# **ABSTRACT**

Deep learning methods have shown great success in many research areas such as object recognition, speech recognition, and natural language understanding, due to their ability to automatically learn a hierarchical set of features that is tuned to a given domain and robust to large variability. This motivates the use of deep learning for neurological applications, because the large variability in brain morphology and varying contrasts produced by different MRI scanners makes the automatic analysis of brain images challenging.

However, 3D brain images pose unique challenges due to their complex content and high dimensionality relative to the typical number of images available, making optimization of deep networks and evaluation of extracted features difficult. In order to facilitate the training on large 3D volumes, we have developed a novel training method for deep networks that is optimized for speed and memory. Our method performs training of convolutional deep belief networks and convolutional neural networks in the frequency domain, which replaces the time-consuming calculation of convolutions with element-wise multiplications, while adding only a small number of Fourier transforms.

We demonstrate the potential of deep learning for neurological image analysis using two applications. One is the development of a fully automatic multiple sclerosis (MS) lesion segmentation method based on a new type of convolutional neural network that consists of two interconnected pathways for feature extraction and lesion prediction. This allows for the automatic learning of features at different scales that are optimized for accuracy for any given combination of image types and segmentation task. Our network also uses a novel objective function that works well for segmenting underrepresented classes, such as MS lesions. The other application is the development of a statistical model of brain images that can automatically discover patterns of variability in brain morphology and lesion distribution. We propose building such a model using a deep belief network, a layered network whose parameters can be learned from training images. Our results show that this model can automatically discover the classic patterns of MS pathology, as well as more subtle ones, and that the parameters computed have strong relationships to MS clinical scores.

**BIOGRAPHICAL NOTES**

Place of Birth: Magdeburg, Germany

Academic Studies: Dipl.Ing., Otto-von-Guericke-Universität Magdeburg, 2010

# **GRADUATE STUDIES**

Field of Study: Biomedical Engineering

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| --- | --- | --- |
| **Courses**  BMEG 556  EECE 544  CPSC 540  PHYS 545  EECE 518 | Clinical and Industrial Biomedical Engineering  Medical Imaging  Machine Learning  Anatomy, Physiology and Statistics for Medical Physicists  Human Interface Technologies | **Instructors**  Prof. B. Jaggi  Dr. R. Rohling  Dr. N. de Freitas  Dr. A. MacKay  Dr. S. Fels |
|  |  |  |

# **AWARDS**

UBC MS Connect Education Program Travel Award, 2015

MICCAI Student Travel Award, 2015

MICCAI Student Travel Award, 2014

Faculty of Applied Science Graduate Award, 2012

Best Graduate of 2010 in Computational Visualistics, 2010

**PUBLICATIONS**

***Journal Papers***

* Brosch, Tom and R. Tam. Efficient training of convolutional deep belief networks in the frequency domain for application to high-resolution 2D and 3D images. Neural Computation, 27(1), pages 211–227, 2015.
* Brosch, Tom, L.Y.W. Tang, Y. Yoo, D.K.B. Li, A. Traboulsee, and R. Tam. Deep 3D convolutional encoder networks with shortcuts for multiscale feature integration applied to multiple sclerosis lesion segmentation. IEEE Transactions on Medical Imaging, 2016. (accepted)

***Conference Papers***

* Brosch, Tom and R. Tam, for the Alzheimer’s Disease Neuroimaging Initiative.

Manifold learning of brain MRIs by deep learning. In: K. Mori et als. (Eds.): MICCAI 2013, Part II, LNCS 8150, pages 633–640, 2013.

* Brosch, Tom, Y. Yoo, A. Traboulsee, D.K.B. Li, and R. Tam. Modeling the variability in brain morphology and lesion distribution in multiple sclerosis by deep learning. In: P. Golland et al. (Eds.): MICCAI 2014, Part II, LNCS 8674, pages 462–469, 2014.
* Brosch, Tom, Y. Yoo, L.Y.W. Tang, D.K.B. Li, A. Traboulsee, and R. Tam. Deep

convolutional encoder networks for multiple sclerosis lesion segmentation. In: N.

Navab et al. (Eds.): MICCAI 2015, Part III, LNCS 9351, pages 3–11, 2015.

***Book Chapters***

* Brosch, Tom, Y. Yoo, L.Y.W. Tang, and R. Tam. Deep learning of brain images and its application to multiple sclerosis. In: G. Wu and M. Sabuncu (Eds.): Machine Learning and Medical Imaging, chapter 3, Elsevier, 2016. (in press)

## SUPERVISORY COMMITTEE

Dr. Roger Tam (Research Supervisor)

Dr. Rafeef Abugharbieh (Research Co-supervisor)

Dr. Purang Abolmaesumi (Committee Member)

Dr. Jane Z. Wang (Committee Member)

Dr. Ghassan Hamarneh (Committee Member)



### PROGRAMME

The Final Oral Examination

For the Degree of

DOCTOR OF PHILOSOPHY

(Biomedical Engineering)

##### TOM BROSCH

Dipl.Ing., Otto-von-Guericke-Universität Magdeburg, 2010

Monday, June 13, 2016, 12:30 pm

Room 418, MacLeod Building

*Latecomers will not be admitted*

# **“Efficient Deep Learning of 3D Structural Brain MRIs for Manifold Learning and Lesion Segmentation with Application to Multiple Sclerosis”**

## EXAMINING COMMITTEE

Chair:

To be completed by G+PS

Supervisory Committee:

Dr. Roger Tam, Research Supervisor (Biomedical Engineering)

Dr. Purang Abolmaesumi (Electrical & Computer Engineering)

University Examiners:

Dr. Martin J. McKeown (Neuroscience)

Dr. Jim Little (Computer Science)

External Examiner:

To be completed by G+PS