



# Annual Report 2019



## **Statement of authorship**

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## **Contact information**

Visit the Mohn Medical Imaging and Visualization center at the 5th floor of the Haraldsplass Diakonale Sykehus (new building), Ulriksdal 8, N - 5009 Bergen/Norway.

## **MOHN MEDICAL IMAGING AND VISUALIZATION CENTER- ACTIVITIES REPORT**

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# 1. Introduction



**-Ingfrid Haldorsen**

Mohn Medical Imaging and Visualization center (MMIV) was inaugurated in December 2017. The creation of MMIV was enabled by generous financial support from the Trond Mohn Foundation (TMF) coupled by human and financial support by Haukeland University Hospital (HUS) and the University of Bergen (UiB). These institutions shared a dream: the establishment of an imaging- and visualization center in Bergen. This center was established in order to facilitate high-impact research capitalizing on the advanced preclinical- and clinical imaging infrastructure recently installed at Haukeland UiB. Furthermore, closer cooperation across institutions, faculties and departments was required in order to foster interdisciplinary research with the potential of yielding novel insight relevant for patient care.

Although still in its infancy, MMIV has already grown to become a strong interdisciplinary research center hosting >40 dedicated scientists. Since March 2019 MMIV has been co-localized in the new HUS premises on the top floor of the new Haraldsplass building, providing an excellent view of Bergensdalen. More importantly, the center comprises a vibrant hub for the exchange of ideas and expertise among researchers that all work on projects that prosper within MMIV.

MMIV is a part of the Department of Radiology at Haukeland University Hospital, and we are proud to be a research center located within the hospital – close to the patients and the factors that impact patient care: precise diagnosis and staging, accurate prognostication, and the development of tailored and targeted treatment strategies. The support from CEO Eivind Hansen, HUS and the Head of Dep. of Radiology Aslak Aslaksen, HUS has been instrumental for the successful organization of MMIV within HUS. Furthermore, we highly appreciate the support from UiB and Western Norway University of Applied Sciences (HVL) and their researchers working at MMIV, who represent cornerstones of the center. Importantly, the collaborative and mutually supportive attitudes displayed from all the institutions is central for the success of the center!

One highlight in 2019 was the MMIV conference entitled: "Convergence of medical data science for improved patient care" with >150 participants. The title of the conference captures one of the missions of MMIV: By capitalizing on the multidisciplinary expertise within the center, we strive to merge efforts with clinical doctors in their endeavors to transform patient care. Close integration between medical sciences and basic sciences, often denoted as convergence between sciences, is needed if we are to make substantial advances in medical health care in the years to come. Advances in computer science with the introduction of machine learning are likely to transform medicine in the near future, and this has an immediate relevance particularly within sciences related to diagnostic imaging as well as pathology and genetics. The conference featured world-leading experts in machine learning and advanced imaging technologies as well as clinical experts highlighting the clinical relevance and potential impact of these novel methods for patient care.

As the newly appointed Head of MMIV, it is my true privilege to introduce you to this report, showcasing some of the highlights and successful achievements at MMIV to date. I am confident that we are on the right track pursuing scientific success at MMIV in the years to come. Most importantly, we will continue to scrutinize and search for small pieces in the greater puzzle that may transform patient care! A mission really worth striving for!

## **Vision and Research Areas**

MMIV aims to:

- Bring together technology and medicine for advancing the state of the art in medical imaging and visualization.
- Provide refined imaging tools with which to characterize human disease by revealing imaging markers relevant for early detection and monitoring of disease and for developing individualized and targeted treatment strategies.

## **Organization of the Center**

MMIV is organized as a unit within the Department of Radiology at HUS. Since March 2019 MMIV has been localized on the top floor of the new Haraldsplass building with spacious office facilities including 15 offices and additional meeting-/lunch rooms and mingling area.

The primary investigators (PIs) and researchers at MMIV hold their main positions at HUS, UiB, HVL or Norwegian Research Center (Norce), and some of the PIs also hold adjunct professorships/research positions at UiB/HUS.

HUS has PIs/researchers from Dep. of Radiology and Womens Clinic, and many collaborating partners at other hospital departments. The UiB has PIs/MMIV affiliated researchers from Faculty of Medicine (Depts. of Clinical Medicine, Clinical Science and Biomedicine), Faculty of Mathematics and Natural Sciences (Depts. of Informatics and Mathematics) and Faculty of Psychology (Dep. of Biological and Medical Psychology). HVL (Faculty of Engineering and Science) and NORCE (Dep. of Technology) are also represented with PIs.

## **Research Management**

MMIV research is organized into five focus areas with dedicated teams working closely together on research projects related to:

1. Machine learning
2. Cancer imaging (focus on gynecologic cancer)
3. Neuroimaging (focus on fMRI and psychiatric disorders)
4. Advanced visualization
5. Research- PACS and infrastructure

The leadership group comprising principal investigators of these teams meet monthly to discuss scientific and administrative issues and share updates on progress and plans for the different projects. A monthly public MMIV seminar (duration 60 minutes) followed by coffee/waffles is hosted at Haraldsplass in conjuncture with this leadership meeting. The daily management group at MMIV (comprising the Head of MMIV, Ingfrid Haldorsen, senior researcher Hauke Bartsch, associate professor Noeska Smit and Elin Myhrvold [secretary]) have weekly meetings.

## Biographies



# Marek Kocinski

Marek Kocinski has a master's degree in electronics and telecommunication. He has been involved in projects related to quantitative analysis and modelling of MRI images for tissue characterization. He has as a postdoctoral researcher in the project "Computational medical imaging learning - methods, infrastructure and characterization of tissue surrounding tissue." He is currently working as a postdoctoral researcher in the project "Computational medical imaging learning - methods, infrastructure and characterization of tissue surrounding tissue." He is currently working as a postdoctoral researcher in the project "Computational medical imaging learning - methods, infrastructure and characterization of tissue surrounding tissue."

From 2009 he has been working as an Assistant Professor at Institute of Electronics in TUL. His scientific interests concentrate on 2D, 3D and 4D biomedical image processing, 3D in kidney, prostate, endometrial carcinoma, as well as computer algorithms of vascular tree growth, blood flow computer simulation through vascular tree and compartmental model of exchange between blood at Mohn Medical Imaging and Visualization Centre (MMIV). His research activities are related to design methodologies for 3D biomedical compartmental image analysis with the use of deep learning.



# Lea Starck

" Lea University is about Starck of Bergen. the use of holds a She is perfusion MSc in currently a MRI as medical PhD in the a tool for physics visualization/Hesparing and and Smit potential technology group. Her biomarkers. from the research



# Liucija Vaisvilaite

fMRI

Liucija She is focuses on Vaisvilaite currently reliability holds a PhD of fMRI a MSc stipend at and degree in ReState Cognitive research various exogenous science group and with project endogenous specialization "When in Default that neuroscience is not influence and psychology Default", individual University from the of Bergen, University Norway. signal variability. of Umeå, Her Sweden. research

