Multimodal imaging, deep learning and visualization in clinical imaging reasearch

https://mmiv.no/machinelearning

Mohn Medical Imaging and Visualization Centre

AI in healthcare
Bodø June 18th 2019

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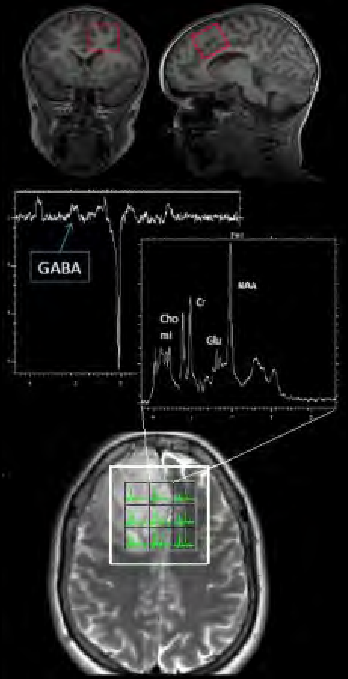
Mohn Medical Imaging and Visualization Centre

AIM: Research quantitative imaging and interactive visualization

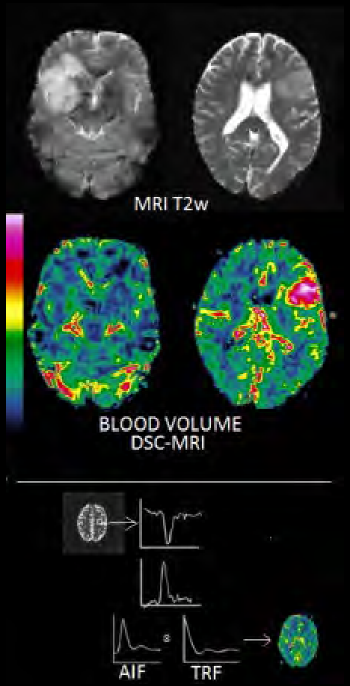
Core activities in machine learning/ artificial intelligence

Feature detection



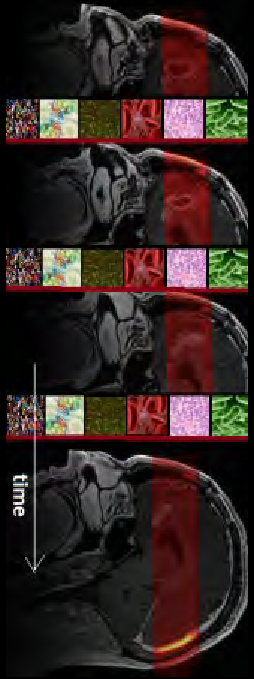
Novelty in data acquisition, reconstruction, visualization

Feature extraction



Novelty in data reduction, pattern recognition, vis.

Feature prediction



Novelty in linking features to prognosis/omics

HELSE BERGEN
Haukeland Universitetssjukehus

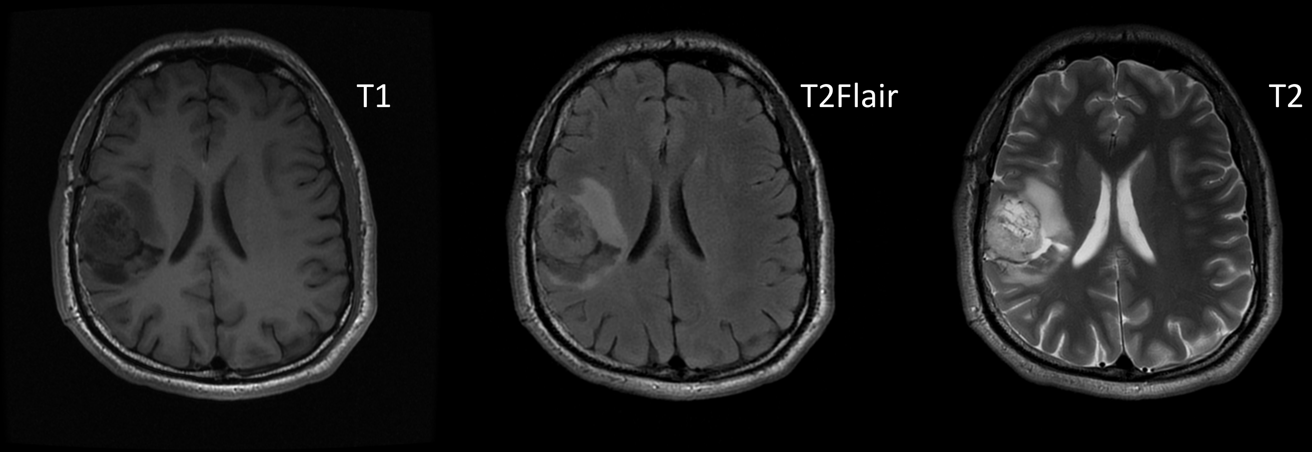
BERGENS FORSKNINGS STIFTELSE

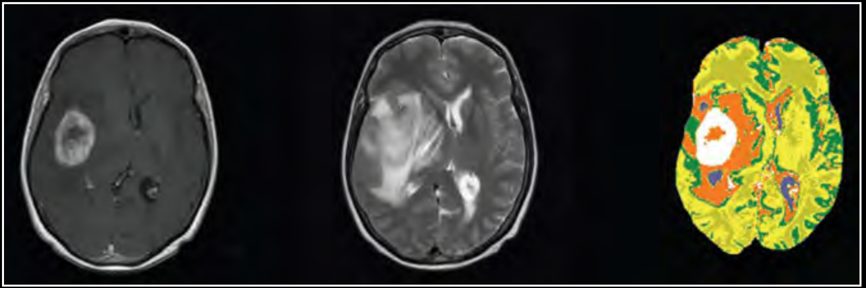
UNIVERSITAS BERGENSIS

MMIV

Classical machine learning (SVM, KNN, ..)

…choosing approriate features



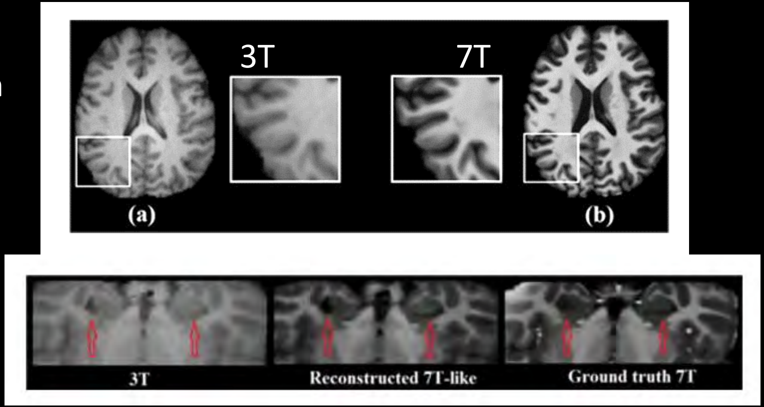


Feature extractions: Multispectral Imaging Analysis.
Kvinnsland, .., Grüner 2009

Deep Learning: Image reconstruction

- Information from high resolution images can be predicted from low resolution images using priors from paired dictionaries

Bahrami K et al. Reconstruction of 7T like images from 3T.
IEEE Trans Med Imaging 2016; 35:2085-2097



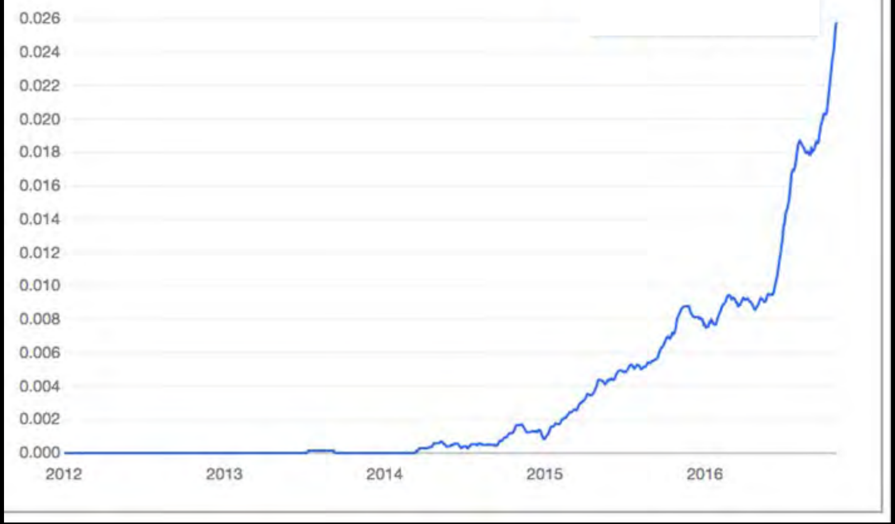
- Sparse sampling:

