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IMPLEMENTATION OF SPATIAL SHIFT ESTIMATION APPROACH FOR 3D PROFILOMETRY BASED ON DIGITAL FRINGE PROJECTION

A thesis submitted in fulfilment of the requirement for the award of the degree of

Master of Engineering Research

from

University of Wollongong

By

PU CAO

B.E, Huazhong University of Science and Technology of China

Master of Internet Technology, University of Wollongong

School of Electrical, Computer and Telecommunications Engineering

2010

CERTIFICATION

I, Pu Cao, declare that this thesis, submitted in partial fulfilment of the requirements for the award of Master of Engineering Research, in the School of Electrical, Computer & Telecommunications Engineering, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualifications at any other academic institution.

Pu Cao

24 March 2010

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LIST OF ABBREVIATIONS

FPP	Fringe Pattern Profilometry
3D	Three-Dimensional
DFP	Digital Fringe Projection
PDE	Phase Difference Estimation
SSE	Spatial Shift Estimation
FTP	Fourier Transform Profilometry
PSP	Phase Shifting Profilometry
PMP	Phase Measuring Profilometry
MMP	Modulation Measurement Profilometry
SPD	Spatial Phase Detection
PLL	Phase Lock Loop
MT	Moiré Technique
FFT	fast Fourier Transform
IFT	inverse Fourier Transform
IFSE	Inverse Function based Shift Estimation
PC	Personal Computer
FIR	Finite Impulse Response
SDE	Screen Door Effect

ABSTRACT

Fringe Pattern Profilometry (FPP) based on Digital Fringe Projection (DFP) is a promising optical noncontact three-dimension (3D) profile measurement technologies due to its accuracy and flexibility. Popular FPP approaches retrieve the 3D profile information using the detection of phase difference, called the Phase Difference Estimation (PDE). Recently, a new kind of FPP approach, referred to as Spatial Shift Estimation (SSE) is introduced, which retrieves the 3D profile information using the detection of spatial shift instead of phase different. Compared with PDE approaches, SSE approaches are advantageous in that the projected fringe patterns do not need to be sinusoidal, and thus accurate reconstruction can be obtained even when nonlinear distortions exist on the fringe patterns. However, efficient implementation of SSE approaches is still an issue.

This thesis work aims to implement the SSE approach for 3D profile measurement based on digital fringe projection. Firstly, a DFP system is designed and adopted in our laboratory, which is utilized as an experiment platform for the work presented in this thesis. SSE approaches are implemented on the system. Some problems associated with the implementation are studied and solved, including elimination of noise and distortion in the fringe patterns. Furthermore, an improved Inverse Function based Shift Estimation (IFSE) method is proposed to improve the performance of SSE approaches.

Secondly, shift unwrapping problem associated with SSE is investigated. Through reviewing the phase unwrapping problem in PDE based FPP, we indicate that a similar shift unwrapping problem also exists in SSE approaches. A method for solving the problem has been proposed and the experiment results are presented to demonstrate the effectiveness of the proposed method.

Finally, the research is carried out to improve the efficiency of SSE approaches. SSE approaches have the advantages that the projected fringe patterns are no longer required to be sinusoidal nor periodic. Therefore, we can choose a fringe pattern which has strong counter-interference capability against the noise and nonlinear distortion with simple implementation. Based on analysis of the limitations of traditional sinusoidal fringe, we propose to use sawtooth fringe pattern. Theoretical analysis has been given to evaluate the complexity of the proposed sawtooth fringe pattern based algorithms, and practical experiment are performed at last to prove the efficiency of this proposed fringe pattern.

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LIST OF PUBLICATIONS

Pu Cao, Jiangtao Xi, Joe Chicharo and Yanguang Yu, “A Fringe Period Unwrapping Technique for Digital Fringe Profilometry based on Spatial Shift Estimation”, in *Optical Inspection and Metrology for Non-Optics Industries*, edited by Peisen S. Huang, Toru Yoshizawa, Kevin G. Harding, Proceedings of SPIE Vol. 7432 (SPIE, Bellingham, WA 2009) 743208.