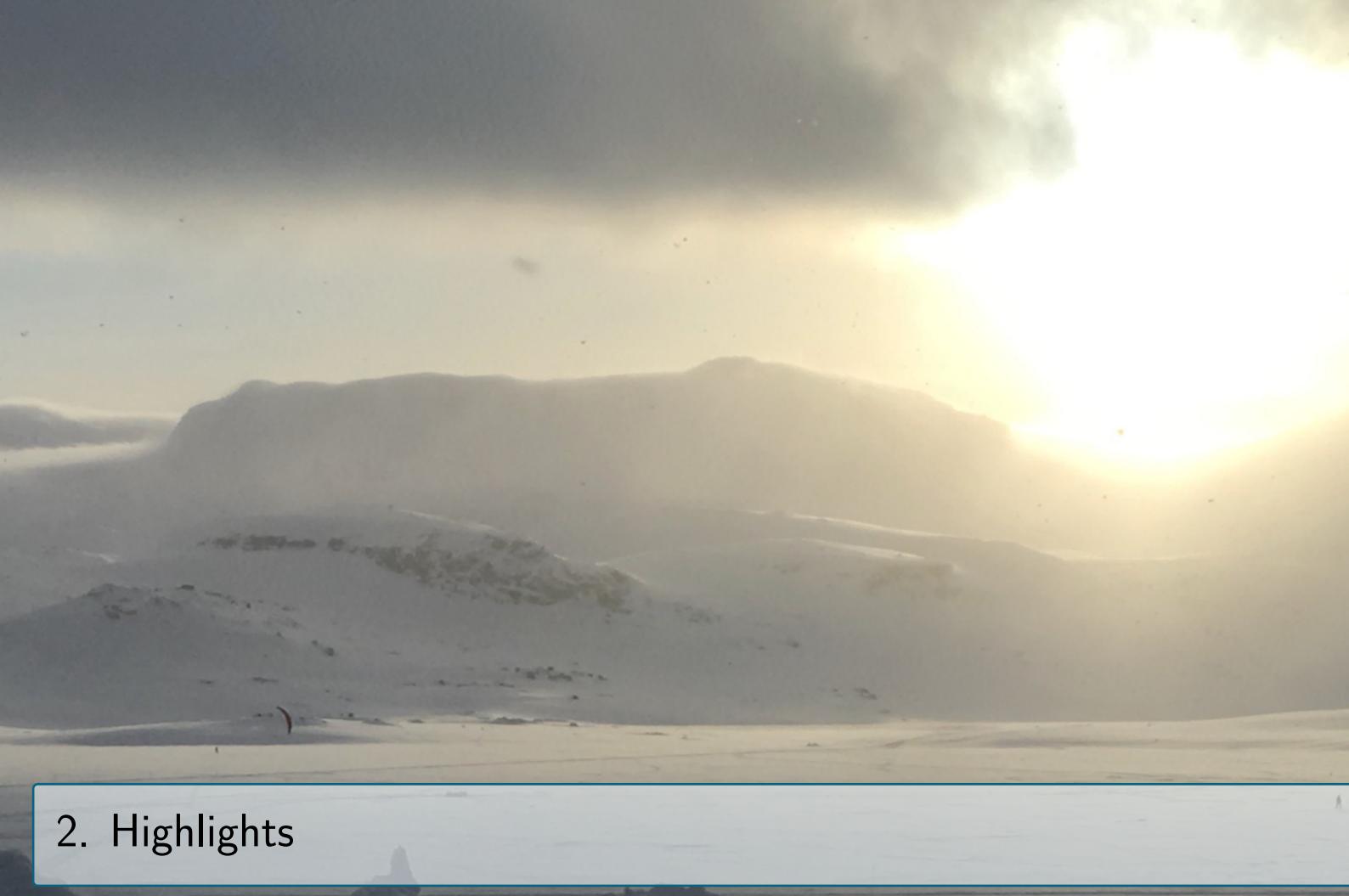


## Kari Strøno Wagner-Larsen

cancer imaging

Kari She is focuses on Strøno currently artificial Wagner-Larsen working intelligence is a MD on a PhD guided from the project in imaging University the Cancer biomarkers of Bergen, Imaging in uterine and a group at cervical specialist MMIV. in Her radiology. research cancer.





## 2. Highlights

## MMIV retreat at Solstrand Hotel

To kick off the opening of the new location at Haraldsplass for the MMIV centre, we organized a retreat at the Solstrand hotel in order to get to know each other and further develop plans for the future of the centre. In the two-day meeting in March, every centre member gave a short presentation introducing themselves and their research activities. In addition to the scientific program, the social program enabled everyone to get to know their colleagues in the now co-located centre.



**The MMIV team at Solstrand.**

## Helse Vest funding to MMIV initiatives

Helse-Vest has allocated funds to 61 of the total 285 applications submitted by the deadline of September 15. Njål Lura, PhD candidate in the gynecological cancer imaging project, has received PhD funding from this competitive call. In addition, Satheshkumar (Sathiesh) Kaliyugaran has received PhD funding for his project in machine learning.

Cecilie Brekke Rygh was awarded financial support for her project "Imaging

biomarkers for precision medicine in Acute Myeloid Leukemia (AML)", in which Noeska Smit and Alexander Lundervold co-lead a workpackage on image data analyses and visualization.

## MMIV at Christiekonferansen

In the "Forsking i front" session from 11:30-12:00, Kristine Eldevik Fasmer presented a talk entitled "Kan vi lære maskiner å finne kreft i MR-bilder?". Kristine, who is a PhD student in the cancer imaging project, talks about her work on machine learning for cancer detection in MRI images. The machine learning project had a stand in the exhibition area, also. Here, they showcased a live demo of human action recognition using deep learning, and displayed how deep neural networks can be used to process and produce useful predictions based on medical images.

## MMIV and COVID-19

The COVID-19 outbreak at the beginning of 2020 allowed researchers of MMIV to focus on research efforts of disease prevention and characterization of patient data affected by the outbreak. The MMIV clinical response team created tools and procedures to manage the data capture of COVID-19 cases for image and assessment instruments. This included simple measures such as adjusting the radiology workflow at MMIV to allow all radiologists working at MMIV to occupy separate offices, limiting the potential effects of an

outbreak. All MMIV seminars switched to a virtual solution.

## MMIV researchers awarded NOK 7m from NRC

In 2020 we received new funding for a project on workflow-related machine learning from the Norwegian Research Council. The project is headed by Hauke Bartsch, Alexander Lundervold, Ingrid Haldorsen, Arvid Lundervold, Erlend Hodneland, and Erling Andersen. The primary objective of this project is to construct a robust, working prototype that receive a DICOM study pushed from the PACS system, setup and run it through deep learning-based image processing methods, and format and return the resulting information, segmentation mask, derived reports, and quantitative measures back into the PACS. The system will also facilitate the evaluation and further training of the deep learning model based on feedback from the user by storing such modifications as annotations in the PACS. The prototype workflow will be assessed by experienced radiologists from the relevant clinical domains. Secondary objective is to prove that our approach is generalizable. This objective is three-fold: the approach should generalize to other computational medical imaging methods, different medical applications, and provide a clear path to embed our product in production-level, widely used PACS and image reading systems.

### 3. Events



Hauke Bartsch, Dr. rer. nat.

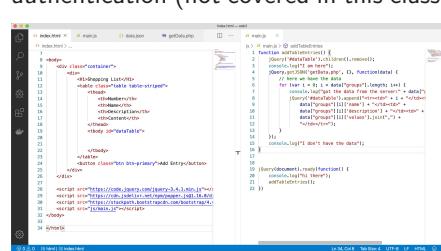
# The very basics of web-programming - without any gaps

A workshop in the without-any-gaps series of MMIV

No prior programming skills are required to participate in this class but, bring a laptop and actively participate. After this class you can create a single page web applications for your machine learning and visualization projects that run on all major web-browsers and have an interface that people are familiar with. Programming concepts are explained in class and step by step we will enhance our example application with interactive components.

Any web-application consists of two components, the web-server that provides the database and the client application component that is executed in the users browser. All programming logic is executed on the client application programmed in JavaScript - a programming language designed for

the web. The minimal server component is programmed in our class in PHP, a simple programming language for the server that implements for example authentication (not covered in this class).



```

<?php
// index.php
$connection = mysqli_connect("localhost", "root", "password");
if (!$connection) {
    die("Connection failed: " . mysqli_connect_error());
}

// get data from database
$data = mysqli_query($connection, "SELECT * FROM users");
echo "<table border='1'><thead><tr><th>id</th><th>username</th><th>password</th></tr></thead><tbody>";
while ($row = mysqli_fetch_assoc($data)) {
    echo "<tr><td>" . $row['id'] . "</td><td>" . $row['username'] . "</td><td>" . $row['password'] . "</td></tr>";
}
echo "</tbody></table>";

// add new user
if (isset($_POST['username']) && isset($_POST['password'])) {
    $username = $_POST['username'];
    $password = $_POST['password'];

    $query = "INSERT INTO users (username, password) VALUES ('" . $username . "', '" . $password . "')";
    mysqli_query($connection, $query);
    echo "User added successfully!";
}

```

The concept of a single page web-application allows us to provide visualizations for the web.

We will focus our efforts on the client side programming and explain how events trigger actions that result in an update of the interface which creates reactive web

experience for the user. The capabilities of styling the website using cascading style sheets (CSS) will allow us to generate custom interface components for special needs. For a basic styling framework we will use Bootstrap (v4). This library extends the HTML code describing the interface by an easy to understand grid-based layout that adapts to the size of the screen. Our applications will therefore adjust to large screens as well as cell-phones.

## Summary

**Tags:** Programming, Web, Education, Workshop  
**Date:** 2020-01-13  
**Location:** MMIV  
**Audience:** World

Hauke Bartsch, Dr. rer. nat.

