Automated visibility map from colonoscopy video to support clinical diagnosis and improve the quality of colonoscopy

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A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPHY OF

THE UNIVERSITY OF CANBERRA

FACULTY OF EDUCATION SCIENCE TECHNOLOGY AND MATHEMATICS

NOVEMBER 2016

I DEDICATE THIS TO MY PARENTS WHO ARE THE LIGHT OF MY LIFE.

Abstract

Colorectal cancer is one of the leading cause of cancer related deaths in the world. In 2012, it was reported to have claimed more than 694,000 lives worldwide [1], [2]. When diagnosed early, survival from cancerous polyps can increase up to 90% [1]. Current reports estimate that one in 12 Australian males will develop colorectal cancer within their lifetime, one of the highest rates in the world [1]. Among screening methods, optical colonoscopy is widely used to diagnose and remove cancerous polyps. Although optical colonoscopy is an effective procedure for diagnosing colorectal cancer, there are many factors that affect the quality of this intervention [3]. Inspecting the whole colon surface in order to detect polyps and other lesions is challenging because haustral folds can hide lesions, the organ might deform, visibility can be reduced due to dirty lens, and also because challenges in operating the colonoscope could result in not visualising all the colon surface. An undesirable consequence is missing cancerous lesions, up to 33% according to recent publications [4], [5].

The aim of this research project is to enhance the quality of colon inspection by improving the quality and extent of the visual inspection of the internal colon surface. We developed an assistive technology to provide a panoramic view of internal colon surface (visibility map) from a colonoscopy video. A visibility map could provide feedback to clinicians about the quality of the intervention (potentially in real time), for example by increasing their awareness of uncovered areas by the video. It could also be beneficial for following up patients and tracking lesions over multiple exams. Visibility map could also be a core technology for training junior clinicians.

Challenges to generate visibility maps include: (i) Colonoscopy videos comprises many uninformative frames (frame with no technical or clinical information); (ii) the colon is a flexible tubular organ that makes navigation challenging, not only for clinicians, but also for computer vision algorithms; (iii) the structure of the colon is complex with many haustral folds requiring complicated modelling.

Our novel framework comprises four main phases: (i) detect uninformative frames from motion and colour features, (ii) compute camera parameters including intrinsic and extrinsic one using epipolar geometry analysis, (iii) model the colon and project the model into colonoscopy frames using camera parameters, and (iv) unroll and stich the frames, correcting camera parameters, and generate a visibility map. We leveraged the existing state of art CSIRO realistic simulator by generating test examples and validation experiments where ground truth could be known from the simulator. Our results showed that this method could detect uncovered areas and help clinicians to identify them. Although more work is required, the wide spread use of this technology could help reducing the miss rate of polyps, which will increase the quality of colonoscopy procedure and ultimately save lives.

Acknowledgments

PhD is a long journey when you are alone, but I have done this with the support of the knowledgeable, wise, and experienced scholars. I would like to express my deep gratitude to A/Prof. Olivier Salvado and A/Prof. Girija Chetty, my supervisors at Commonwealth Scientific Industrial and Research Organisation (CSIRO) in Brisbane and University of Canberra (UC), for their continuous support toward my PhD study and research, their patience, enthusiasm, encouragement, and immense knowledge. Their aspiring guidance helped me in all the time of research and writing of this thesis. I could have never completed this thesis without their generous support.

I also would like to thank the rest of my supervisory panel, Professor Roland Goecke, A/Prof Cedric Dumas, and A/Prof Hans de Visser for their encouragement, and insightful comments. In addition, I would like to thank Dr Florian Grimpen for providing us with actual colonoscopy videos, and assisting us to analyse the outcomes of this research. David Conlan, the senior software engineer at the heart of colonoscopy simulation team is another person that I would like to deeply appreciate for his kind assistance with the simulator.

My grateful thanks also go to Professor Roland Goecke the research leader for the Information Technology & Engineering research program, and HCT Centre director at UC not only because he introduced the science of image processing and computer vision to me, but also because he generously supported my study. I also would like to appreciate the Dean Professor Geoffrey Riordan for his warm support, and my previous lecturers at the university of Canberra, especially A/Prof Dat Tran, A/Prof Masoud Mohamadian, and my friends A/Prof Sharon Kazemi and Prof Alan Forghani.

Furthermore, I would like to express my heartfelt gratitude to my parents and my dearest friends Amir Fazlollahi and Zahra Shahabi who inspired me through this research.

I also like to thank all e-health research centre members in Brisbane, who were supportive and inspired me through my PhD journey. I also would like to express my appreciation to the Research Student office, graduate research office, UC and CSIRO library for their support.

Last but not least, during this research my dearest uncle and two of my relatives passed away due to lung and colon cancer, so I would like to dedicate this achievement to them and all other patients, and I hope the application of this research can potentially save peoples' lives in future.

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Abbreviations

ADR	....	Adenoma Detection Rate
AIHW	....	Australian Institute of Health and Welfare
ARENA	....	Automatic Real-time ENdoscopy Assistance
ASGE	....	American Society for Gastrointestinal Endoscopy
ASKC	....	Adaptive scale kernel consensus technique
ANNs	....	Artificial Neural Networks
CSIRO	....	Commonwealth Scientific Industrial and Research Organisation
CTC	....	Computed Tomography Colonography
CBIR	....	Content Based Image Retrieval
DOF	....	Degree of Freedom
EKF	....	Extended Kalman Filter
FOBT	....	Fecal Occult Blood Test
GLCM	....	Grey level Co-occurrence Matrices
HA	....	Hidden Areas behind haustral fold
HSV	....	Hue-Saturation-Value
IVUS	....	Intravascular Ultrasound
IPR	....	Isolated Pixel Ratio
KLT	....	Kanade Lucas Tomasi
MEMS	....	Micro Electro-Mechanical System
MIS	....	Minimal Invasive Surgery
NBI	....	Narrow Band Imaging
OC	....	Optical Colonoscopy
RANSAC	....	RANdom Sample Consensus
RF	....	Random Forests
RGB	....	Red-Green-Blue
RMS	....	Root Mean Square
SIFT	....	Scale Invariant Feature Transform
SLAM	....	Simultaneous Localisation and Mapping
SVD	....	Singular Value Decomposition
SURF	....	Speed Up Robust Features
STD	....	Standard Deviation

SFM	....	Structure From Motion
SSD	....	Sum of Squared Differences
TCE	....	Tethered Capsule Endoscopy
UA	....	Uncovered Areas which have not been observed
VO	....	Visual Odometry
WCE	....	Wireless Camera Endoscopy

Key Terms

Camera motion correction

Camera parameters

Classification

Colonoscope

Colorectal cancer

Computer vision

Cylindrical model

Hidden area

Machine learning

Missed polyp rate

Motion, colour and edge feature

Optical colonoscopy

Optical flow

Quality of colonoscopy

Registration

Simulator

Uncovered area

Uninformative frames

Visibility map