Laparoscopy Image Enhancement

A Dissertation
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Master of Technology
by

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28 April 2017

Dedicated to my parents

Approval Sheet

This dissertation entitled "Laparoscopy Image Enhancement" by Ayush Baid is approved for the degree of Master of Technology.

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Abstract

Laparoscopy images exhibit artifacts like occlusion from surgical smoke, specular highlights, and noise. These artifacts hinders visibility, and degrades post processing (e.g. segmentation). We tackle these degradations as a novel *unified Bayesian inference problem*. We propose *probabilistic graphical models* and *sparse dictionary models* as image priors. We obtain maximum-apriori probability (MAP) estimate by *variational Bayesian expectation-maximization*. Results on simulated and real-world laparoscopy images show that our joint optimization strategy outperforms the state-of-the-art.

Index terms — Laparoscopy, desmoking, specularity re-moval, denoising, variational Bayes, EM, graphical models

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Chapter 1

Introduction

Laparoscopy is a popular *minimally invasive surgery* technique in which operations are performed by inserting equipments through small incisions. Laparoscopic surgery offers advantage such as less pain and hemorrhaging, shorter recovery times over open procedures. The key equipment is a **laparoscope**, an optical imaging instrument which relays the visuals on a screen. Another main equipment is a cold light source to illuminate the area of operation.

The closed nature of laparoscopy images presents some challenges. The images can get severely corrupted with specular highlights [1, 2], surgical smoke [3], and noise.

Specular highlights result from strong reflection of the light source by body fluids like blood and mucus. Speckles interfere with post-processing like segmentation [4, 5] and tracking [6]. Electrical cauterization of a tissue generates surgical smoke, which hinders visibility for surgeons and robots alike. Noise is present in all optical imaging systems and a laparoscope is no exception.

Our work jointly tackles the mentioned artifacts. We use probabilistic graphical models for variables in the system and formulate a unified Bayesian inference problem, which is solved using expectation-maximation (EM) algorithm. We introduce variational Bayesian approximation to overcome the analytical intractability in the optimization scheme.

Chapter 2

Literature Survey

To the best of our knowledge, no existing work tackles smoke, speckles, and noise in a joint setting. We will cover these three and some related problem separately. First, we will look into specular highlights removal in laparoscopy images, which is mostly tackled as an inpainting problems. Inpainting is a process in filling in missing information, usually using true information in the surroundings. Then, we will cover dehazing, both with and without noise removal. Dehazing is haze removal in outdoor images and bears similarity with desmoking laparoscopic images. This will be followed with desmoking. We will not cover denoising as an independent domain.

2.1 Speckle Removal In Laparoscopy Images

[7] use a 2-step inpainting process. In the first step, they fill in the missing data by the centroid of available data within a certain distance and perform strong smoothing using a Gaussian kernel. The smooth image output of the first step and the original image is combined using a weight mask in step 2. The weight mask has high weights near the speckles and decays non-linearly with distance. This results in a gradual transition between original image and the smooth median filtered image. The results however, are smooth and lack texture. This is expected because median filtering is not suitable to interpolate texture.

Isotropic color diffusion is used by [2]. They use discrete convolutions with a kernel repeatedly untill convergence is reached.

Chapter 3

Materials and Methods

3.1 Including Figures

Figures are conveniently included using postscript format. If you are generating a figure in a software, please check if the software supports writing to a postscript or a PDF format. This format is loss less vector format and with reproduce in any magnification without any pixelation. Make sure to write it to an "Encapsulated Post-script"or .eps format.

Figures should be given a label and which can be used to refer to them in the running text using `\ref{}` command. Figure **??** describes the process flow sheet of the experimental set up used in this report. The Figure **??** can also be refered by a short form notation a pre-defined macro `\Figref`.

Chapter 4

Results and Discussions

4.1 Including Tables

Tables are to be used in a special environment so that they have a Number, caption and appear in the list of tables. Table 4.1 is a sample table. In the case of tables, it is a convention to write the caption above the table. Note that in the case of figures the caption appears below the figure.

Table 4.1: Physical properties of the materials used.

Property	Value
Particle Density, ρ_{p}	2500 kg/m^3
Viscosity, η_{s}	1×10^{-3} Pa-s

Appendix A

Supporting Material

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List of Publications

Put your publications from the thesis here. The packages `multibib` or `bibtopic` or `biblatex` or enumerate environment or thebibliography environment etc. can be used to handle multiple different bibliographies in the document.

Acknowledgements

This section is for the acknowledgments. Please keep this brief and resist the temptation of writing flowery prose! Do include all those who helped you, e.g. other faculty/staff you consulted, colleagues who assisted etc.

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COLOPHON

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