# The very basics of R-programming - without any gaps

A workshop of the without-any-gaps series of MMIV

No prior programming experience is required and everyone is welcome to our class, but bring a laptop. We start with an overview of tasks related to data imports and quality checks, cover basic visualization using ggplot2 and the simplest of regression models suitable as a baseline classification for your machine learning projects. Due to the complexity of the statistical models we will focus in this class on the data management part which starts any analysis task in the R-programming language.

R is especially suited as a programming language supporting data management tasks as well as basic and advanced statistical analysis tasks. With high-quality graphic generating packages all components of a scientific paper for bio-science can be created using R. In class we will use RStudio an integrated development environment that provides a convenient MATLAB-like interface

for our class. The notebook feature is similar to python-notebooks and combines explanatory text, programming code and output generated by R.

```
This is an R Markdown Notebook. When you execute code within the notebook, the results appear beneath the code.
Try executing this chunk by clicking the Run button within the chunk or by placing your cursor inside it and pressing Cmd+Shift+Enter.
Go to my directory:
setwd("~/Desktop/R-without any gaps")
cod <- read.csv('cod.csv')
#write.csv(cod, file="out.csv")
saveRDS(cod, file="cod.Rds")
cod2 <- readRDS("cod.Rds")
plot(cars)
```

```
for (row in seq(1,nrow(cod)) ) {
  for (col in seq(1,ncol(cod)) ) {
    r = cod[row,col]
    print(paste(r))
  }
}
data = c("858 736 7027", "33.4334 222.44", "123 444-333")
```

R language class for everyone.

Together with the RStudio environment the CRAN package store is a useful repository of many advanced packages that integrate with R. We will use the TableOne package to explain how R can be extended with CRAN software. In the last part of the workshop we will look at ggplot as a language for specifying graphics in R.

In a future workshop we will focus on the basic statistical packages for linear models up to the use of generalized additive mixed models (gamm4, mgcv). Such packages provide the tools for many life-science analysis tasks.

## Summary

Tags: Programming, Education, Workshop

Date: 2020-02-24

Location: MMIV

Audience: World



## Seminar series October 2019

MR & I – Magnetic resonance imaging from different viewpoints within the MMIV

The seminar talks of Mohn Medical Imaging and Visualization center are organized by a committee composed of graduate student, PhD students and post-docs. The format of the seminars is that of an open forum for 4 talks per day of 20min each about work in progress research topics across all of the MMIV projects. Each seminar day combines research of all projects at MMIV and each talk ends with a short discussion

and feedback for the presented work. The seminar day concludes with a social get-together at MMIV with waffles and coffee.

Especially the more informal format of the seminar invite lively discussions that bridge the projects and presenters usually leave with many helpful suggestions for future research and potential collaborations. The multi-project format of the seminars

provide a valuable revenue to foster inter-group relationships at MMIV.

### Summary

Tags: Education, Seminars  
Date: 2019-10-01  
Location: MMIV  
Audience: MMIV

### Noeska Smit



## Memento: Localized Time-Warping for Spatio-Temporal Selection in fMRI data

Seminar talk provided at the MMIV

This talk was presented by Noeska Smit of the MMIV. It is titled "Memento: Localized Time-Warping

for Spatio-Temporal Selection in fMRI data".

She introduced her talk with: *Interaction techniques for temporal data are often focused on affecting the spatial aspects of the data, for instance through the use of transfer functions, camera navigation, or clipping planes. However, the temporal aspect of the data interaction is often neglected. The temporal component is either visualized as individual time steps, an animation, or a static summary over the temporal*

*domain. We propose a novel technique that allows users to interactively specify areas of interest in the spatio-temporal domain. By employing a time-warp function, we are able to slow down time, freeze time, or even travel back in time, around spatio-temporal events of interest. The combination of such a (pre-defined) time-warp function and brushing directly in the data to select regions of interest allows for a detailed review of temporally and spatially localized events, while maintaining an overview of the global*

*spatio-temporal data. In this talk, I will demonstrate an application of this technique to functional MRI (fMRI) data in particular.*

#### Summary

Tags: Education, Seminars

Date: 2020-01-01

Location: MMIV

Audience: MMIV

## Nj  l Lura



# MRI-assessed tumor size parameters predict mortality in uterine cervical cancer

Seminar talk provided at the MMIV

This talk was presented by Nj  l Lura of MMIV. It is titled "MRI-assessed tumor size parameters predict mortality in uterine cervical cancer".

He introduced his talk with: *Uterine cervical cancer represents a major threat to female health worldwide; it is the fourth most common female cancer and one of the leading causes of cancer-related death in low-income*

*countries. Important limitations in cervical cancer treatment are due to: 1) insufficient diagnostic tools with which to identify high-risk disease and 2) insufficient diagnostic tools with which to guide more individualized treatment. This project aims to address these limitations by focusing on the value of preoperative advanced imaging to provide functional and morphological tumor characteristics*

*relevant for treatment and prognosis in uterine cervical cancer.*

#### Summary

Tags: Education, Seminars

Date: 2020-01-01

Location: MMIV

Audience: MMIV

### Saruar Alam



## Analyzing atlas-based MRI features on Alzheimer's disease detection

Seminar talk provided at the MMIV

This talk was presented by Saruar Alam of MMIV. It is titled "MRI-assessed tumor size parameters predict mortality in uterine cervical cancer".

He introduced his talk with: *Alzheimer's disease (AD) can be distinguished using the features obtained from Magnetic resonance imaging (MRI), and a supervised classifier. Multi-atlas-based-likelihood fusion (MALF) algorithms extract the volumes features of subcortical regions of interest (ROI). The correlation among these ROI*

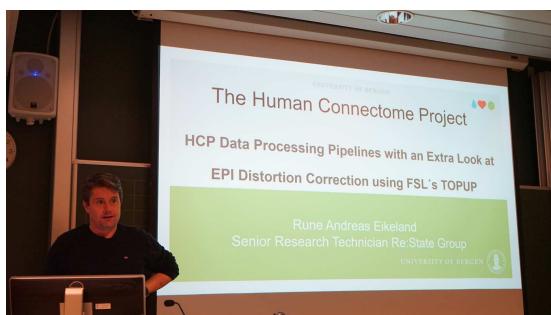
*features from different brain regions may provide additional valuable information. Subsequently, these ROI-correlative features may affect the classification performance of a supervised classifier. We have classified AD and Mild Cognitive Impairment from cognitively normal subjects using these features and a Support Vector Machine classifier. This article investigates the difference in classification performance between the ROI and ROI-correlative features. Our work also reports the ranks of*

*ROI and ROI-correlative regions. We have observed marginal differences in classification performance and ranking of the most effective regions.*

#### Summary

Tags: Education, Seminars  
Date: 2020-01-01  
Location: MMIV  
Audience: MMIV

### Rune Eikeland



# The Human Connectome Project data processing pipeline and data visualization toolbox

Seminar talk provided at the MMIV

This talk was presented by Rune Eikeland of MMIV. It is titled "The Human Connectome Project data processing pipeline and data visualization toolbox".

He introduced his talk with: *The Human Connectome Project (HCP) is a five-year project sponsored by sixteen components of the National Institutes of Health, split between two consortia of research institutions. The project was launched in July 2009 as the first of three Grand Challenges of the NIH's Blueprint*

*for Neuroscience Research.*

*The goal of the Human Connectome Project is to build a "network map" (connectome) that will shed light on the anatomical and functional connectivity within the healthy human brain, as well as to produce a body of data that will facilitate research into brain disorders such as dyslexia, autism, Alzheimer's disease, and schizophrenia.*

*The data, processing and visualization tools are freely available for the HCP and Rune will present them in this*

*talk with an in-depth focus on EPI data pre-processing to reduce susceptibility and motion artefacts with FSL's eddy tool (<https://fsl.fmrib.ox.ac.uk/fsl/fslwiki/eddy>).*

## Summary

Tags: Education, Seminars

Date: 2020-01-01

Location: MMIV

Audience: MMIV



## Seminar series September 2019

From mouse to man – Spatial and temporal medical imaging in different species and development phases

The seminar talks of Mohn Medical Imaging and Visualization center are organized by a committee composed of graduate student, PhD students and post-docs. The format of the seminars is that of an open forum for 4 talks per day of 20min each about work in progress research topics across all of the MMIV projects. Each seminar day combines research of all projects at MMIV and each talk ends with a short discussion

and feedback for the presented work. The seminar day concludes with a social get-together at MMIV with waffles and coffee.

Especially the more informal format of the seminar invite lively discussions that bridge the projects and presenters usually leave with many helpful suggestions for future research and potential collaborations. The multi-project format of the seminars

provide a valuable revenue to foster inter-group relationships at MMIV.