Schlemper et al. A Deep Cascade of CNN for dynamic MRI image reconstruction.
IEEE Trans Med Img. Vol 2; 20018

AI: An accelerating field

- «Human-level performance»
- Methods
- Companies (startups)
- Investments
- Universities (courses and publications)
- Media
- Governments

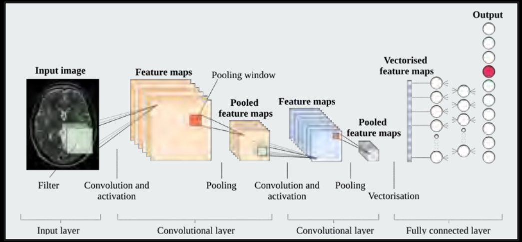
https://aiindex.org



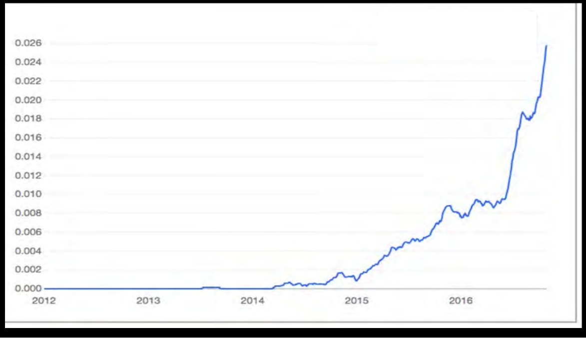
“Big data”

GPU

Old models, some new tricks



Investments



Open science

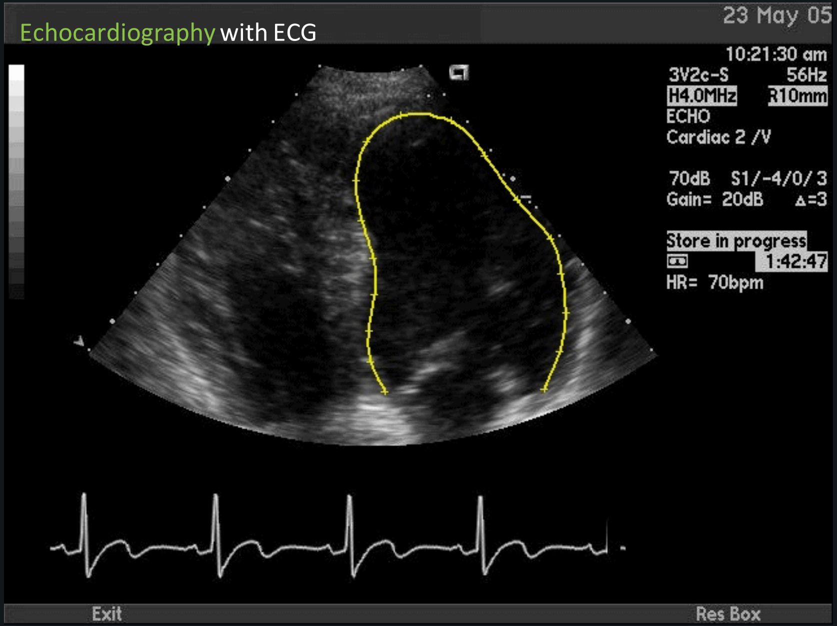
Frameworks

Open source
Open competitions
Open courses
Open data

Courtesy Prof. A Lundervold, UIB

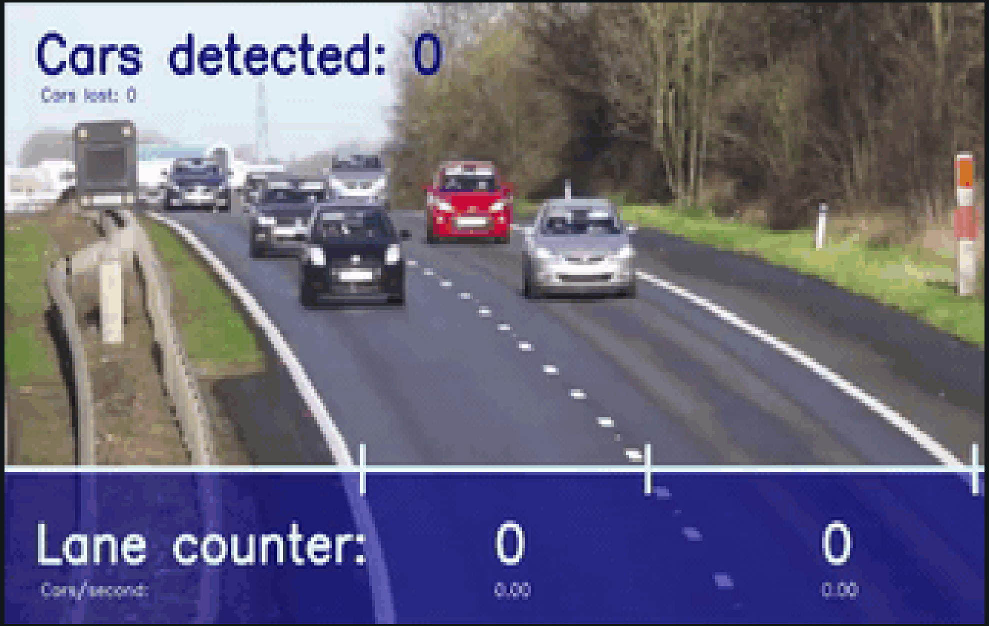
Computational imaging & machine learning

… generic technologies



Contour detection + tracking + volume estimation
=> cardiac output [ml/min]

Peng Wang, S. Zhou, M. Szucs, Endocardium tracking by fusing optical flows in straightened images with learning based detections, IEEE International Symposium on Biomedical Imaging: From Nano to Macro (ISBI), 2011

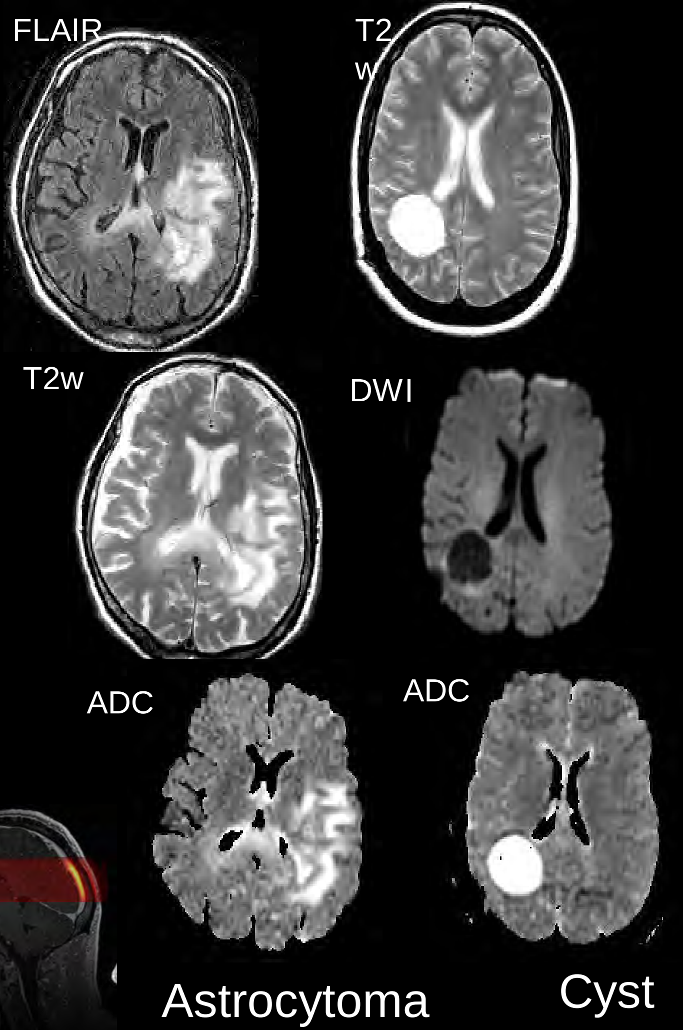


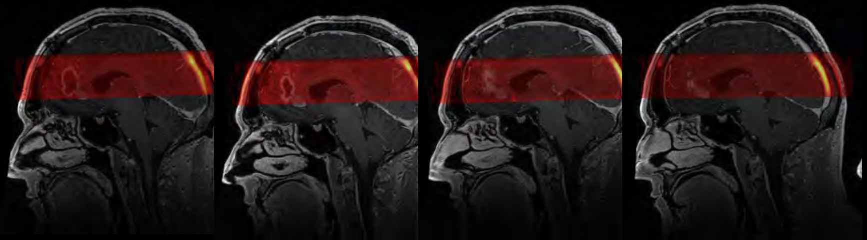
Object detection + tracking + number-plate recognition
=> electronic toll collection / vehicle speed [km/h]

https://developer.ibm.com/code/2018/05/11/using-computer-vision-to-detect-and-track-moving-objects-in-video/

