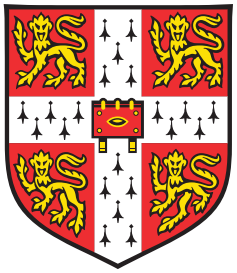
Sequential Labeling with Structural SVM Under Non-decomposable Loss Functions



Guopeng Zhang

Supervisor: Prof. Massimo Piccardi

Faculty of Engineering and Information Technology
University of Technology, Sydney

This dissertation is submitted for the degree of
Doctor of Philosophy

March 2017

Declaration

I, Guopeng Zhang, hereby declare that except where specific reference is made to the work of others, the contents of this dissertation are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This dissertation is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Acknowledgements. This dissertation contains fewer than 65,000 words including appendices, bibliography, footnotes, tables and equations and has fewer than 150 figures.

Guopeng Zhang
March 2017

Acknowledgements

It is not easy to just say "I would like to thank someone" in the acknowledgements section of a PhD thesis. And I really lack words to express my heartfelt thanks to those who have helped me during my PhD study. However, I will always remember that I had the privilege to work with such excellent researchers.

- I would like to sincerely thank Prof. Massimo Piccardi for his kind help during the whole period of my PhD study. Prof. Massimo Piccardi constantly held meetings with me every week to give essential advice on theory and paper annotation in order to help me become a researcher. He is not only a professor but a good friend to me. Since I first came to Sydney he has cared about my life in every respect. It has been an honor for me to be his student and to work with him.
- Dr. Ava Bargi and Dr. Ehsan Zare Borzeshi are also very good researchers. They both started PhD study earlier than me and gave me helpful advice. We frequently exchanged ideas and held discussions with each other to improve our paper writing. I am very glad to have had the chance to work with them.
- I would also like to thank Dr. Shaukat Abidi, Mr. Zhen Wang, Mrs. Fairouz Hussein and Mr. Sari Awwad. Although PhD study is hard and tiring, I was always happy to chat and drink coffee with you all!
- I would like to dedicate this thesis to my loving parents Zhenbo Zhang and Meilin Zhou who supported me emotionally and financially for the duration of my time in Sydney. They made every effort to ensure that I studied and lived well here.
- Last but not least, I would like to extend my sincere thanks to my lovely wife Zhibin Li, who has been my constant support for over 11 years. She has given me more than I can ever say. She worked hard to earn money during my study and cooked meals for me. She encouraged me whenever I felt down or fatigued Without her, I definitely would not have got through the years of exacting study and research. I thank her most

sincerely for everything that she has done for me.

Guopeng Zhang,
June 2016, Sydney

Abstract

This thesis mainly focuses on the sequential labeling problem. Sequential labeling is a fundamental problem in computer vision and machine learning areas and has been researched in many applications. The most popular model for sequential labeling is the hidden Markov model where the sequence of class labels to be predicted is encoded as a Markov chain. In recent years, other structural models, in particular, the extension of SVM to the classification of sequences and other structures have benefited from minimum-loss training approaches which in many cases lead to greater classification accuracy. However, SVM training requires the choice of a suitable loss function. Common loss functions available for training are restricted to decomposable cases such as the zero-one loss and the Hamming loss. Other useful losses such as the F_1 loss, average precision (AP) loss, equal error rates and others are not available for sequential labeling. For the average precision, some results have been proposed in the past, but our results are more general. On the other hand, classification accuracy often suffers from the uncertainty of ground truth labeling and traditional structural SVM only ensures that the ground-truth labeling of each sample receives a score higher than that of any other labeling. However, no specific score ranking is imposed among the other labelings.

For the loss functions problem, we propose a training algorithm that can cater for the F_1 loss and any other loss function based on the contingency table. In our thesis, we propose exact solutions for the F_1 loss, precision/recall at fixed value of recall/precision, precision for a fixed value of predicted positives ("precision at k"), precision/recall Break-Even Point and a formulation of the Average Precision (AP loss). For further experiments, we not only apply the AP loss in the training, but also in testing.

For the uncertainty in the ground-truth labeling problem, we extend the standard constraint set of structural SVM with constraints between "almost-correct" labelings and less desirable ones to obtain a partial ranking structural SVM (PR-SSVM) approach.

We choose different datasets to verify our approaches: human activity datasets including the challenging TUM Kitchen dataset and CMU-MMAC dataset, and the Ozone Level Detection dataset. The experimental results show the efficiency of our approaches on different performance measurements, such as detection rate, false alarm rate and F_1 measure,

compared to the conventional SVM, HMM and structural SVM with decomposable losses such as the 0-1 loss and Hamming loss.

Table of contents

List of figures

List of tables