## Summary

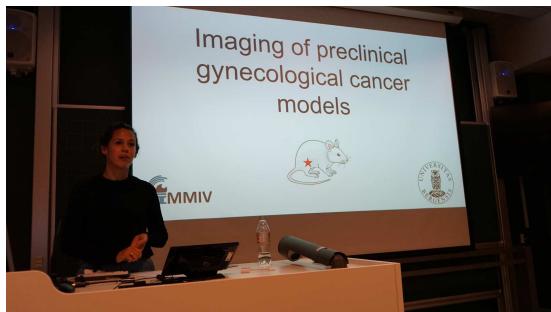
Tags: Education, Seminars

Date: 2019-09-01

Location: MMIV

Audience: MMIV

### Heidi Espedal



## Imaging of preclinical gynecologic cancer models

Seminar talk provided at the MMIV

This talk was presented by Heidi Espedal of MMIV. It is titled "Imaging of preclinical gynecologic cancer models". She is a post-doctoral fellow working at the molecular imaging center (MIC) of Haukeland University Hospital.

She introduced her talk with: *Endometrial cancer is the most common type of cancer of the female reproductive tract. Although prognosis is generally good for patients with low-grade and early-stage diseases, the outcomes for high-grade and metastatic/recurrent cases*

*remain poor, since traditional therapy have limited effects. No targeted agents have been approved so far, although several new drugs have been tested without striking results in clinical trials. Patient-derived tumor xenograft (PDX) mouse models represent useful tools for preclinical evaluation of new therapies and biomarker identification. Preclinical imaging by PET-CT and MRI during disease progression enables visualization and quantification of functional tumor characteristics, which may serve as*

*imaging biomarkers guiding targeted therapies. The primary objective for this presentation is to give an introduction of current and novel preclinical imaging methods relevant for endometrial cancer mouse models.*

### Summary

Tags: Education, Seminars

Date: 2020-09-01

Location: MMIV

Audience: MMIV

### Eric Mörth



## The Vitruvian Baby: Interactive reformation of 3D ultrasound data to a T-pose

Seminar talk provided at the MMIV

This talk was presented by Eric Mörth of MMIV. It is titled

"The Vitruvian Baby: Interactive reformation of 3D ultrasound data to a T-pose". Eric is a PhD candidate for multi-modal medical visualization under the supervision of Noeska Smit (MMIV).

He introduced his talk with: *Three-dimensional (3D) ultrasound imaging and visualization is often used in medical diagnostics, especially in prenatal screening. Screening the development of the fetus is important to assess possible complications early on. Performing the analysis in a 3D view would enable the*

*viewer to better discriminate between artefacts and representative information. Additionally making data comparable between different investigations and patients is a goal in medical imaging techniques and is often achieved by standardization.*

*"The Vitruvian Baby" incorporates a complete pipeline for standardized measuring in fetal 3D ultrasound. The input of the method is a 3D ultrasound screening of a fetus and the output is the fetus in a standardized T-pose. In*

*this pose, taking measurements is easier and comparison of different fetuses is possible. In addition to the transformation of the 3D ultrasound data, we create an abstract representation of the fetus based on accurate measurements.*

#### Summary

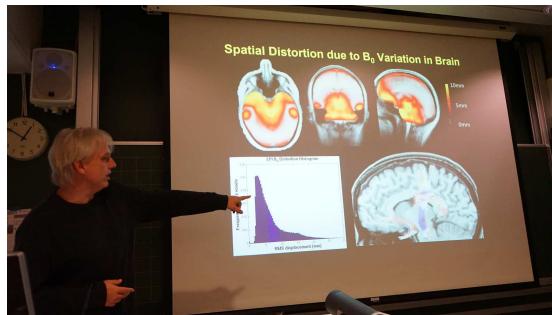
Tags: Education, Seminars

Date: 2020-09-01

Location: MMIV

Audience: MMIV

### Hauke Bartsch



## The Brain Imaging Data of the ABCD Study – an Introduction into Protocols and Tasks

Seminar talk provided at the MMIV

This talk was presented by Hauke Bartsch of MMIV. It is titled "The Brain Imaging Data of the ABCD Study – an Introduction into Protocols and Tasks". Hauke is a researcher at the MMIV.

The ABCD study is recruiting and following the brain development and health of over 10,000 9-10 year olds through adolescence. The imaging component of the study was developed by the ABCD Data Analysis and Informatics Center (DAIC) and the ABCD Imaging Acquisition Workgroup. Imaging methods and assessments were selected, optimized and harmonized across all 21 sites to measure brain structure and function relevant to adolescent development and addiction. This article provides an overview of

the imaging procedures of the ABCD study, the basis for their selection and preliminary quality assurance and results that provide evidence for the feasibility and age-appropriateness of procedures and generalizability of findings to the existent literature.

He introduced his talk with: *The Adolescent Brain Cognitive Development (ABCD) Study is the largest long-term study of brain development and child health in the United States. The ABCD Research Consortium have invited 11,878 children ages 9-10 to join the study. Researchers will track their biological and behavioral development through adolescence into young adulthood.*

*Using cutting-edge technology, scientists will determine how childhood*

*experiences (such as sports, video-games, social media, unhealthy sleep patterns, and smoking) interact with each other and with a child's changing biology to affect brain development and social, behavioral, academic, health, and other outcomes.*

*As part of a research agreement, MMIV will obtain access to the raw data that includes an extensive MRI protocol as well as behavioral and environmental data.*

#### Summary

Tags: Education, Seminars

Date: 2020-09-01

Location: MMIV

Audience: MMIV

### Sathiesh Kaliyugaran



## Artificial intelligence in image diagnostics – transfer learning and active learning for efficient use of data and radiologist's expertise

Seminar talk provided at the MMIV

This talk was presented by Sathiesh Kaliyugaran of MMIV. It is titled "Artificial intelligence in image diagnostics – transfer learning and active learning for efficient use of data and radiologist's expertise". Sathiesh is a PhD candidate at the MMIV.

He introduced his talk with: *A common stumbling block for supervised learning methods based on deep neural networks is the large number of labeled examples required for training. This is particularly troublesome when trying to use deep learning methods for segmentation in 3D medical image data. As creating labeled data for medical images is often a time-consuming, difficult and unreliable process, the amount of training data available is in general very small. To mitigate this problem we are looking into using design methodologies such as transfer learning and active*

*learning for efficient use of data and radiologist's expertise.*

#### Summary

Tags: Education, Seminars

Date: 2020-09-01

Location: MMIV

Audience: MMIV

#### 4. Dissertations



## Hva kan MRI lære oss om hallusinasjoner?

### Gerard Dwyer

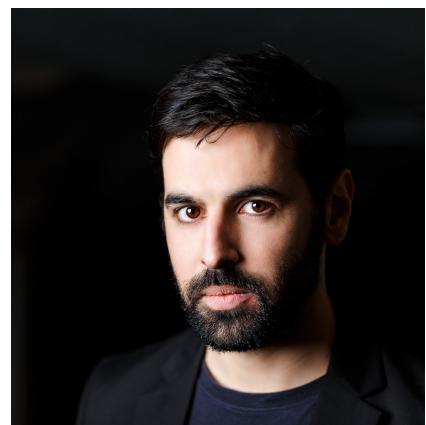
Gerard Dwyer (f. 1985) har master i biomedisin med spesialisering i biomedisinsk avbildning fra Universitetet i Bergen. Doktorgraden ble utført ved Instituttet for biologisk og medisinsk psykologi (IBMP), Det psykologiske fakultetet ved Universitetet i Bergen. Hovedveileder var Renate Grüner med biveiledere Kenneth Hugdahl og Lars Ersland.

Hva skjer i hjernen til folk som hører stemmer som ikke finnes? Hørselshallusasjoner, ofte kalt «stemmer i hodet» er et av de sentrale symptomene som kjennetegner schizofreni, og er et kjent symptom ved en rekke andre psykiske lidelser.