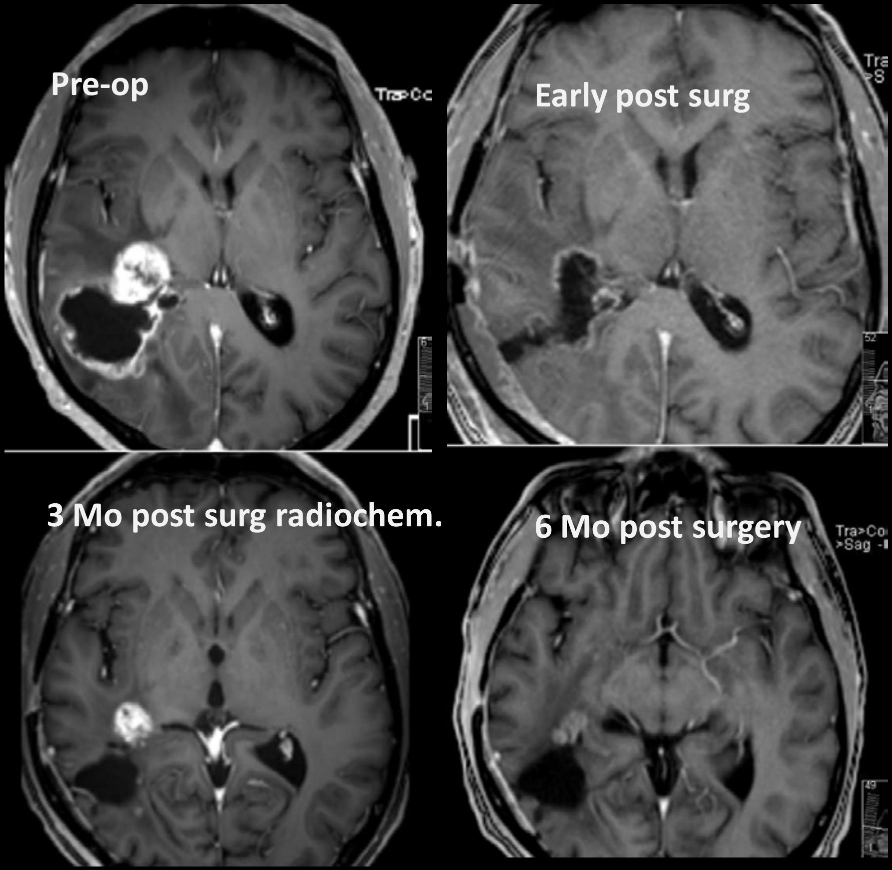
Clinical imaging

- Differential diagnostics: Primarily morphology including vessel mapping (MRI) or glucose metabolism (PET) ("Surgical level")
- Qualitative assessments
- Individual, personalized
- Longitudinal information
- Patient history information





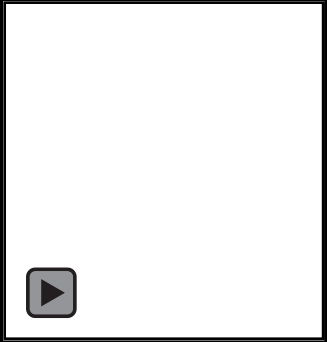
Motivation: «*Every biopsy is an imaging failure*»



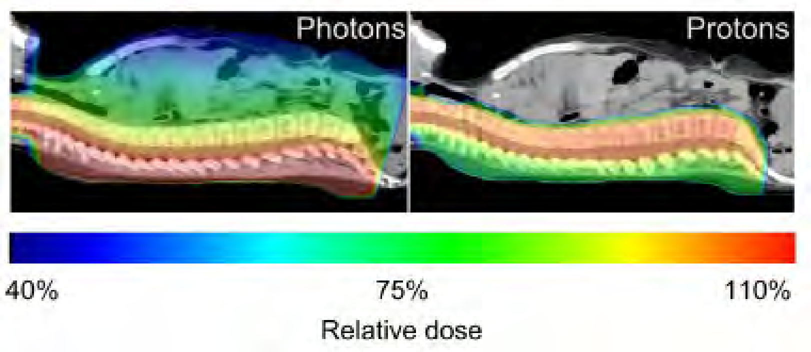
Motivation: Novel therapeutic interventions

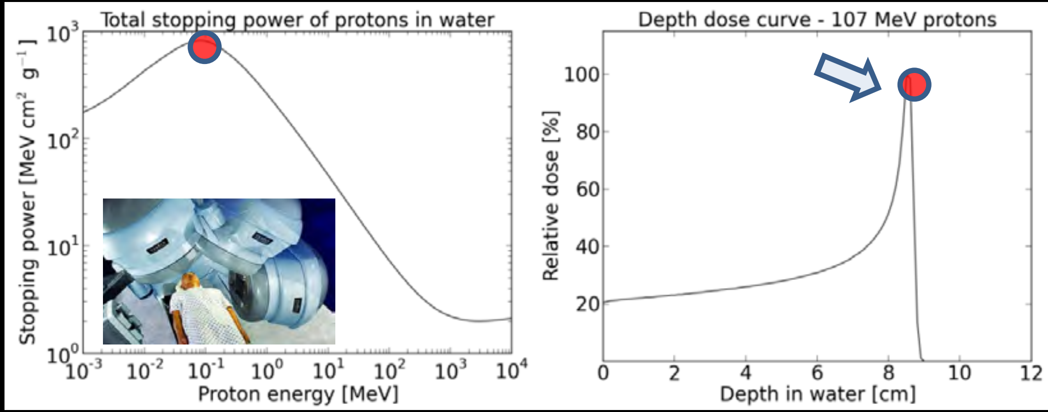
(larger variety/ more precise)

$$-\frac{dE}{dx} = 2\pi N_a r_e^2 m_e c^2 \rho \frac{Z}{A} \frac{z^2}{\beta^2} \left[ln \left(\frac{2 m_e \gamma^2 v^2 W_{max}}{I^2} \right) - 2\beta^2 - \delta - 2\frac{C}{Z} \right]$$

