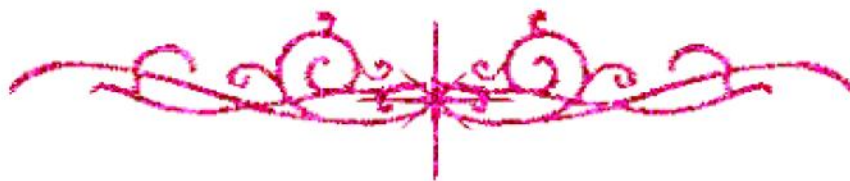


بسم الله الرحمن الرحيم





شبكة المعلومات الجامعية التوثيق الالكتروني والميكروفيلم



جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

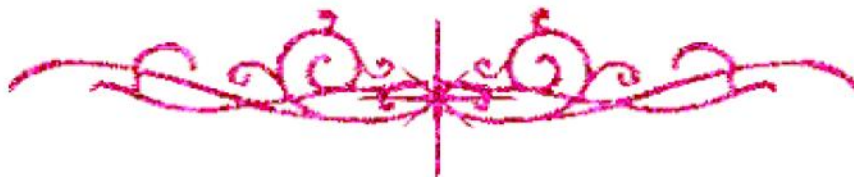
قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار



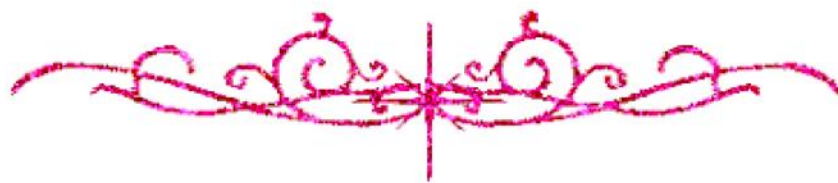


بعض الوثائق الأصلية تالفة





بالرسالة صفحات
لم ترد بالأصل





Cairo University

DEVELOPMENT AND VALIDATION OF A SYSTEM FOR OSCILLATION MONITORING USING SINGLE NON-METRIC CAMERA

By

OMAR AHMED IBRAHIM KAMAL EL-KADI

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the degree of
DOCTOR OF PHILOSOPHY

In
Civil Engineering - Public Works

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2020

**DEVELOPMENT AND VALIDATION OF A SYSTEM FOR
OSCILLATION MONITORING USING SINGLE
NON-METRIC CAMERA**

By

OMAR AHMED IBRAHIM KAMAL EL-KADI

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the degree of
DOCTOR OF PHILOSOPHY

In
Civil Engineering - Public Works

Under the Supervision of

Prof. Dr. Adel H. El-Shazly

.....
Professor of Surveying and Geodesy
Public works Engineering
Faculty of Engineering, Cairo University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2020

DEVELOPMENT AND VALIDATION OF A SYSTEM FOR OSCILLATION MONITORING USING SINGLE NON-METRIC CAMERA

By

OMAR AHMED IBRAHIM KAMAL EL-KADI

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the degree of
DOCTOR OF PHILOSOPHY

In
Civil Engineering - Public Works

Approved by the
Examining Committee

Prof. Adel H. El-Shazly

Professor of Surveying and Geodesy, Faculty of Engineering, Cairo University

Thesis Main Advisor

Prof. Mostafa A. Baraka

Professor of Surveying and Geodesy, Faculty of Engineering, Cairo University

Internal Examiner

Prof. Mohamed I. Zahran

Professor of Surveying and Geodesy, Faculty of Engineering at Shoubra, Banha University

External Examiner

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2020

Engineer's Name: Omar Ahmed Ibrahim Kamal EL-Kadi
Date of Birth: 23/11/1980
Nationality: Egyptian
E-mail: o.elkadi@aucegypt.edu
Phone: +2-01006041007
Address: Villa 218, El Banafseg 1, first-settlement, Cairo
Registration Date: 1/10/2014
Award Date: / /
Degree: Doctor of Philosophy in Civil Engineering
Department: Civil Engineering – Public Works



Supervisors:

Prof. Adel H. El-Shazly

Examiners:

Prof. Adel H. El-Shazely (Thesis Main Advisor)
Prof. Mostafa A. Baraka (Internal Examiner)
Prof. Mohamed I. Zahran (External Examiner)
Professor of Surveying and Geodesy,
Shoubra Faculty of Engineering – Banha University

Title of Thesis:

