analysis technique for practical purposes such as thermal expansion.