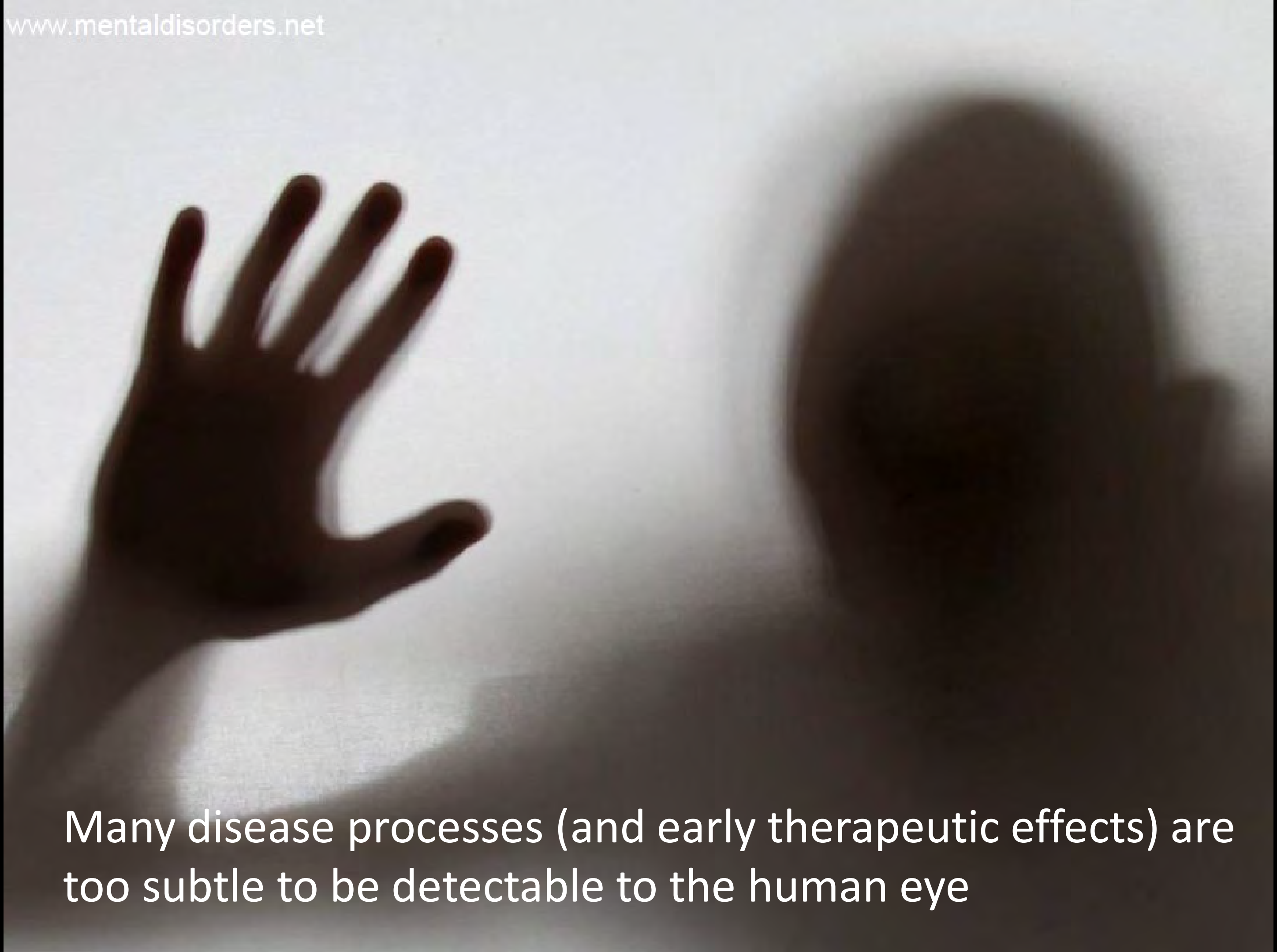


Anticancer drugs



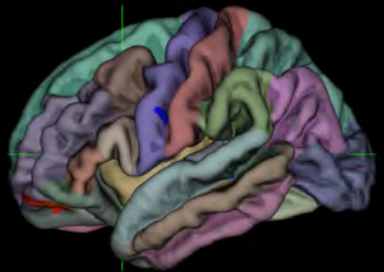


Courtesy K. Ytre-Hauge, Dept of Physics and Technology, UIB



Many disease processes (and early therapeutic effects) are too subtle to be detectable to the human eye

Research imaging



- Morphology (macrostructure)
- Physiology
  – Diffusion based imaging
  – Perfusion based imaging
  – fMRI (task/ rest)
  – Structural/functional connectivity (-> DCM)
- Metabolites (MRS) & metabolism and biochemistry (PET/ NM)
- New approaches

Traditional cross sectional:

- ”Purity of diagnosis”*
- Sample size
- Control group (age, gender, …)
- Medication (native vs washout)
- ….

Versus:

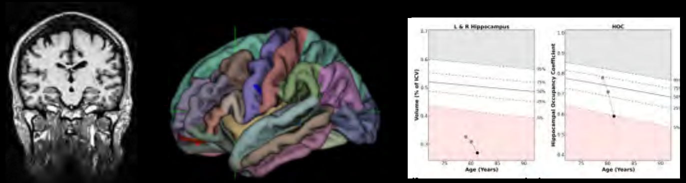
Big data, deep learning

- XXXomics/ Imaging genetics

-> personalized medicine

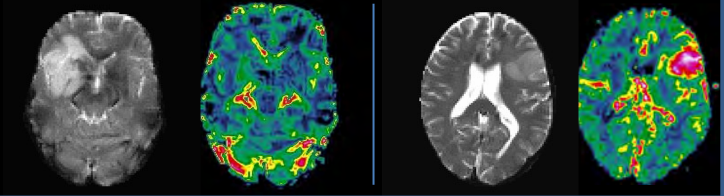
Imaging biomarkers

Structure



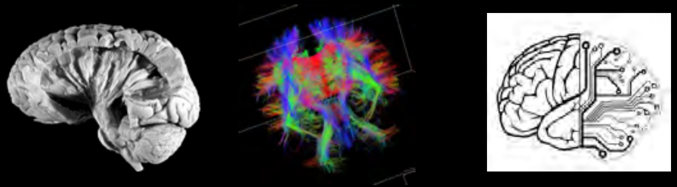
e.g. Volume

Microvasculature



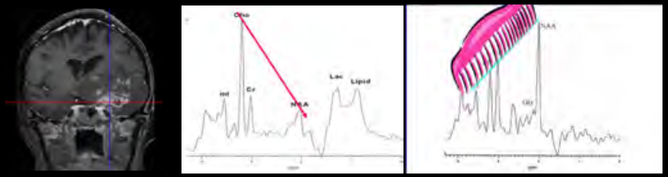
e.g. Blood flow

Microstructure



e.g. Orientation

Biochemistry



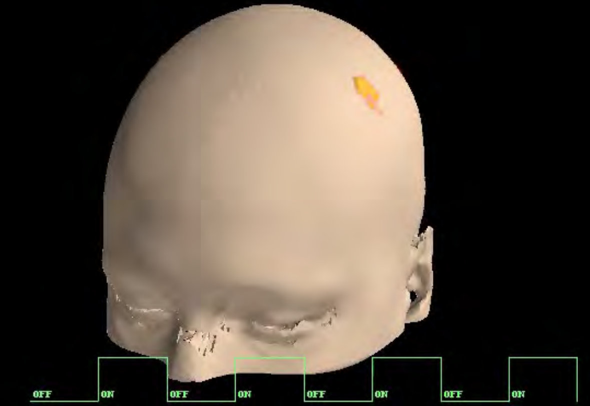
e.g. Molecular concentrations

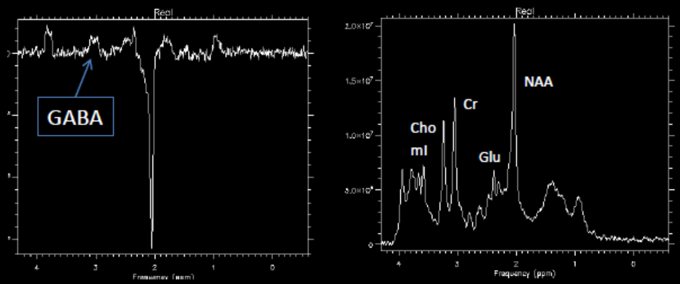
and more!!!

Auditory hallucinations:
Perception of sounds that do not exist

K. Kompus, R. Westerhausen, K. Hugdahl *Neuropsychologia* (2011)

N = 103





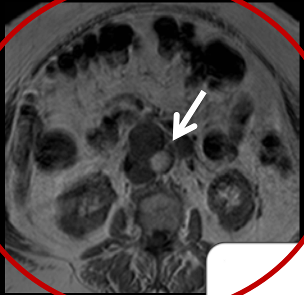
DMN: Raichle et al 2001, 2010, 2015
EMN: Hugdahl, Raichle et al 2015

Nordic Center of Excellence NCoE Cognitive Control
erc European Research Council
ERC Advanced Investigators Grant
Senter for fremragende forskning
BP Bergen Psykoseprosjekt 2
Stiftelsen KGJ
Bergen fMRI Group
Universitas Bergensis
HELSE BERGEN
Haukeland Universitetssjukehus

Courtesy Prof Kenneth Hugdahl, Faculty of Psychology, UIB

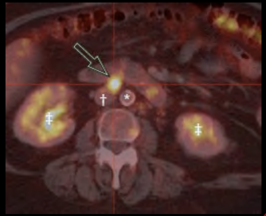
Precision Imaging in Gynecologic Cancer

Imaging is an important part of the diagnostic work up, *guides therapy* and is an important *research tool*