DEVELOPMENT AND VALIDATION OF A SYSTEM FOR OSCILLATION
MONITORING USING SINGLE NON-METRIC CAMERA

Key Words:

Artificial Intelligence, Neural networks, Oscillation monitoring, Slender Structures monitoring, Terrestrial Photogrammetry

Summary:

This research aims the development of in-plane oscillation – deformation monitoring technique using available on shelf cameras and taking advantage of the high optical zoom offered by bridge type cameras and DSLR lenses. Consequently, a photogrammetric model is developed to accommodate the lens distortions effect, which requires forth degree polynomial function to be used for image projection. The proposed technique relies on a predefined gridded target pattern that is used as control points to rectify the initial frame, resulting in projected ortho-photo and eliminating both radial and tangential lens distortions effect. The target is detected by Harris corner detector (C.Harris, 1998), and target points detection precision is achieved in sub-pixel accuracy using neighbor gradient technique.

The limitation of testing in controlled lighting conditions is handled by AI techniques that are adopted by implementing Faster RCNN network for detecting a tracking pattern located at the targets' center. The deep network is trained to detect a track point at various lighting conditions. The resulting monitoring using AI is compared to the previously proposed technique, and the impact of using AI on measurement precision is evaluated. The approach is validated by a set of tests comparing the monitored oscillation in the time domain with different measuring techniques; starting by the usage of predefined moving patterns, then using an oscillating dynamic actuator, and shaking table, the resulting monitoring data is compared to measured data, then a field test is performed to measure the oscillations of an industrial chimney. The proposed monitoring technique proved to be precise and robust in different environmental conditions.

Disclaimer

I hereby declare that this thesis is my own original work and that no part of it has been submitted for a degree qualification at any other university or institute.

I further declare that I have appropriately acknowledged all sources used and have cited them in the references section.

Name: Omar Ahmed Ibrahim Kamal EL-Kadi Date: / /2020

Signature:

Dedication

To those whom nothing can return their favor, sacrifice, and suffer. To *my father* and *my mother*, I dedicate not only this thesis but also every beautiful thing in my life to both of you.

To my *angel wife* and our lovely children, *Laila, Nour, and Mohamed*, for all of you, I dedicate this modest work and to those souls that lighten our lives with love and guidance and left our world.

Acknowledgments

In The Name of ALLAH the Beneficent, the Merciful

"Praise to Allah, Who guided us to this; And in no way could we have been guided, unless Allah has guided us" (AL A'raf 43)

There are many people who, directly or indirectly, contributed to this endeavor, and to each, a deep appreciation must be extended. However, some deserve special recognition.

It is my pleasure to gratefully acknowledge the assistance and express sincere gratitude to my advisor, **Professor Adel EL-Shazly**, Prof. of Surveying and Geodesy, Faculty of Engineering – Cairo University, for his continuous guidance, kind supervision, encouragement, and invaluable support from the first beginning of my study.

I would like to express the deepest appreciation to my supervisor, **Professor Khaled Nassar**, Prof. of construction engineering, construction engineering department, The American University in Cairo, who has shown the attitude and the substance of a great mentor. Without his supervision and constant help, this thesis would not have been possible.

I would like to express my sincere thanks to my teachers and professors, that guided and educated with love and dedication **Professor Farouk El-Kadi, Professor Safwan Khedr, Professor Fathallah EL Nahas, Professor Hisham Arafat, Professor Yasser El Mosallamy, Professor Ezzat Fahmy, Professor Mostafa Baraka, Dr. Ahmed EL Kadi, Ass. Prof Emad El Dardiry and Dr. Anwar El Kadi** for unlimited support and continued encouragement to do my best that helping me to achieve this stage.

I would like to express my appreciation to **The Construction Department, The American University in Cairo**, for allowing the use of laboratory facilities and equipment and providing support for this research.

I would like to acknowledge the favors of professors **Professor El Maghraby and Professor El Manadily**, who influence the lives of many researchers in the field of geomatics. I ask Allah to forgive them and rest their souls. In spite of that, they had passed away; their influence is presented in every word of this research.

Finally, I know that this thesis is a result of the prayers and support of **my dear father and mother** and **my angel wife** for continuous support, patience, and care of **our lovely children, Laila, Nour, and Mohamed**. For all of them, I dedicate this work.

