Oula Puonti

Senior Researcher

Danish Research Centre for Magnetic Resonance (DRCMR) / Athinoula A. Martinos Center for Biomedical Imaging

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Education

Technical University of Denmark — *Kgs. Lyngby, Denmark*
PhD Computer Science — *February, 2016*
- Thesis title: ”Computational Analysis of Brain Images: Towards a Useful Tool in Clinical Practice”

University of Helsinki — *Helsinki, Finland*
MSc Theoretical Physics — *October, 2012*
- Thesis title: ”Automatic Parcellation of Brain Images Using Parametric Generative Models”

Professional Experience

2026 -	**Senior Researcher**, Danish Research Centre for Magnetic Resonance, Hvidovre, Denmark
2022 -	**Affiliated Researcher**, Laboratory for Computational Neuroimaging, Athinoula A. Martinos Center for Biomedical Imaging, Boston, MA
2021 - 2026	**Research Fellow**, Danish Research Centre for Magnetic Resonance, Hvidovre, Denmark
2018 - 2021	**Postdoc**, Danish Research Centre for Magnetic Resonance, Hvidovre, Denmark
2016 - 2018	**Postdoc**, Department of Health Technology, Technical University of Denmark, Kgs. Lyngby, Denmark
2016	**Postdoc**, Department of Neurology, Technical University of Munich, Munich, Germany
2012 - 2016	**PhD student**, Department of Applied Mathematics and Computer Science, Technical University of Denmark, Kgs. Lyngby, Denmark
2010 - 2012	**Research Assistant**, Department of Information and Computer Science, Aalto University, Espoo, Finland
2010 - 2012	**Research Assistant**, Department of Biomedical Engineering and Computational Science, Aalto University, Espoo, Finland
2009	**Research Assistant**, Low Temperature Laboratory, Brain Research Unit, Aalto University, Espoo, Finland

Awards, Fellowships, & Grants

2025	**“Cerebellum redux: generating detailed cerebellar surface models for source localization”**, Lundbeckfonden	*150,000 DKK*
2024-2028	**Member of the Lundbeck Foundation Investigator Network**, Lundbeckfonden	
2021	**Lundbeck & NIH BRAIN Initiative Grant: “Mapping the lateral prefrontal cortex: improved parcellation and laminar models”**, Lundbeckfonden	*2,980,000 DKK*
2021	**Subrecipient Investigator on NIH Grant “FreeSurfer Development, Maintenance, and Hardening” (2R01EB023281-05, PI: Douglas N. Greve)**, National Institutes of Health	*46000 $*
2012	**Full PhD Scholarship**, Technical University of Denmark (DTU)	

Mentoring & Teaching Experience

- **Current supervision:** Main supervisor of Jesper D. Nielsen (postdoc, DRCMR). Co-supervisor of four postdocs at DRCMR and the Martinos Center. Co-supervisor of Merle Diedrichsen (PhD student, DTU). Co-supervisor of five BSc students.

- **Previous supervision:** Co-supervisor of two postdocs. Co-supervisor of two PhD students. Supervisor of multiple Bachelor and Master students.

- **Teaching:** Co-organizer and lecturer on course 2252 Medical Image Analysis (Technical University of Denmark). Co-organizer of a weekly ”methods clinic”, which is an open forum for people to bring technical questions at the Danish Research Centre for Magnetic Resonance.
- **External examiner (Censor)**: I have acted as an external examiner in six Master’s thesis defences and in one Bachelor’s thesis defence. Additionally, I have been an external examiner in oral exams for the following courses:
  - *02463 Active machine learning and agency*, 5 ECTS, Level: Bachelor, Years: 2022, 2024, 2025, Department for Applied Mathematics and Computer Science, Technical University of Denmark.
  - *02526 Mathematical Modeling*, 5 ECTS, Level: Bachelor, Years: 2022, Department for Applied Mathematics and Computer Science, Technical University of Denmark.
  - *Data Mining*, 7.5 ECTS, Level: Master, Years: 2025, IT University Copenhagen

Professional Service

Organization of Meetings and Workshops

2023	**Boston Medical Imaging Workshop**, Organizer	*Boston*
2021-	**Copenhagen Brain Stimulation Week**, Speaker, organizer of hands-on software sessions	*Copenhagen*

