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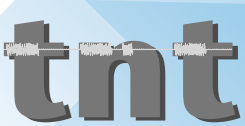
Saif Dawood Salman Al-Shaikhli, M. Sc.,
Hannover

Medical Image Segmentation using Level Sets and Dictionary Learning



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Medical Image Segmentation using Level Sets and Dictionary Learning

Von der Fakultät für Elektrotechnik und Informatik

der Gottfried Wilhelm Leibniz Universität Hannover

zur Erlangung des akademischen Grades

Doktor-Ingenieur

(abkürzung Dr.-Ing.)

genehmigte Dissertation

von

M.Sc. Saif Dawood Salman Al-Shaikhli

geboren am 26 May 1981 in Baghdad

2015

Referent:	Prof. Dr.-Ing. Bodo Rosenhahn
Korreferent:	Prof. Dr. Xiaoyi Jiang
Prüfungsvorsitz:	Prof. Dr.-Ing. Jörn Ostermann
Tag der Promotion:	11/12/2015

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Salman Al-Shaikhli, Saif Dawood
Medical Image Segmentation using Level Sets and Dictionary Learning
Fortschr.-Ber. VDI Reihe 21 Nr. 415. Düsseldorf: VDI Verlag 2016.
130 Seiten, 39 Bilder, 16 Tabellen.
ISBN 978-3-18-341521-2, ISSN 0178-9481,
€ 52,00/VDI-Mitgliederpreis € 46,80.

Keywords: Segmentation – Classification – Level set – Dictionary learning – Medical images – Computed tomography – Magnetic resonance imaging

This dissertation addresses the segmentation and classification problem of normal and abnormal structures in the human body. Due to the boundary ambiguity between regions in medical images, organ segmentation is a challenging task, and it requires prior knowledge for accurate segmentation. The segmentation objectives in this dissertation are to develop fully automatic methods for anatomical organ segmentation using prior knowledge. Prior knowledge is incorporated in terms of local and global image features. Two novel strategies are proposed. The first one is based on global image features. The second strategy is combining the local and global image features using both the level set and the dictionary learning methods.

Bibliographische Information der Deutschen Bibliothek
Die Deutsche Bibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliographie; detaillierte bibliographische Daten sind im Internet unter http://dnb.ddb.de abrufbar.

Bibliographic information published by the Deutsche Bibliothek
(German National Library)
The Deutsche Bibliothek lists this publication in the Deutsche Nationalbibliographie (German National Bibliography); detailed bibliographic data is available via Internet at http://dnb.ddb.de.

ISSN 0178-9481

ISBN 978-3-18-341521-2

Acknowledgements

I would first like to express my special appreciation and thanks to my advisor Prof. Dr.-Ing. Bodo Rosenhahn. I would like to thank you for his patience and encouragement through my PhD research, and for allowing me to grow as a research scientist.

Special thanks to the remaining members of my dissertation committee, Prof. Dr.-Ing. Jörn Ostermann and Prof. Dr. Xiaoyi Jiang, for dedicating the time to review my thesis and evaluate my work. I would especially like to thank Dr.-Ing. Michael Ying Yang for his support and advice through my PhD study and pushing me to successfully complete my PhD thesis.

Many thanks to German Academic Exchange Service "Deutscher Akademischer Austauschdienst (DAAD)" and MOHESR-Iraq (Baghdad University) for their partially funding and support. I gratefully acknowledge these supports.

I would also like to thank all of my friends who supported me in writing my dissertation and supported me to strive towards my goal. Many thanks to all members of the Institute for Information Processing (TNT).

Special thanks to my parents, Mrs. Khalidah Majeed and Mr. Dawood Al-Shaikhli, and my parents-in-law, Dr. Wareda Korshid and Dr. Thabit A. Abdulkhaleq Dagstan. I never forget their unconditional trust, encouragement, and generous love.

Finally and the most importantly, I would like to express with love appreciation to my sunshine and beloved wife Zainab T. Ahmed Dagstan (Zezo) and my moonlight and lovely son Zaid. Zainab's encouragement, endless patience, support, and unwavering love were undeniably during the past four years. Zainab has been my great companion and best friend, entertained, and helped me during my PhD to be in the most right way. Therefore, I would like to dedicate this work to my family.