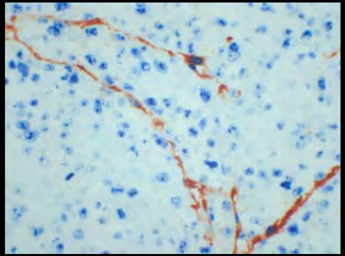


Gynecologic cancer patient

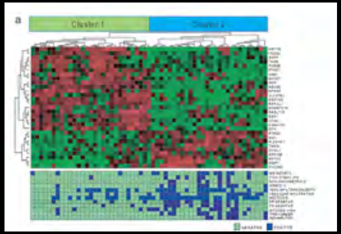
Preoperative imaging



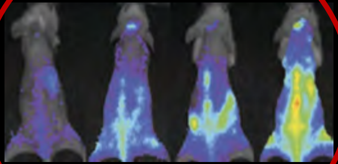
Biopsy and surgery
Tissue biobank



Molecular and genetic testing

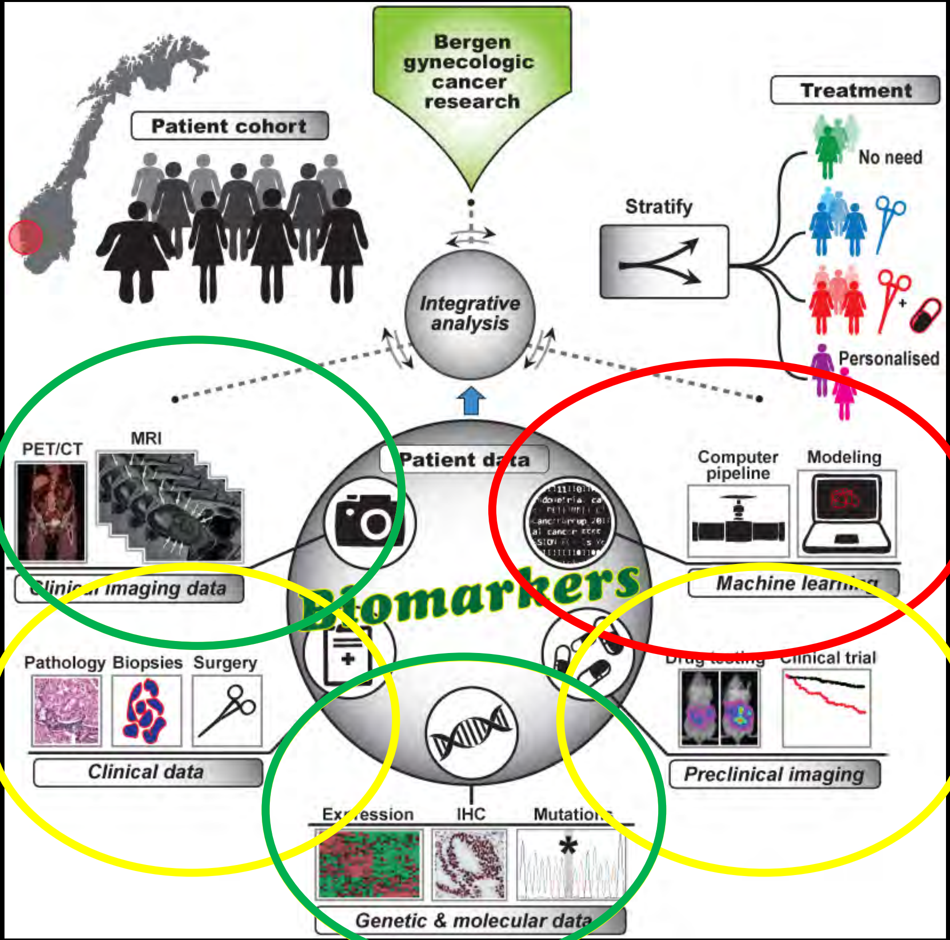


Preclinical trials



Clinical trials

Core MMIV project: Precision Imaging in Gynecologic Cancer



PI: Prof MD/ PhD I Haldorsen/
CR: PhD E. Hodneland (Norse)

WP 1.) Biomarker- and preclinical/clinical studies (MR~800, PETCT~500)

WP 2.) Radiogenomics

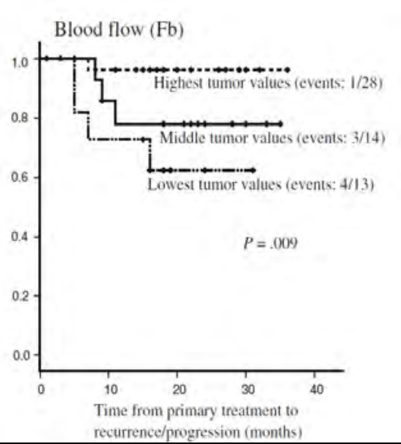
WP 3.) Machine learning

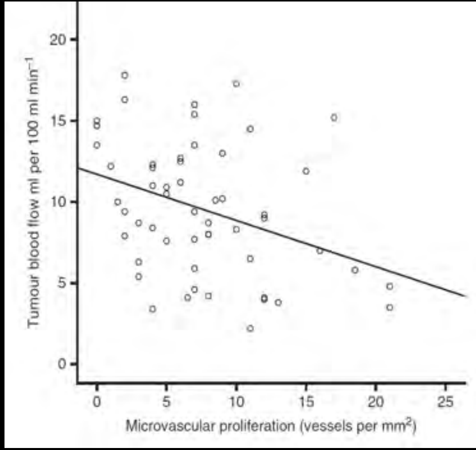
Jan'18

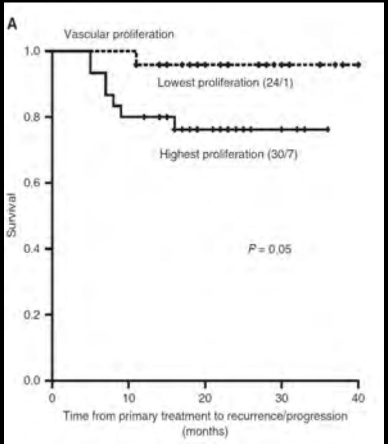

Medisin

Kan gi skreddersydd kreftbehandling

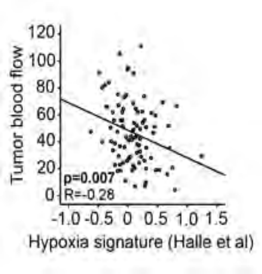
DCE- MRI in endometrial cancer identifies patients at increased risk of recurrence and links low tumor blood flow to increased vascular proliferation and hypoxia

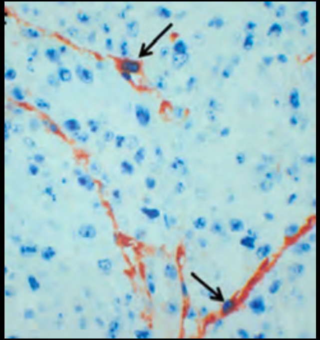






- Aggressive tumors are characterized by ↓blood flow and ↑microvascular proliferation.
- Low tumor blood flow is linked to upregulated hypoxia gene signature



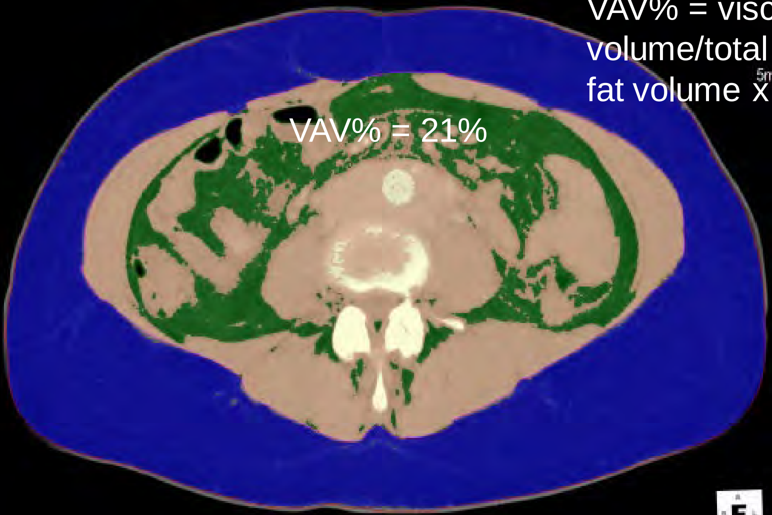


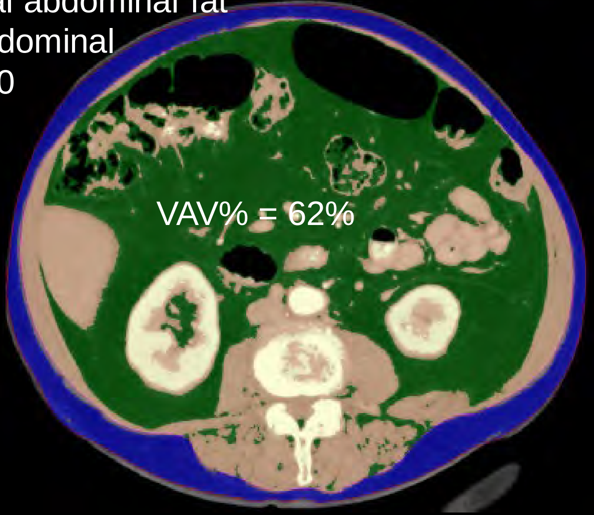
Ki67/factor VIII

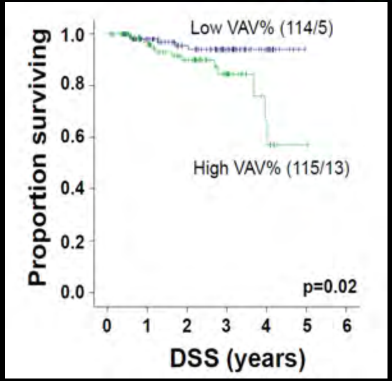
Haldorsen et al, Eur Rad, 2013, Haldorsen et al Br. J Cancer, 2014 and Berg et al, Oncotarget, 2016