Selv om den er best kjent som en avbildningsteknikk, finnes det andre anvendelsesområder for Magnetresonanstromografi (MRI) som har gjort teknikken til et viktig verktøy for å undersøke hjernen. Dette prosjektet fokuserte på to slike MRI-metoder, nemlig funksjonell MRI (fMRI) og magnetresonansspektroskopi (MRS), og hvordan de kunne potensielt brukes for å kartlegge hva som skjer i hjernen ved hørselshallusasjoner. Med fMRI kan man fremstiller endringer i nevronal aktivitet i forskjellige områder i hjernen som kan være involvert med ulike mentale oppgaver og prosesser. Med MRS kan man måle ulike kjemiske stoffer som glutamat og GABA, to av hjernens viktigste nevrotransmittere. Formålet med dette prosjektet har vært å prøve ut om MRS egner seg for å måle endringer i konsentrasjon av nevrotransmittere over tid, det vil si på en «funksjonell» måte som blir kalt «fMRS», og hvis fMRI og MRS kunne kombineres for samtidig måling av endringer i nevral aktivitet og assosiert endringer i nevrotransmitter nivåer.

Den første studien ga oversikt av hvordan MRS brukes for å måle visse kjemiske forbindelser som er av betydning for forståelse av schizofreni. Den andre studien foreslo en ny tilnærming til fMRS, og testet ut den varianten for å måle biokjemiske endringer i respons til svak elektrisk stimulering (tDCS). Den siste studien prøvde ut en ny fMRS metode for samtidig måling av både aktivitet i hjernen og assosiert endringer i nevrotransmitter nivåer i respons til visuell stimulering.

Resultatene fra dette prosjektet foreslår nye muligheter for bruk av fMRS, og kan måle både aktivitet og assoserte endringer i nivå av signalstoff samtidig. De foreløpige resultatene er lovende, men trenger videre forskning for å validere metodene.



#### Author Information

Gerard Dwyer

Defense: 10/2019



heat equation cxx — HeatEquation

## EXPLORER

## ◀ OPEN EDITORS

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## ✓ HEATEQUATION

>	.vscode	●
>	CMakeFiles	●
>	data	●
>	img	
>	ITKFactoryRegis...	●
≡	cmake_install.cm...	U
≡	CMakeCache.txt	U
≡	CMakeCache.txt~	U
M	CMakeLists.txt	M
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{}	data_1wm_2ven...	U
🐳	Dockerfile	
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## 5. Software

- `GradientImageFilter...`
- `GradientImageFilter...`
- `GradientImagePoin...`
- `GradientImageType...`
- `GradientMagnitude...`
- `GradientMagnitude...`
- `GradientPixelType ...`
- `ImageReaderType ...`
- `ImageType` `typedef`
- `json` `type alias`
- `OutputImageType t...`
- `OutputPixelType ty...`
- `OutputReaderType ...`
- `PixelType` `type alias`
- 📦 `computeMagGradF...`
- 📦 `main(int, char * [])`
- 📦 `oneStep(ImageTyp...`
- ✉ `data`
- ✉ `ImageDimension`
- ✉ `output`
- ✉ `resultJSON`
- ✉ `tmpData`
- ☰ `toindex(x, y, z)`
- ☰ `VERSION_MAJOR`

C++ heat\_equation.cxx X

C++ heat\_equation.cxx >  main(int, char \* [])

```
171 command.AddField("outdir", "Output directory", MetaCommand
172
173 command.SetOption("Temperatures", "t", false,
174 | | | | | "Specify the temperature per label as <
175 | | | | | "N the number of label and temperature
176 | | | | | "4 0 0.0 1 100.0'. A label that is not
177 | | | | | "assumed to be variable and used for the
178 command.SetOptionLongTag("Temperatures", "temperature-label")
179 command.AddOptionField("Temperatures", "temperature", Meta
180
181 command.SetOption("Iterations", "i", false,
182 | | | | | "Specify the number of iterations (defa
183 | | | | | "large number of iterations like 2000 (i
184 | | | | | "monitored using the change value print
185
186 command.AddOptionField("Iterations", "iterations", MetaCo
187
188 // supersample the input (2 means 4 times more voxel)
189 command.SetOption("SuperSample", "s", false,
190 | | | | | "Specify the number up-sampling steps u
191 | | | | | "the resolution.");
192 command.AddOptionField("SuperSample", "supersample", Meta
193
194 // quantize the output temperature
195 command.SetOption("Quantize", "q", false, "Quantize the o
196 command.AddOptionField("Quantize", "quantize", MetaCommand
197
198 command.SetOption("UnitNormalVector", "n", false,
199 | | | | | "Export the unit normal vector and the
200 | | | | | "(exported gradient field is the tangent
201
202 command.SetOption(
203 | | | | | "InitField", "c", false,
204 | | | | | "Initialize the temperature field with this volume. T
205 | | | | | "of small to large volumes is created where each stag
206 command.AddOptionField("InitField", "initfield", MetaComm
207
208 command.SetOption("VectorFileFormat", "f", false,
209 | | | | | "Specify the file format for the vector
210 command.AddOptionField("VectorFileFormat", "vectorfilefor
211
212 if (!command.Parse(argc, argv)) {
213 | return 1;
214 }
215
216 std::string input = command.GetValueAsString("infile");
217 std::string outdir = command.GetValueAsString("outdir");
218 // fprintf(stdout, "input: \"%s\"\n", input.c_str());
219 // fprintf(stdout, "outdir: \"%s\"\n". outdir.c_str());
```

**Hauke Bartsch, Dr. rer. nat.**

<https://github.com/mmiv-center/LungSegmentation.git>

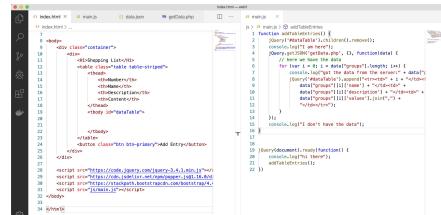
## Geodesic distances in white matter

Curvilinear coordinates in human white matter

This module creates curvilinear coordinates from volumetric label fields. It simulates the heat equation and exports the temperature (potential) field and the gradient of the potential field (tangent unit vector). The gradient field represents the directions of geodesic lines connecting the fixed temperature regions.

This module can be used to compute the shortest path between points of the ventricles and points of the white/gray matter border using

structural information (white matter) only. It can also be used to sample the white matter at a given distance perpendicular to the gray/white matter border.



```

<html>
<head>
<title>Index</title>
</head>
<body>
<h1>Index</h1>
<pre>
4 index.html ...
5
6 <div class="container">
7   <div>Hello, world!</div>
8   <div>This is a test page</div>
9   <div>The page has been generated</div>
10  <div>by Hauke Bartsch</div>
11  <div>from the mmiv-center</div>
12  <div>repository</div>
13  <div>on GitHub</div>
14  <div>https://github.com/mmiv-center/index.html</div>
15  <div>with the command</div>
16  <div>git clone https://github.com/mmiv-center/index.html</div>
17  <div>cd index.html</div>
18  <div>node index.js</div>
19  <div>in the terminal</div>
20  </div>
21  </div>
22  </body>
23  </html>
</pre>
<script>
4 <script>
5   function readTextFile(file) {
6     var rawFile = new XMLHttpRequest();
7     rawFile.open("GET", file, false);
8     rawFile.onreadystatechange = function() {
9       if(rawFile.readyState === 4) {
10          var allText = rawFile.responseText;
11          console.log(allText);
12        }
13      }
14      rawFile.send(null);
15    }
16    readTextFile('index.html');
17    readTextFile('match');
18  </script>
</body>
</html>

```

A repository for software.

We share such source code to support similar research efforts internationally. The open-source nature of this research allows national and international researchers to test and verify our solutions, provide essential feedback and suggestions for improvement supporting advances in medical data handling.