Peer Review

Reviewer for Medical Image Analysis, IEEE Transaction on Medical Imaging, Imaging Neuroscience, NeuroImage, NeuroImage:Clinical. Ad-hoc reviewer for Journal of Neural Engineering, Brain Stimulation, Nature Neuroscience, IEEE Transaction on Biomedical Engineering, Brain Structure and Function, Human Brain Mapping, Computer Methods and Programs in Biomedicine

Scientific Output

Research metrics:

h-index: 20 (Google scholar), i10-index: 37 (Google scholar), Citations: 3610 (Google scholar)

ORCID: 0000-0003-3186-244X

Google scholar: `https://scholar.google.com/citations?user=sVDWresAAAAJ&hl=en`

Software :

FreeSurfer (`https://surfer.nmr.mgh.harvard.edu/`): I have developed and contributed to multiple brain image analysis tools distributed within the *FreeSurfer* software suite, which has more than 50000 activated licenses, making it one of the largest neuroimaging toolboxes. I have been a part of the development of the following tools.

- `SAMSEG`: A Bayesian segmentation approach for neuroanatomical segmentation of MR scans of any contrast and resolution. SAMSEG uses traditional optimization-based segmentation for each input scan and is highly tunable to ”difficult” data, e.g., clinical scans that have low resolution or a partial field of view. The base version of SAMSEG has been extended for tumor and lesion segmentation.
- `NextBrain`: A segmentation tool based on a histological atlas consisting of more than 300 different structures. `NextBrain` uses a similar algorithm as SAMSEG, but has much better detail. `NextBrain` can be used to measure changes at the level of individual sub-structures enabling fine-grained analysis of changes within and across subjects.

* `SynthSeg:` A deep-learning based approach for segmenting MR scans of various contrast and resolution. `SynthSeg` uses a novel training paradigm called ”domain randomization” where no actual MR data is used for training. Instead, the training data is synthesized during training yielding extremely variable data, which makes the model generalize well across different scanners and scan sequences.
* `Recon-all-clinical & Recon-any:` A deep learning approach for placing cortical surfaces on clinical data (`recon-all-clinical`) and low field MR data acquired using a scanner with a field strength of 65 mT (`recon-any`). Similar to `SynthSeg` these tools use domain randomization for training, but instead of predicting a segmentation, they output a distance map to the cortex. This distance map can then be used to place the white matter and gray matter surfaces using the surface placement steps implemented in *FreeSurfer*.

SimNIBS (`http://simnibs.org`): I am one of the main developers of the Simulation of Non-Invasive Brain Stimulation (*SimNIBS*) toolbox, which can be used to create realistic head models for modeling the propagation of an externally induced electric field. *SimNIBS* is widely adopted by the brain stimulation field and has to date more than 49000 downloads across different versions. Apart from maintaining the whole code base, fixing bugs, and supporting users, my main contributions to *SimNIBS* are:

* `charm:` A pipeline for generating volumetric tetrahedral meshes from MR scans. The pipeline consists of multiple steps starting with segmentation of the head and brain structures, registration to standard MNI space, creating surface models of the cortical sheet and finally constructing a tetrahedral mesh from the segmentation. I have specifically developed a probabilistic atlas for the whole head, which contains more than 50 brain and head structures, and forms the basis of the segmentation and registration parts. The detailed segmentation allows for more accurate simulations of the electric field propagation through the head.
* `TopoSynth:` A deep-learning based cortical surface placement approach, which is based on domain randomization and can thus be used to model the cortical sheet given any type of input scans. The model is trained to predict the surface location directly from the input scan, which makes it extremely fast (1 second for a full cortical surface reconstruction). `TopoSynth` is part of the `charm` pipeline and is used to improve the simulation accuracy at the cortex which consists of the neurons targeted by non-invasive brain stimulation.

I have a strong motivation to develop open-source tools, which: 1) solve real medical image analysis and biophysical modeling tasks, 2) are easy-to-use, maintain, and extend, and 3) work robustly across different input data. I am contributing these tools to two important open-source software packages and more recently started exploring possibilities to translate them also into commercial products.