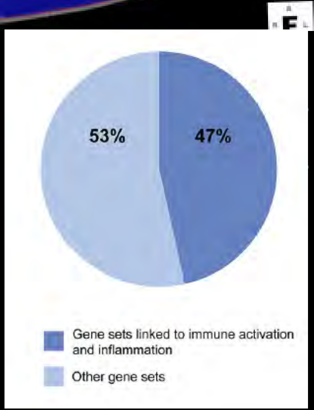
Visceral fat percentage in EC:

VAV% = visceral abdominal fat volume/total abdominal fat volume x 100







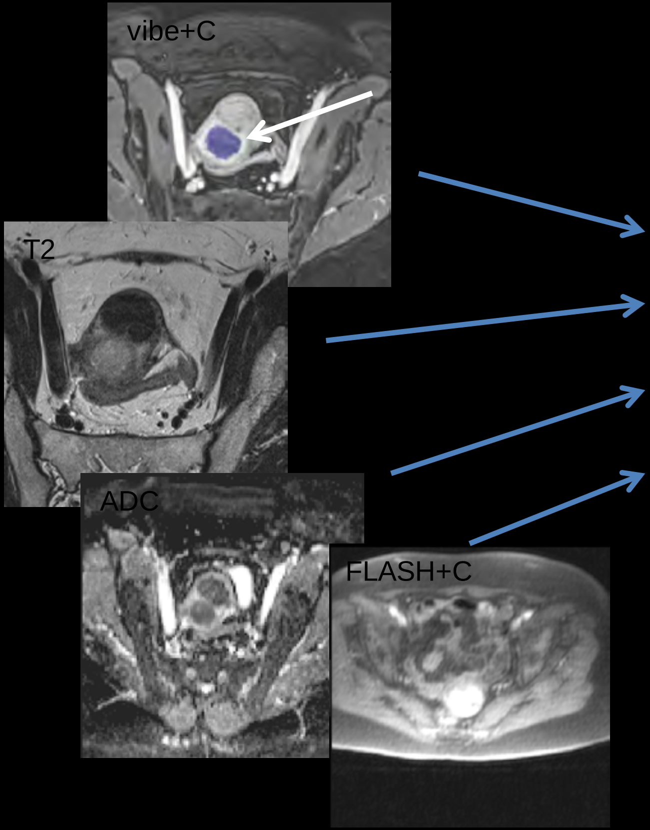


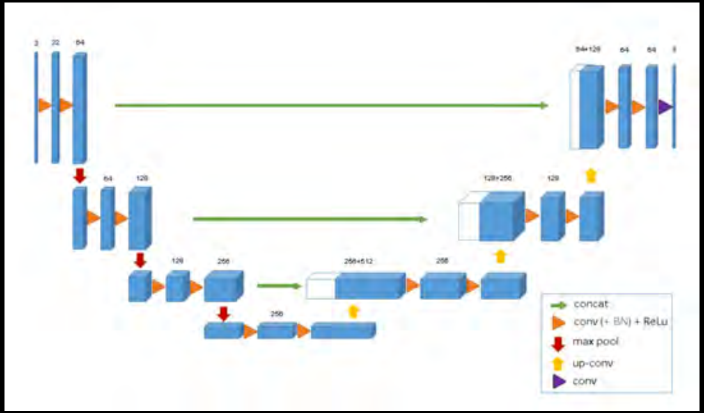
predicts aggressive disease
is linked to activation of gene sets linked to immune activation and inflammation

Mauland et al, Oncotarget 2017

WP3 (MACHINE LEARNING)

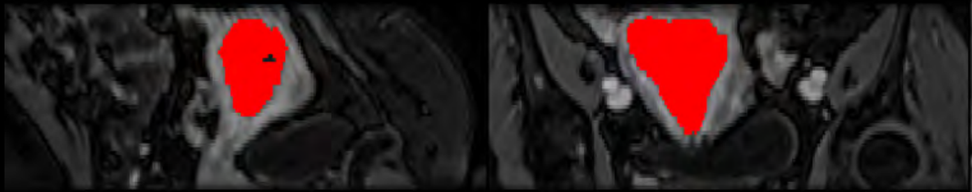
STEP 1: Training of a deep learning segmentation network

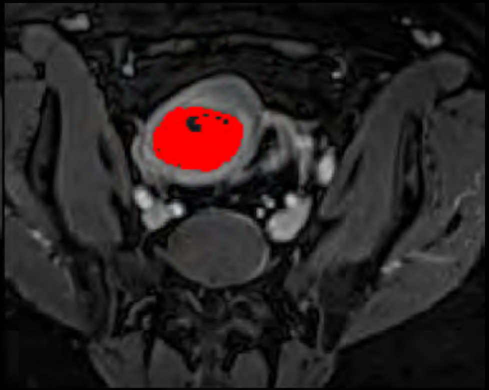




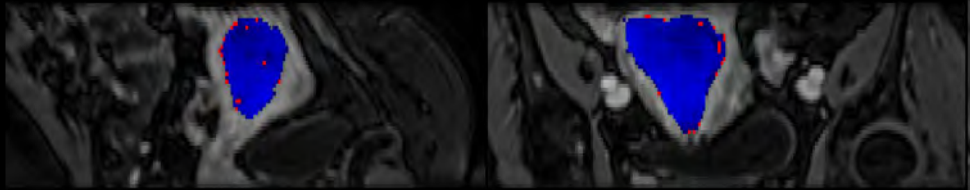
Training of a deep learning segmentation network