### Summary

Tags: Programming, Software

Date: 2020-01-13

**Hauke Bartsch, Dr. rer. nat.**

<https://github.com/mmiv-center/gen-id.git>

## Research PACS component Gen-ID

Generate random participant ID's from regular expressions

This repository provides access

to program developed at

MMIV that creates random

participant identifiers based on a regular expression pattern. This feature allows research projects to use short participant identifiers that do not repeat and that blind the study to the order of enrollment. The generated participant identifiers remain concise and recognizable as belonging to the study. The software is part of the Research PACS at MMIV that provides a safe technical solution to perform medical data collection and data analysis.

```

1 // IndexShelf.java
2
3 import java.io.*;
4 import org.json.*;
5
6 public class IndexShelf {
7     public static void main(String[] args) {
8         String indexFile = "index.json";
9         String dataFile = "data.json";
10        String url = "http://127.0.0.1:8080/getData.php";
11
12        try {
13            JSONObject indexObject = new JSONObject(new JSONParser().parse(new FileReader(indexFile)).get("index"));
14            JSONArray dataObjects = new JSONArray(new JSONParser().parse(new FileReader(dataFile)).get("data"));
15
16            for (Object object : indexObject) {
17                String id = ((JSONObject) object).get("id").toString();
18                String name = ((JSONObject) object).get("name").toString();
19
20                String urlPath = url + "?id=" + id;
21
22                URL urlObject = new URL(urlPath);
23                HttpURLConnection connection = (HttpURLConnection) urlObject.openConnection();
24                connection.setRequestMethod("GET");
25
26                BufferedReader reader = new BufferedReader(new InputStreamReader(connection.getInputStream()));
27                String response = reader.readLine();
28                reader.close();
29
30                JSONObject dataObject = new JSONObject(response);
31
32                dataObjects.add(dataObject);
33            }
34
35            JSONObject dataObject = new JSONObject();
36            dataObject.put("data", dataObjects);
37
38            File dataFileObject = new File(dataFile);
39            BufferedWriter writer = new BufferedWriter(new FileWriter(dataFileObject));
40            writer.write(dataObject.toJSONString());
41            writer.close();
42
43        } catch (Exception e) {
44            e.printStackTrace();
45        }
46    }
47 }

```

A repository for software.

We share such source code to support similar research efforts

internationally. The open-source nature of this research allows national and international researchers to test and verify our solutions, provide essential feedback and suggestions for improvement supporting advances in medical data handling.

### Summary

Tags: Programming, Software

Date: 2020-03-10

**Hauke Bartsch, Dr. rer. nat.**

<https://github.com/mmiv-center/LungSegmentation.git>

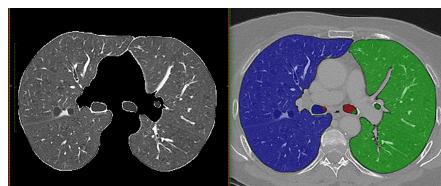
## LungSegmentation package

Create lung-segmentation fields from spiral CT

This repository provides access to programs developed at MMIV for lung segmentation of spiral CT images. This program is using a series of labelling and morphological operations to extract the Lung volume intensity image from chest CT scans. It was tested with the data from the LIDC-IDRI (Lung Image Database Consortium) project and depends on ITK/cmake.

After the initial step of extracting the intensities of the lungs and airways

the algorithm attempts to separate the two lungs and the airways.



Lung segmentation into airways (red), left (green) and red (blue) lung.

We share such source code

to support similar research efforts internationally. The open-source nature of this research allows national and international researchers to test and verify our solutions, provide essential feedback and suggestions for improvement supporting advances in medical data handling.

### Summary

Tags: Programming, Software

Date: 2020-03-10

**Hauke Bartsch, Dr. rer. nat.**

<https://github.com/mmiv-center/RewritePixel.git>

## Sanitize DICOM image data

Machine learning algorithms for the removal of burned in image information

This repository provides access to programs developed at MMIV for the removal of burned in pixel information in secondary capture DICOM images.

Sharing medical images is most often straight forward as the DICOM format provides a globally agreed on file format for all reconstructed 2D, 3D, and 4D data generated by medical equipment. Special care has to be taken if DICOM data is generated as part of data analysis workflows. Such 'secondary-capture' DICOM images can contain burned in text information that might contain participant identifying information such as names. Before such data can be shared as part of research

projects at Haukeland University Hospital the burned in image information needs to be removed. Previous approaches

This project uses the tesseract optical character recognition machine learning engine to identify text that is burned into DICOM images. For each text fragment (usually a word) a square black frame is written into the DICOM pixel information. The resulting DICOM file should be inspected - hopefully it is free of participant identifying information.

Warning: This program does not try to anonymize DICOM tags. Please check out the <https://github.com/mmiv-center/DICOMAnonymizer> project for a fast tag anonymizer.

Warning: There is no information yet on false/positive detection rates, verify the output by hand!

We share such source code to support similar research efforts internationally. The open-source nature of this research allows national and international researchers to test and verify our solutions, provide essential feedback and suggestions for improvement supporting advances in medical data handling.

### Summary

Tags: Programming, Software

Date: 2020-03-10

**Hauke Bartsch, Dr. rer. nat.**

<https://github.com/mmiv-center/DICOMAnonymizer.git>

# DICOM-Anonymizer

Fast-anonymization engine for DICOM meta-data

This repository provides access to programs developed at MMIV for the removal of participant identifying information in meta-data tags of DICOM files.

This source code demonstrates how to anonymize DICOM files based on the DICOM PS 3.15 AnnexE. I provide a Dockerfile that can be used to build the executable and to run anonymizations. Entries such as uid entries are replaced with hash values. This ensures that partial runs of a studies DICOM files can be merged afterwards. This project is written in C++ using the gdcm library and multiple threads to accelerate processing.

**Warning:** The operation performed by this tool is a 'soft' de-identification. Instead of a white list of allowed tags the tool keeps a list of tags known to frequently contain personal identifying information (PII) and replaces only those. On the command line you specify a patient identifier (PatientID/PatientName). Only if you do not keep a mapping of the new and the old identifier this is considered an anonymization. If such a list exists the operation performed is a de-identification

(permits a later re-identification).

I suggest to review files generated by this tool for additional PII information that might be present in text fields.

For a more flexible anonymizer please see the CTP DICOM Anonymizer project.

## Unique features

- fast de-identification (multi-threaded, C++)
- de-identifies data inside sequences instead of deleting them so overlays survive the procedure

## Limitations

This tool has been written to work as an importer for a (vendor neutral) PACS system. In such a setup data de-identified from the same participant is expected to align with previous data for the same participant and study if the same participant ID and name is used. This is achieved by using study instance uids that are hashed. Series that comes later should therefore match at the study level. It is not possible to recover the original patient ID, patient name and study/series/image instance UIDs from the de-identified fields as no tracking

information is stored in the DICOM files. But, identical input data will result in the same hashes. This can be seen as an implicit coupling list - a price we have to pay to be able to use the tool in our research PACS during the data capture stage of a project.

The used SHA256 algorithm for hashing per project is very fast to compute. This will allow an attacker to create many random tries for a brute-force attack. At the worst case this would allow the attacker to recover the original study/series/image instance UIDs. PatientID and PatientName tags are set manually and are therefore not exposed to such an attack.

We share such source code to support similar research efforts internationally. The open-source nature of this research allows national and international researchers to test and verify our solutions, provide essential feedback and suggestions for improvement supporting advances in medical data handling.

## Summary

Tags: Programming, Software

Date: 2020-03-10

Hauke Bartsch, Dr. rer. nat.

<https://github.com/mmiv-center/LesionProject.git>

# Identifying Lesions in brain MRI

A software provided by MMIV

This repository provides access to programs developed at

to programs developed at

MMIV for the detection of

brain lesions.

After detecting lesions in-painting can be used to synthetically create a version of the raw data where lesions are masked with assumed intensity values similar to the neighboring voxel in the data. Such synthetic data can be used for algorithms that are sensitive to the lesions otherwise - such as FreeSurfer.

The provided algorithm performs a region growing of initially 2 voxel to create a lesion border. This border might be affected by partial volume effect. Afterwards another 2 voxel morphological grow operation defines a region of background voxel used for the interpolation of the lesion and the lesion border voxel intensities.

For lesions that are close to the

border of white matter the interpolation might not be correct as it would blur intensities from different tissue types across the lesion volume. Instead it might be more appropriate to limit the intensities for interpolation to the voxel of a single material. For these purposes you can provide an additional mask argument - limiting the sample points for the interpolation to the white matter material only.

In order to quantify the location of a lesion relative to the cortical surface an approach can be used that calculates curvilinear (geodesic) distances between two labels, the ventricles located in the center of the brain and the cortical gray to white matter surface. This approach mimics the general direction

of the path neurons travel during cortex development.

Please visit the <https://github.com/mmiv-centre/BrainLesionSegmentation> project that implements such a method.

We share such source code to support similar research efforts internationally. The open-source nature of this research allows national and international researchers to test and verify our solutions, provide essential feedback and suggestions for improvement supporting advances in medical data handling.