- **Publication list:**
  - 10 highlighted papers († and ‡ denote shared first and last authorship respectively):
    1. **Oula Puonti**, Koen Van Leemput, Guilherme B Saturnino, Hartwig R Siebner, Kristoffer H Madsen and Axel Thielscher. *Accurate and robust whole-head segmentation from magnetic resonance images for individualized head modeling*. In: Neuroimage 219, 2020, p. 117044
    2. Guilherme B Saturnino†, **Oula Puonti**†, Jesper D Nielsen, Daria Antonenko, Kristoffer H Madsen and Axel Thielscher. *SimNIBS 2.1: a comprehensive pipeline for individualized electric field modelling for transcranial brain stimulation*. In: Brain and human body modeling: computational human modeling at EMBC 2018, 2019, pp. 3–25
    3. Jesper D Nielsen, Kristoffer H Madsen, **Oula Puonti**, Hartwig R Siebner, Christian Bauer, Camilla Gøbel Madsen, Guilherme B Saturnino and Axel Thielscher. *Automatic skull segmentation from MR images for realistic volume conductor models of the head: Assessment of the state-of-the-art*. In: Neuroimage 174, 2018, pp. 587–598.

       These three papers describe the head modeling pipelines in the old (papers 2 and 3) and the new (paper 1) version of *SimNIBS*. Paper 1 describes the method behind the `charm` pipeline. The three papers have been jointly cited 800 times.

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    4. **Oula Puonti**, Juan Eugenio Iglesias and Koen Van Leemput. *Fast and sequence-adaptive whole-brain segmentation using parametric Bayesian modeling*. In: NeuroImage 143, 2016, pp. 235–249.

       Paper 4 describes the `SAMSEG` segmentation pipeline and has been cited 229 times.

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    5. Jesper Duemose Nielsen, Karthik Gopinath, Andrew Hoopes, Adrian Dalca, Colin Magdamo, Steven Arnold, Sudeshna Das, Axel Thielscher, Juan Eugenio Iglesias and **Oula Puonti**. *End-to-end Cortical Surface Reconstruction from Clinical Magnetic Resonance Images*. In: arXiv preprint arXiv:2505.14017, 2025
    6. Karthik Gopinath, Douglas N Greve, Colin Magdamo, Steve Arnold, Sudeshna Das, **Oula Puonti**, Juan Eugenio Iglesias, Alzheimer's Disease Neuroimaging Initiative et al. *"Recon-all-clinical": Cortical surface reconstruction and analysis of heterogeneous clinical brain MRI*. in: Medical Image Analysis, 2025, p. 103608

       Papers 5 & 6 describe the methods behind `TopoSynth` and `recon-all-clinical`, respectively, and illustrate my more recent deep learning-based work on placing cortical surfaces on MR scans.

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    7. Xiaoling Hu, Karthik Gopinath, Peirong Liu, Malte Hoffmann, Koen Van Leemput, **Oula Puonti**‡ and Juan Eugenio Iglesias‡. *Hierarchical uncertainty estimation for learning-based registration in neuroimaging*. In: International Conference om Learning Representations (ICLR), 2025
    8. Karthik Gopinath, Xiaoling Hu, Malte Hoffmann, **Oula Puonti**‡ and Juan Eugenio Iglesias‡. *Registration by regression (RbR): A framework for interpretable and flexible atlas registration*. In: International Workshop on Biomedical Image Registration. Springer Nature Switzerland Cham. 2024, pp. 205–215

       Papers 7 & 8 are focused uncertainty estimation and explainability of deep learning-based medical image registration. They show how incorporating uncertainty estimates can *increase* the accuracy of these models. Paper 7 was presented at ICLR, which is one of the leading artificial intelligence conferences.

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9. Xiangrui Zeng, **Oula Puonti**, Areej Sayeed, Rogeny Herisse, Jocelyn Mora, Kathryn Evancic, Divya Varadarajan, Yael Balbastre, Irene Costantini, Marina Scardigli et al. *Segmentation of supragranular and infragranular layers in ultra-high-resolution 7T ex vivo MRI of the human cerebral cortex*. In: Cerebral Cortex 34.9, 2024, bhae362

   Paper 9 shows how deep learning based segmentation can be scaled up to high resolution *ex vivo* data. The main challenge to be solved here is how to balance between context and detail, and sparse training data, when segmenting the layered structure of the cortex. Overcoming the challenge results in extremely detailed segmentations given the resolution of the data set.

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10. **Oula Puonti**, Guilherme B Saturnino, Kristoffer H Madsen and Axel Thielscher. *Value and limitations of intracranial recordings for validating electric field modeling for transcranial brain stimulation*. In: Neuroimage 208, 2020, p. 116431

    Paper 10 illustrates how a Bayesian re-analysis of a fairly simple linear regression problem can yield very different results compared to a more standard frequentist approach. Correct modeling of the error in the regression variables revealed a linear relationship that was muddled by outliers.