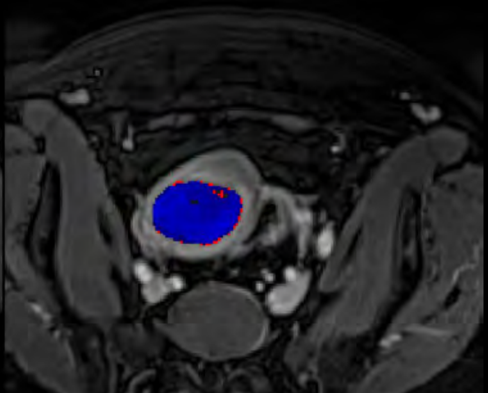
Manual segmentation of tumor



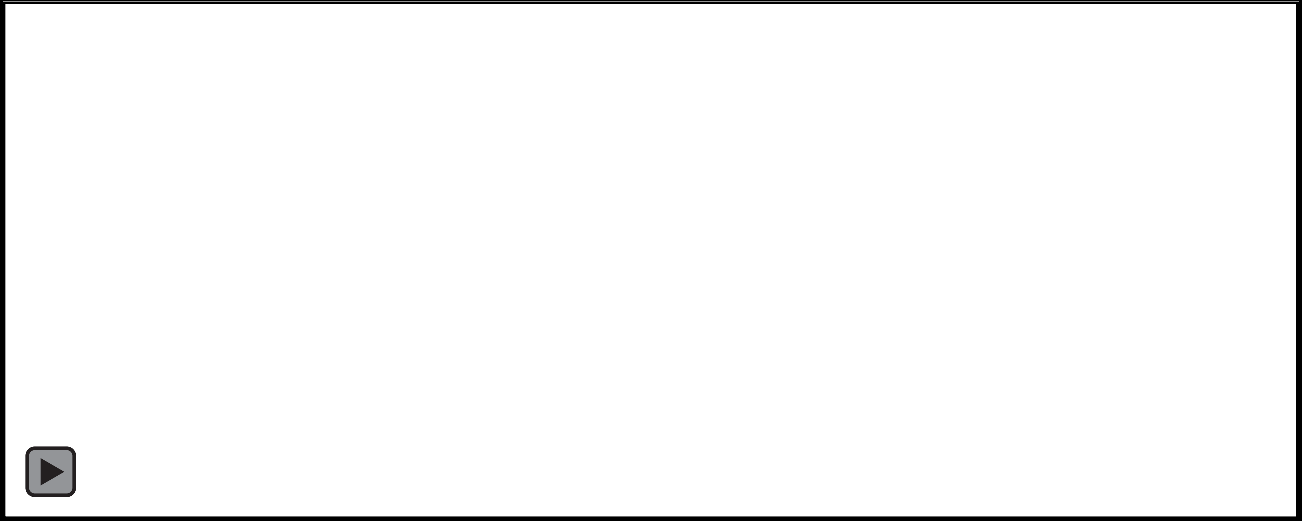


Automatic segmentation of tumor using machine learning



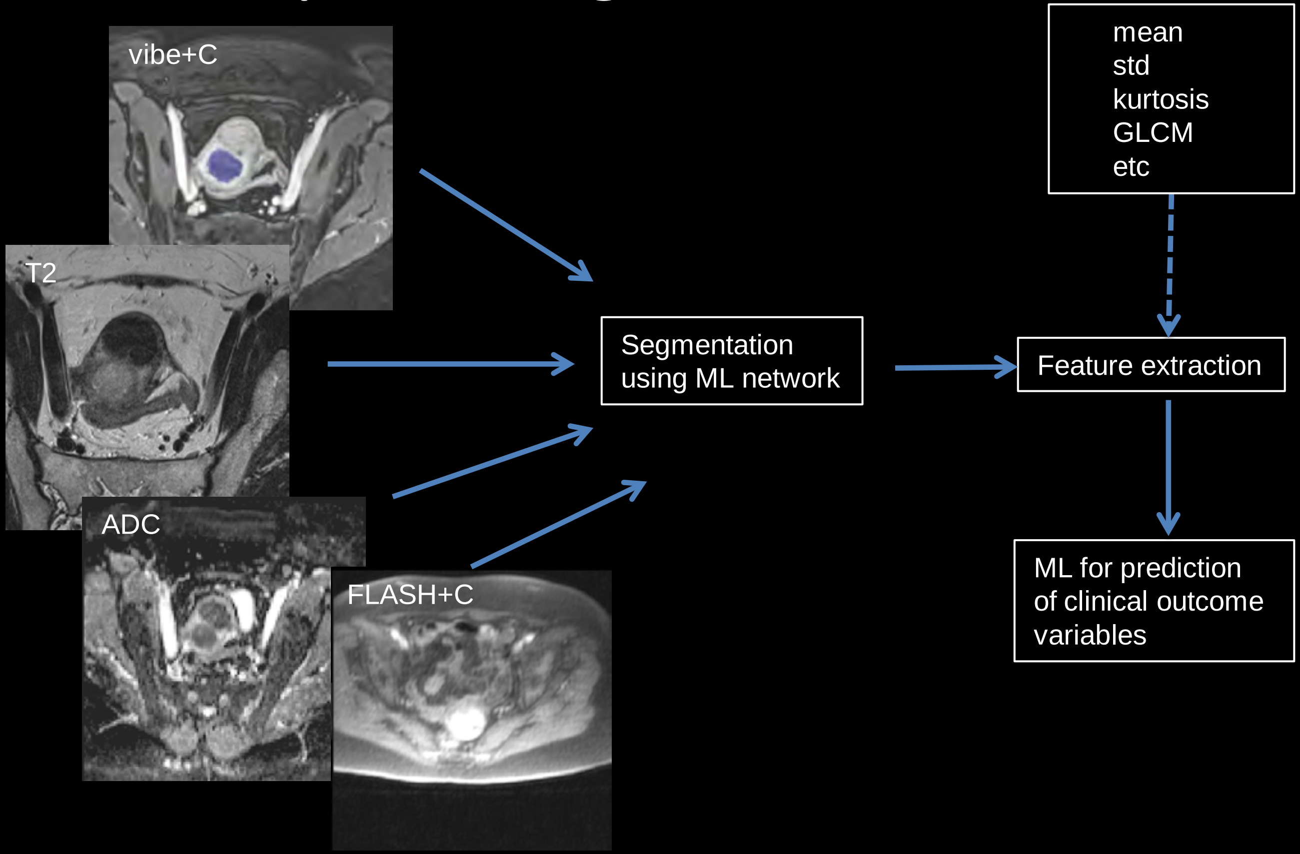


Automatic tumor segmentation using machine learning

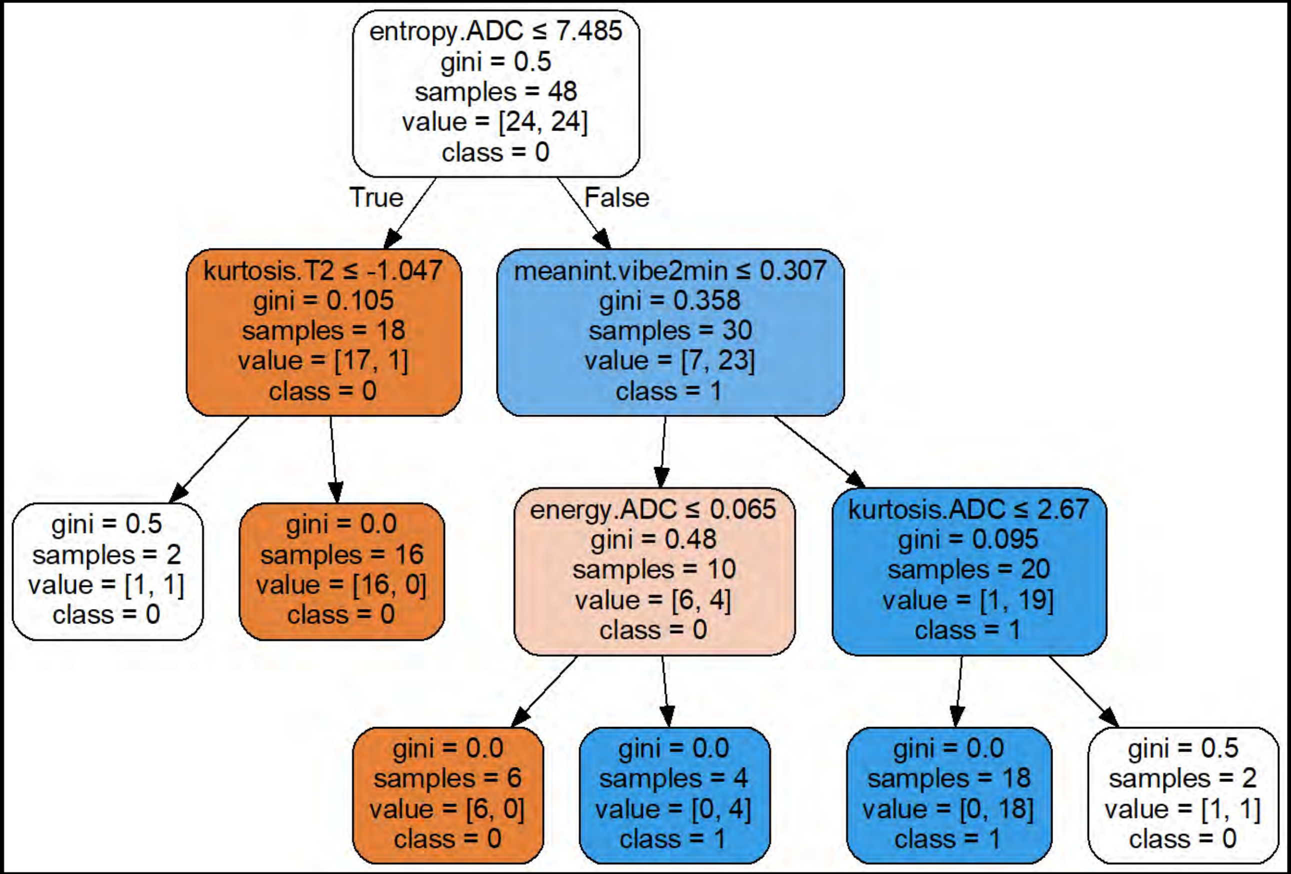


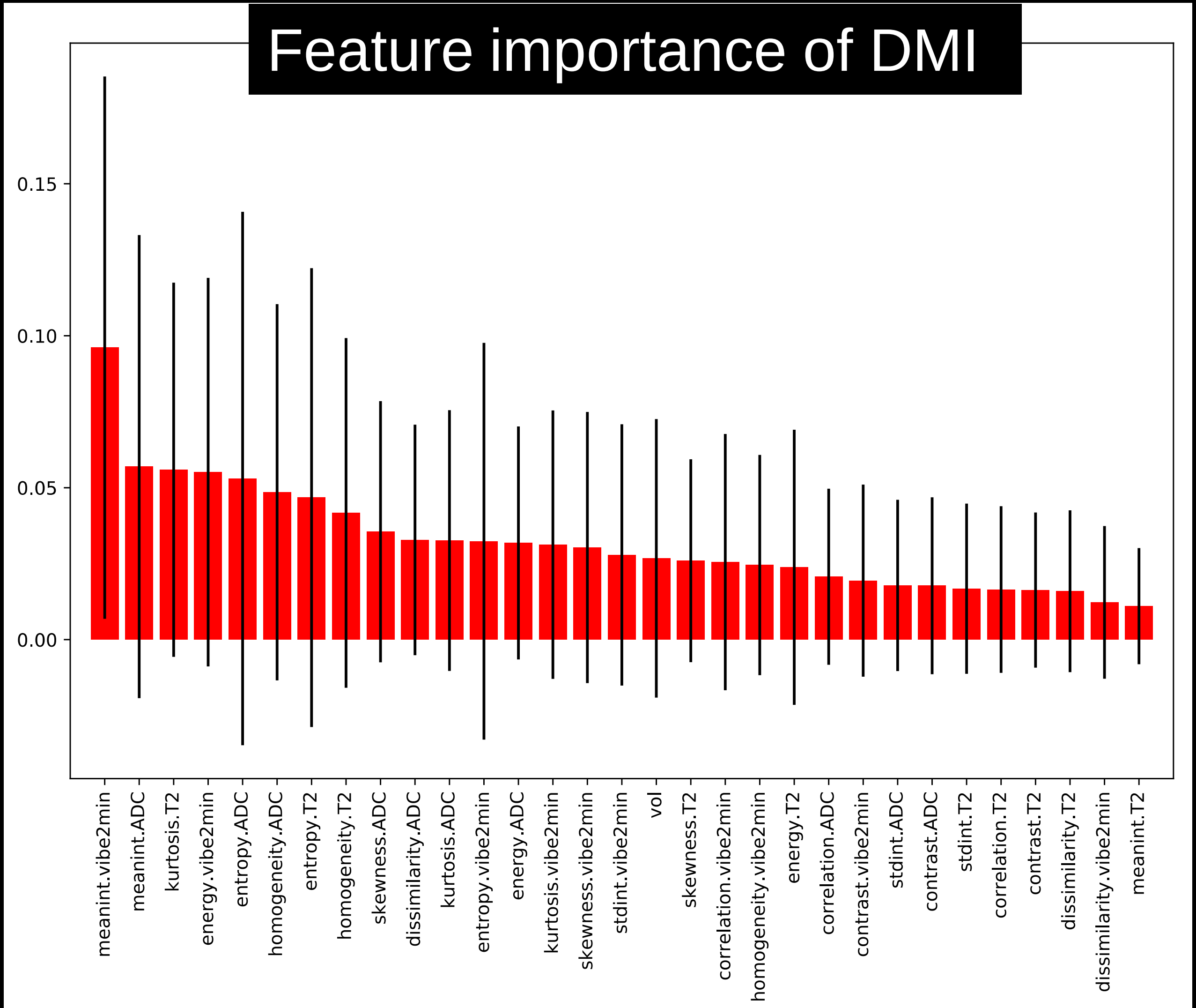
blue: true positive,
yellow: false positive,
orange: false negative

STEP2: Applying the MR data and segmented masks for predicting clinical outcome



Prediction of the staging parameter deep myometrial invasion (DMI)



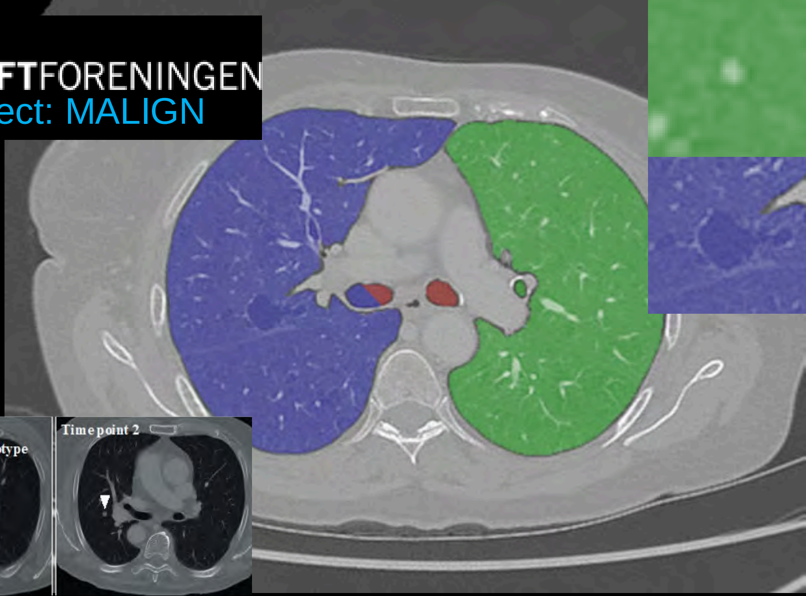

Feature importance of DMI
0.15
0.10
0.05
0.00
meanint.vibe2min
meanint.ADC
kurtosis.T2
energy.vibe2min
entropy.ADC
homogeneity.ADC
entropy.T2
homogeneity.T2
skewness.ADC
dissimilarity.ADC
kurtosis.ADC
entropy.vibe2min
energy.ADC
kurtosis.vibe2min
skewness.vibe2min