#### Summary

Tags: Programming, Software

Date: 2020-03-10



## 6. Research Projects



*New funding 2020: Innovation Project for the Public Sector*  
**-Hauke Bartsch**

## Workflow-integrated machine learning

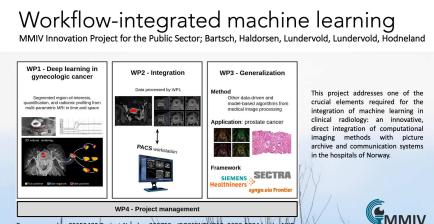
Recent years have seen exciting applications of machine learning in medical data analysis, from radiology and dermatology to electronic health records and drug discovery. This has led to great interest and enormous expectations from the medical profession. However, it is still early days for the evaluation and integration of artificial intelligence and machine learning-derived information in clinical practice. This proposal addresses one of the crucial missing elements required for implementation and integration in clinical radiology: an innovative, direct integration of computational imaging methods with picture archive and communication systems (PACS). To ensure the usefulness of our innovation, we will apply it to two of the most important health challenges in modern society: cancers in women (uterus) and men (prostate).

Modern machine learning algorithms integrated deep into clinical workflows can have immense impact by offering more personalized treatments and predictions of outcome

for a wide variety of conditions. By producing accurate measurements, predictions and pre-processing in close to real-time, machine learning methods make it feasible to do advanced image and data-processing in the clinical setting, potentially lessening workload, empowering physicians, and reducing interobserver variability. If machine learning is able to show convincing results in the clinic this could potentially open the avenue for innovations based on other advanced computational methods that have the potential to improve our understanding and predict health and disease, facilitating a stronger clinical presence for the broader field of computational medicine, an area that holds great promise for the future of medicine.

Primary objective: construct a robust, working prototype that receive a DICOM study pushed from the PACS system, setup and run it through deep learning-based image processing methods, and format and return the resulting information, segmentation mask, derived reports,

and quantitative measures back into the PACS. The system will also facilitate the evaluation and further training of the deep learning model based on feedback from the user by storing such modifications as annotations in the PACS. The prototype workflow will be assessed by experienced radiologists from the relevant clinical domains. Secondary objective: prove that our approach is generalizable. This objective is three-fold: the approach should generalize to other computational medical imaging methods, different medical applications, and provide a clear path to embed our product in production-level, widely used PACS and image reading systems.



A new project supported by the Norwegian research council.

**Team**

**Team leader:** Hauke Bartsch

**Partners:** Ingfrid Haldorsen, Alexander Lundervold, Arvid Lundervold, Erlend Hodneland, Erling Andersen

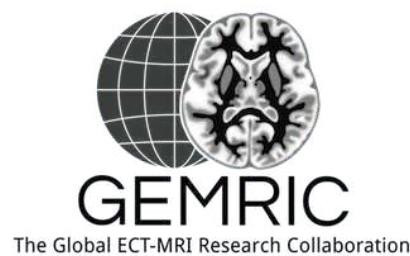
*Understanding treatment mechanisms and predictors of clinical response*  
**-Leif Oltedal**

## Brain changes induced by electroconvulsive therapy (ECT)

Electroconvulsive therapy (ECT) is a procedure, done under general anesthesia, in which electric currents are passed through the brain, intentionally causing a brief seizure. Although ECT has remained the most effective acute treatment for major depressive episodes for nearly 80 years, how it works and why it is effective is not well known. Only a small proportion of patients with treatment resistant depression are offered ECT, and typically 60-80% experience a good response (> 50% symptom reduction).

Several neuroimaging studies of ECT have demonstrated volume increases of brain areas after treatment. The most consistent finding has been volume increase of the hippocampus. However, a link between the treatment induced brain changes and clinical improvement has not been established.

This project explores how ECT changes the brain, and if the structural (or functional) changes that are seen can explain the effect (or side-effects) of the treatment.



The Global ECT MRI Research Collaboration.



The researchers at the global ECT MRI meeting 2019.

An important reason for our knowledge gap is that single studies have limited samples and lack statistical power to reach firm conclusions. The Global ECT-MRI Research Collaboration was founded with a belief that collaboration and mega-analysis of combined data will lead to new knowledge that can be generalized across individual research sites.

In May 2019 the group arranged a gathering to discuss how to combine the neuropsychological analyses with data in the study. At the seminar, Åsa Hammar (neuropsychologist and professor), Maria Semkovska (neuropsychologist and experienced researcher in the ECT field), Olga Therese Ousdal (PhD), Hauke Bartsch (director of informatics, image analyst IV), Ole Johan Evjenth Sørhaug (medical student), and Shawn McClintoch (neuropsychologist (via Skype)) presented ongoing projects, preliminary analyses, earlier research, and future recommendations. The gathering was a good day for discussions and new ideas.

Team

**Team leader:** Leif Oltedal

**Co-PI:** Ute Kessler; clinical effects of ECT, Co-PI Jan Haavik; studies of Blood Biomarkers

*Re:State*  
-Karsten Specht

## When Default Is Not Default

When Default Is Not Default project is part of Karsten Specht's newly formed Re:State research group at the Institute of Biological and Medical Psychology, University of Bergen.



The Re:State research group.

This project addresses a very timely and highly important question of cognitive and clinical neuroscience studies: What factors influence the reliability of neuroimaging studies? What are the sources of individual variability? Which constraining factors may help predicting the outcome of a certain therapy?

Recent studies have estimated the reproducibility of psychological studies to be 39% or less and indicated a severe limitation of neuroimaging (fMRI) study reliability. Too small sample sizes, low to moderate effect sizes, and only partly understood

neurophysiological mechanisms behind the BOLD/fMRI signal make it difficult to generalize results, thereby impeding the impact of highly needed neuroscience studies on theoretical (scientific), methodological, and clinical progress.

The overall objectives of this project are to (i) improve our understanding of the neurophysiological mechanism of the BOLD signal and its sources of variability, to (ii) extend current methods on effective and functional connectivity measures (Connectoms), to (iii) find a solution to the replication crisis by developing new Bayesian, topology-based, and machine-learning based analysis methods as alternative approaches to today's analysis strategies, and to (iv) induce a paradigm shift from the current focus on an easy to measure but susceptible BOLD signal to the underlying, but (partly) hidden neuronal states that are presumably more stable and reliable.

The project aims to generate new insights into the neurophysiological mechanisms of the BOLD signal, its variability, dependency on endogenous and exogenous parameter, and reliability, and it will advance the

research field of basic and clinical neuroimaging by providing new analysis strategies.

### Collaborating Partners

National Partners: Assoc. Prof. Morten Brun, Dept. of Mathematics, University of Bergen Prof. Gaupe Einevoll, Faculty of Science and Technology, Norwegian University of Life Sciences

International partners: Prof. Karl Friston, Wellcome Trust Centre for Neuroimaging, University College London

Prof. Viktor Jirsa, CNRS and Institut de Neurosciences des Systèmes, Aix-Marseille University.

Prof. Vince Daniel Calhoun, Mind Research Network and University of New Mexico

### New Staff Members

We are happy to announce that we start the year 2020 with two new PhD candidates in the Re:State group: Tania Martínez Montero and Vetle Hushagen, and in Mai Meng-Yun Wang will join us as PostDoc. We wish them welcome and best of luck in their endeavors.

**Team**

**Team leader:** Karsten Specht

**Collaborators:** prof. Morten Brun, prof. Gaute Einevoll, prof. Karl Friston, prof. Vince Daniel Calhoun, prof. Viktor Jirsa

**PostDoc:** Kjetil Vikene, Meng-Yun Wang

**PhD candidates:** Liucija Vaisvilaite, Katarzyna Anna Kazimierczak, Vetle Hushagen, Tania Martínez Montero

**Senior research technician:** Rune Andreas Eikeland

**Master students:** Guro Sjuls, Julia Tuominen

*From conventional and novel imaging markers to radiomic tumor profiling unraveling targets for therapy and personalized treatment strategies in gynecologic cancer*

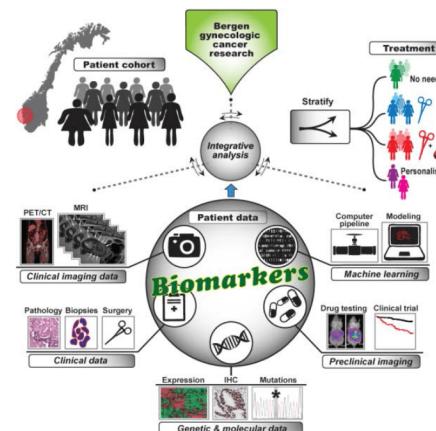
-**Ingfrid Haldorsen**

## Precision imaging in gynecologic cancer

**Research focus:** Gynecologic cancers have characteristic structural and functional imaging features reflected in clinical phenotypes, and these imaging biomarkers highlight pathogenic mechanisms potentially targetable by novel treatments. The focus in this project is to integrate these imaging biomarkers into clinically relevant treatment algorithms by identifying molecular targets for treatment based on imaging biomarker profiles.