Table of Contents

DISCLAIMER	I
DEDICATION	II
ACKNOWLEDGMENTS.....	III
TABLE OF CONTENTS	IV
LIST OF TABLES.....	VIII
LIST OF FIGURES.....	IX
NOMENCLATURE	XIX
ABSTRACT	XXI
CHAPTER 1 : INTRODUCTION	1
1.1 INTRODUCTION.....	1
1.2 LITERATURE REVIEW	3
1.2 PROBLEM DEFINITION	5
1.3 OBJECTIVES	5
1.5 THESIS OUTLINES	5
CHAPTER 2 : DEFORMATION MONITORING TECHNIQUES	7
2.1 INTRODUCTION.....	7
2.2 MONITORING USING DIFFERENTIAL LEVELING	8
2.3 MONITORING USING TRILATERATION /TRIANGULATION AND DISTANCE MEASUREMENTS TECHNIQUES.	9
2.4 MONITORING USING GPS/GNSS.....	14
2.4.1 DGPS and RTK techniques.....	15
2.4.2 Applications of Monitoring with GNSS/GPS	16
2.5 DEFORMATION MONITORING USING LIDAR	19
2.5.1 Co-registration of imagery to point cloud (image Fusion).....	21

2.5.2 Airborne LIDAR systems.....	22
2.5.3 Terrestrial LIDAR systems	23
2.5.4 Mobile terrestrial LIDAR systems	26
2.5.5 Applications of Monitoring using LiDAR	28
2.6 MONITORING BY PHOTOGRAMMETRY	32
2.6.1 Analog photogrammetry	34
2.6.2 Digital Cameras	35
2.6.3 Photogrammetric Mathematical Models	38
2.6.4 Applications of Monitoring using Photogrammetry	45
2.7 Miscellaneous Techniques of Monitoring.....	51
CHAPTER 3 : APPLIED ASPECTS OF PHOTOGRAMMETRY	53
3.1 DIGITAL IMAGE.....	53
3.1.1 Digital image composition and pixels indexing.....	53
3.1.2 Digital image histogram	56
3.2 IMAGE PROCESSING BY POINT OPERATIONS.....	57
3.2.1 Image Thresholding.....	57
3.2.2 Histogram normalization (contrast stretching).....	58
3.2.3 Histogram equalization	59
3.3 IMAGE PROCESSING BY NEIGHBORHOOD OPERATIONS	60
3.3.1 Smoothing spatial filters.....	60
3.3.2 Sharpening spatial filters	61
3.3.3 Edge-based segmentation	63
3.3.4 Region-based segmentation.....	65
3.3.5 Corner detection	66
3.4 IMAGE MATCHING.....	68
3.5 IMAGE CLASSIFICATION.....	71
3.6 IMAGE REMAPPING	73
3.7 NEURAL NETWORKS AND AI.....	75
3.7.1 Basic structure of neural networks	76

3.7.2 Network learning and backpropagation	78
3.7.3 Deep neural networks general training aspects	83
3.7.4 Convolutional neural networks	85
3.7.5 R-CNN, Fast R-CNN, and Faster R-CNN	87
CHAPTER 4 : OSCILLATION MONITORING BY TERRESTRIAL PHOTOGRAMMETRY	89
4.1 PRE-ANALYSIS	89
4.1.1 Camera's monitoring pixel precision analysis	90
4.1.2 Effect of refraction and out of plan movements.....	91
4.2 MONITORING APPROACH	93
4.2.1 Image Geometric correction based on nonlinear distortion model	93
4.2.2 Image Geometric correction based on 4 th -degree polynomial distortion model 95	
4.2.3 AI aided target detection	97
4.3 VALIDATION OF PROPOSED MONITORING APPROACH	101
4.3.1 Monitoring hand-controlled movements	101
4.3.2 Monitoring dynamic actuator oscillation	105
4.3.6 Monitoring oscillation of high-speed shaking table and applying AI target tracking.....	108
Checking consistency of proposed monitoring technique	108
Examining the precision of the proposed monitoring technique	111
Testing the reliability of monitoring technique in exposure condition	119
4.3.3 Monitoring dynamic actuator oscillation while testing pavement	121
4.3.4 Monitoring deformation of a wooden structure at the outdoor condition 125	
4.3.5 Monitoring deformation of steel bracket during structural testing.....	127
4.3.7 Monitoring oscillation of industrial chimney	130
CHAPTER 5 : CONCLUSIONS AND RECOMMENDATIONS	137
5.1 SUMMARY	137