Contents

Abstract

In recent years, medical image analysis technology has grown rapidly. Several algorithms have been innovated to segment and classify anatomical organs, using different medical image modalities such as computed tomography (CT) and magnetic resonance imaging (MRI). Medical image segmentation is a key problem in many applications, such as detection of brain tumors and disorders, or volumetric analysis of the normal brain. In this dissertation, I address the segmentation and classification problem of normal and abnormal structures in the human body. The segmentation objectives in this dissertation are to develop fully automatic methods for anatomical organ segmentation using prior knowledge. Prior knowledge is incorporated in terms of local and global image features using level set and dictionary learning methods. The first part of this dissertation presents an efficient way to include global features to improve organ segmentation. I address the problem of the Mumford-Shah model in segmenting brain structures due to their boundary ambiguity by proposing a topological prior. It provides prior knowledge about the brain topology that helps to accurately segment brain structures. The classical level set energy functional is extended by adding the topological prior. Further, the topological graph is used as a feature to classify normal and abnormal brains. In the second part of this dissertation, I present an efficient strategy to couple the local features of grayscale and label image data using both the level set formulation and the dictionary learning method. I show that the embedding of the sparse representation of local features in the level set formulation leads to a potential boost in segmentation accuracy compared to using only the voxel-wise dictionary learning method. This algorithm is applied to solve single- and multi-region segmentation problems. The third part of this dissertation focuses on a new method that combines the local and global image information in a level set formulation using the dictionary learning approach. I show that such a combination leads to a significant improvement in the segmentation accuracy. Overall, I show that the embedding of prior knowledge in the level set formulation using the dictionary learning approach obtains more accurate segmentation results (92.7 %). For all the proposed methods, I present extensive validation using real clinical data.

Keywords: segmentation, classification, level set, dictionary learning, medical images, computed tomography, magnetic resonance imaging.

Zusammenfassung

In den letzten Jahrzehnten haben die Technologien der medizinischen Bildanalyse große Fortschritte gemacht. Dabei wurden mehrere Algorithmen zur Segmentierung und Klassifizierung verschiedener anatomischer Organe mit verschiedenen medizinischen bildgebenden Verfahren entwickelt. Diese Dissertation befasst sich mit der Segmentierung und Klassifizierung von normalen und abnormalen Strukturen des menschlichen Körpers. Zielsetzung der Segmentierung im Rahmen dieser Dissertation ist die Entwicklung eines vollautomatischen Verfahrens für die Organsegmentierung. Dazu wird Vorwissen in Form von lokalen und globalen Bildmerkmalen in bestehende Level-Set-Verfahren und Dictionary Learning Methoden integriert. Der erste Teil dieser Dissertation stellt eine effiziente Methode für die Integration globaler Merkmale vor, um die Organsegmentierung zu optimieren. Bei der Verwendung des Mumford-Shah-Modells zur Segmentierung der Hirnstrukturen entstehen Mehrdeutigkeiten in Randbereichen, die ich durch Hinzufügen von topologischen Vorwissen auflöse. Die klassische Level-Set-Energiefunktion durch zusätzliches, topologisches Vorwissen erweitert. Des Weiteren wird dieser topologischer Graph auch als ein Merkmal für das Klassifizieren normaler und anormaler Gehirne verwendet. Im zweiten Teil der Arbeit präsentiere ich eine effiziente Strategie, welche die Level-Set-Formulierung sowie Dictionary Learning verwendet, um lokale Merkmale der Grauwerte und gelabelte Bilddaten gleichermaßen einzubeziehen, berücksichtigen. Ich demonstriere, dass die Verwendung der "Sparse Representation" der lokalen Bildmerkmale in der Level-Set-Formulierung zu einer Erhöhung der Segmentierungsgenauigkeit im Vergleich zum konventionellen voxelbasierten Dictionary Learning, führt. Der dritte Teil dieser Arbeit beschäftigt sich mit einer neuen Methode, welche durch die Verwendung von Dictionary Learning die lokalen und globalen Bildinformationen in einer Level-Set-Formulierung kombiniert. Diese Kombination führt zu einer signifikanten Verbesserung der Segmentierungsgenauigkeit. Allgemein stelle ich fest, dass das Hinzufügen von Vorwissen in der Level-Set-Formulierung durch die Verwendung von Dictionary Learning ausgenutzt werden kann, um genauere Segmentierungsergebnisse (92.7 %) zu erhalten.

Stichworte: Segmentierung, Klassifikation, Level-Set, Dictionary-Lernen, medizinische Bilder, Computertomographie, Magnetresonanztomographie.