**Current challenges in the field:** Three major clinical challenges in gynecologic cancers are: (1) Overtreatment of low-risk patients (with early stage disease) who experience unnecessary surgical and/or radiotherapy/chemotherapy-induced side effects and thereby reduced quality of life. (2) Undertreatment of patients falsely categorized as low-risk patients who will experience recurrence. (3) Poor survival in metastatic disease with no effective targeted therapy or response marker to conventional systemic therapies. The role of imaging markers and radiomic tumor profiling for risk-stratified tailored treatment algorithms and development of targeted therapies

is not yet defined.



**Project:** Imaging- and molecular/tissue biomarkers in gynecologic cancer are studied in patients and in preclinical gynecologic cancer models (Figure). Potential imaging biomarkers are identified using machine learning algorithms applied to multiparametric and functional magnetic resonance imaging (MRI) and positron emission tomography/computed tomography (PET/CT) from patients and in mouse models during therapy. Furthermore, the molecular and genetic alterations in the same tumors as well as clinical phenotype and survival are studied in relation to the corresponding imaging biomarker profile. This setup provides

a unique platform for identifying promising molecular targets for treatment and their corresponding imaging biomarker profiles.

**Important results:** MRI- and CT based tumor textural features (radiomic signatures) predict aggressive disease in endometrial cancer.

**Future plans:**

- Develop and validate AI platforms for automated and accurate tumor segmentation in gynecologic cancer for extraction of whole-volume radiomic tumor signatures (in collaboration with Machine Learning Group/A. Lundervold).
- Develop novel visualization tools with which to explore and assess multidimensional imaging data in relation to clinical/tissue data in gynecologic cancer (in collaboration with Visualization Group/N. Smit).
- Collect and analyze imaging data (for validation in "external" test sets) from gynecological cancer patients treated at different institutions using Research PACS (in

collaboration with Hauke Bartsch).

- Assess the radiogenomic tumor profile linking genetic signature to radiomic signature in

gynecologic cancer (in collaboration with Bergen Gynecologic Cancer Research Group/Prof. Camilla Krakstad. Our focus in the coming years is

to explore and exploit the potential of precision imaging to enable more targeted treatment strategies and improved patient care in gynecologic cancer.

#### Team

**Team leader:** Ingfrid Haldorsen

**Senior researchers:** prof. Camilla Krakstad, prof. Antonella Zanna Munte-Kaas, Erlend Hodneland, Erling Andre Høivik

**PostDocs:** Heidi Espedal, Havjin Jacob

**PhD and medical research students:** Sigmund Ytre-Hauge, Kristine E. Fasmer, Julie Dybvik, Njål Lura, Kari Strøno Wagner-Larsen, Hildegunn Aase, Geir K Nilsen, Agnes J Eide

-Helwig Hauser

## Visual Data Science for Large Scale Hypothesis Management in Imaging Biomarker Discovery

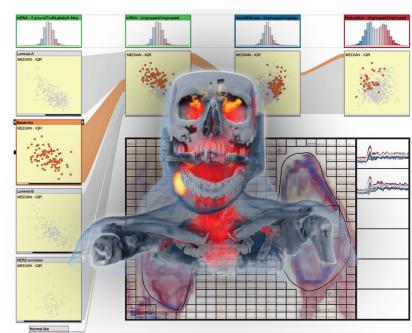
**Research focus:** Technology is revolutionizing medicine. New scanners enable doctors to "look into the patient's body" and study their anatomy and physiology without the need of a scalpel. At an amazing speed new scanning technologies emerge, providing an ever growing and increasingly varied look into medical conditions. Today, we cannot "only" look at the bones within a body, but we can also examine soft tissue, blood flow, activation networks in the brain, and many more aspects of anatomy and physiology. The increased amount and complexity of the acquired medical imaging data leads to new challenges in knowledge extraction and decision making.

In order to optimally exploit this new wealth of information, it is crucial that all this imaging data is successfully linked to the medical condition of the patient. In many cases, this is challenging, for example, when diagnosing early-stage cancer or mental disorders. Analogous to biomarkers, which are molecular structures that are used to identify medical conditions, imaging

biomarkers are information structures in medical images that can help with diagnostics and treatment planning, formulated in terms of features that can be computed from the imaging data. Imaging biomarker discovery is a highly challenging task and traditionally only a single hypothesis (for a new biomarker) is examined at a time. This makes it impossible to explore a large number as well as more complex imaging biomarkers across multi-aspect data. In the VIDI project, we propose to research and advance visual data science to improve imaging biomarker discovery through the visual integration of multi-aspect medical data with a new visualization-enabled hypothesis management framework.

**Project:** We aim to reduce the time it takes to discover new imaging biomarkers by studying structured sets of hypotheses, to be examined at the same time, through the integration of computational approaches and interactive visual analysis techniques. Another related goal is to enable the discovery of more complex imaging biomarkers, across multiple

modalities, that potentially are able to more accurately characterize diseases. This should lead to a new form of designing innovative and effective imaging protocols and to the discovery of new imaging biomarkers, improving suboptimal imaging protocols and thus also reducing scanning costs. Our project is a truly interdisciplinary research effort, bringing visualization research and imaging research together in one project, and this is perfectly suited for the novel Centre for Medical Imaging and Visualization that has been established in Bergen, Norway



**Important results:**

**Future plans:**

**Team**

**Team leader:** Helwig Hauser

**Senior researchers:** Stefan Bruckner, Renate Gruner, Noeska Smit

**PhD candidates:** Laura Garrison, Fourough Gharbalchi, Lea Starck

**Master student:** Jakub Vasicek

*Advanced interactive visualization of multimodal medical imaging data for visual analysis*  
**-Noeska Smit**

## Multimodal Medical Visualization

**Research focus:** Advances in medical imaging techniques are bringing more and more different contrasts that provide additional information. For instance, a single patient can have a CT scan, PET scan, as well as an MRI scan with different weighted images. When there is more than one modality acquired, mental integration of the different contrasts between the different images becomes more challenging. In this project, we aspire to develop novel interactive visualization approaches for improved exploration, analysis, and communication of multimodal medical imaging data. Our current focus in this context is on multi-parametric MR acquisitions.

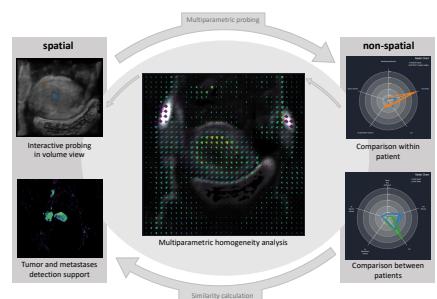
**Current challenges in the field:** Most multimodal medical imaging visualization methods are targetting no more than two modalities at the same time. Our research aims to further improve methods so that a multitude

of modalities can be analyzed at once.

**Project:** In this project, we are currently focusing on two application areas. Eric Mörth is researching novel interactive visualization approaches for the visualization of multimodal MR data in the context of gynecological cancer imaging in collaboration with the MMIV gynecological cancer imaging project and the Bergen Gynecologic Cancer Research Group. Sherin Sugathan researches novel interactive visualization approaches for the visualization of multimodal MR data in the context of MS in collaboration with the MMIV Advanced Neuroimaging project.

**Important results:** The developed methods are prototyped in software applications that can be used by researchers within MMIV. One example of this is the ParaGlyder application developed by Mörth for the analysis of multi-parametric MR

in the context of gynecological cancer imaging.



The ParaGlyder application combines spatial and non-spatial visualization to enable multi-parametric analysis and exploration.

**Future plans:** The team is currently investigating novel tools for visual analysis of multi-modal data across cohorts of patients. In the future, we hope to further investigate time-varying multimodal data analysis.

### Team

**Team leader:** Noeska Smit

**Collaborators:** Ingfrid Haldorsen, Erlend Hodneland, Kari Strønø Wagner-Larsen, Kai Lawonn, Stefan Bruckner, Hauke Bartsch, Frank Riemer, Renate Gruner

**PhD candidates:** Eric Mörth, Sherin Sugathan

**Master students:** Stian Soltvedt, Robin Grundvåg

The background image shows a wide expanse of dark blue ocean meeting a clear, light blue sky at the horizon. On the left side, a dark, rugged cliff face is visible, with some white foam from waves crashing against its base. The overall scene is peaceful and natural.

## 7. Publications



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