A Preference Analysis Approach to Robust Geometric Model Fitting in Computer Vision

by

Hoi Sim Wong

A dissertation submitted to the School of Computer Science, The University of Adelaide for the degree of Doctor of Philosophy

March, 2013

To my parents and my sister,
for their unconditional love and endless support.

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Abstract

Robust model fitting is a crucial task in numerous computer vision applications, where the information of interest is often expressed as a mathematical model. The goal of model fitting is to estimate the model parameters that "best" explain the observed data. However, robust model fitting is a challenging problem in computer vision, since vision data are (1) unavoidably contaminated by outliers due to imperfections in data acquisition and preprocessing, and (2) often contain multiple instances (or structures) of a model.

Many robust fitting methods involve generating hypotheses using random sampling, and then (1) score the hypotheses using a robust criterion or (2) use a mode seeking or clustering method to elicit the potential structures in the data. Obtaining a good set of hypotheses is crucial for success, however this is often time-consuming, especially for heavily contaminated data. In addition, many irrelevant hypotheses are unavoidably generated during sampling process. This frequently becomes an obstacle for accurate estimation, and has been ignored in previous methods. In particular, mode seeking-based fitting methods are very sensitive to the proportion of good/bad hypotheses.

This thesis proposes several sampling methods for rapid and effective generation of good hypotheses, and hypothesis filtering methods to remove bad hypotheses for accurate estimation. The techniques developed here can be easily integrated into existing fitting methods to significantly improve fitting accuracy. We also propose a hierarchical fitting method, which recognizes that details in real-life data are organized hierarchically (i.e., large structures cascading down to finer structures). This can avoid excessive parameter tuning to obtain a particular fitting result, whereas existing fitting methods often fit data with a single number of structures and permit only one interpretation of the data.

The algorithms in this thesis are motivated by preference (or ranking) analysis, which has been widely used in areas such as information retrieval, artificial intelligence and marketing. Preference analysis provides a sophisticated non-parametric approach to analyzing the data and hypotheses in model fitting problems. The algorithms developed here are shown to be more reliable than previous methods, and to perform well in various vision tasks.

Declaration

I, Hoi Sim Wong, certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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Signature

Date

Preface

During my PhD study at the University of Adelaide from 2009 to 2012, I have produced two conference papers and two journal articles. This thesis is based on the content presented in those papers, as listed in the following:

Conference Publications:

- H. S. Wong, T.-J. Chin, J. Yu, and D. Suter. Dynamic and Hierarchical Multi-Structure Geometric Model Fitting. In *Proceedings of International Conference on Computer Vision*, pages 1044–1051, 2011
- H. S. Wong, T.-J. Chin, J. Yu, and D. Suter. Efficient Multi-Structure Robust Fitting with Incremental Top-k Lists Comparison. In *Proceedings of Asian Conference on Computer Vision*, volume 6495, pages 553–564, 2010

Journal Publications:

- H. S. Wong, T.-J. Chin, J. Yu, and D. Suter. Mode Seeking Over Permutations for Rapid Geometric Model Fitting. *Pattern Recognition*, 46(1):257 – 271, 2013. Accepted in 2012
- H. S. Wong, T.-J. Chin, J. Yu, and D. Suter. A Simultaneous Sample-and-Filter Strategy for Robust Multi-Structure Model Fitting. *Computer Vision and Image Understanding*. Submitted in August 2011, currently under minor revision

I have also produced the following dataset, which has been made publicly available.

DataSet:

- AdelaideRMF is a dataset for robust model fitting. It contains a collection of image pairs for homography and fundamental matrix estimation on single and multi-structure data. AdelaideRMF can be downloaded from `http://cs.adelaide.edu.au/~hwong/doku.php?id=data`.

Acknowledgments

This PhD study was an exciting and challenging journey for me, and completing this journey would not have been possible without the support of many people.

First and foremost, I would like to express my deepest gratitude to my supervisor Prof. David Suter, for his continuous guidance, advice and support over the past few years. I am particularly grateful for his countless hours of effort on reviewing and improving my research papers and thesis. He always believed in me when I doubted myself, and kept encouraging me to persevere through difficult times. I am sure that I could not have finished this thesis without his help and support. I am deeply honored and proud to be his student.

I am sincerely grateful to my supervisor Dr. Tat-Jun Chin, for his kind help, support and encouragement in every aspect of my research. He has always made himself available to me for discussing research problems and potential directions. Without him, I could not have completed this PhD journey in such an enjoyable way. I am truly proud to be his first PhD student.

I am truly indebted and thankful to my supervisor Dr. Michael Sheng, for his continuous support, advice and guidance over the past four years. He is the one who inspired and encouraged me to pursue a PhD when I was studying for my honours degree. Without him, this PhD thesis might not even exist.

It is my great pleasure to have had the opportunity to work with Dr. Jin Yu, who was always so kind and supportive. I am very thankful for her time and effort in helping me with the writing and experiments.

I owe a huge debt of gratitude to my parents, my sister Kathy Wong, and my best friends Suki Chan and Emma Fan for their unconditional love, support and encouragement. My most heartfelt thanks go to my family for their spiritual and financial support during my eight years of study in Australia. Special thanks to my sister and Emma for taking good care of my mum and dad while I was not in Hong Kong, making it possible for me to focus on my study. I especially thank Suki for all the joy she has brought me and for all the ways in which she has taken care of me all these years in Australia.

Finally, I thank the University of Adelaide for the financial support through the Adelaide Graduate Research Scholarship over the past three years.