stdint.vibe2min
vol
skewness.T2
correlation.vibe2min
homogeneity.vibe2min
energy.T2
correlation.ADC
contrast.vibe2min
stdint.ADC
contrast.ADC
stdint.T2
correlation.T2
contrast.T2
dissimilarity.T2
dissimilarity.vibe2min
meanint.T2

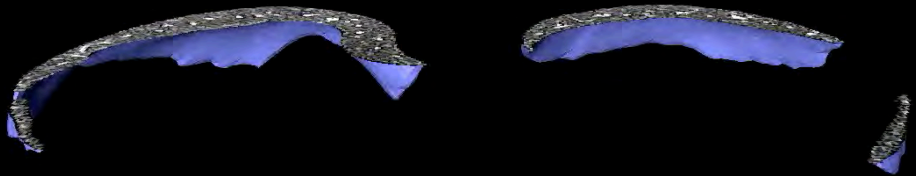
Longitudinal followup:

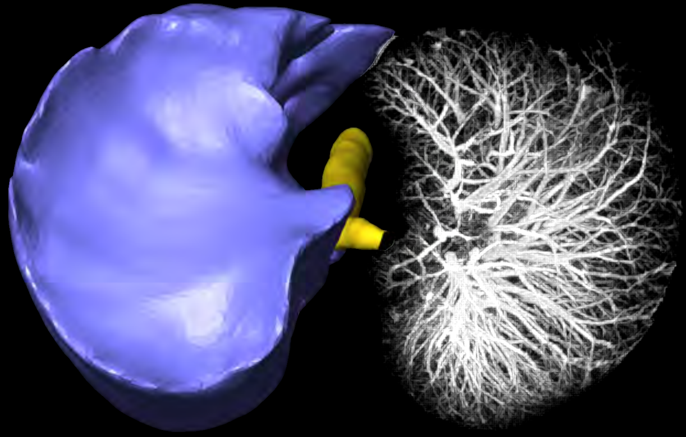
KREFTFORENINGEN
Project: MALIGN

CT Airway and Lung Segmentation for Lung Nodule Detection and Longitudinal Change Analysis

Hauke Bartsch, UCSD



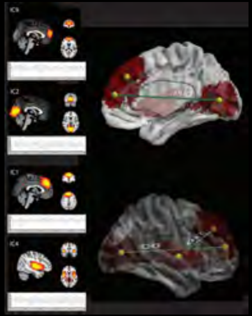


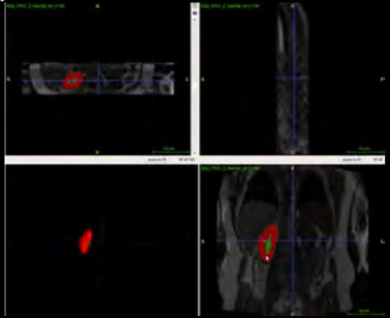


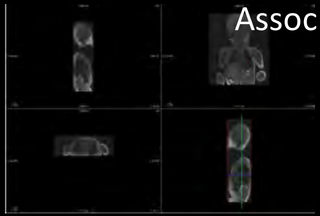
Core MMIV project: Machine learning

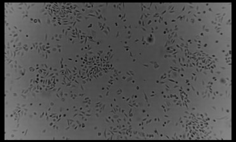
PI: Prof PhD/MD A Lundervold,
Assoc Prof. PhD AS Lundervold

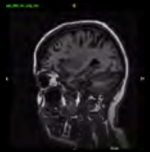
«Computational medical imaging and machine learning
– methods, infrastructure and applications»

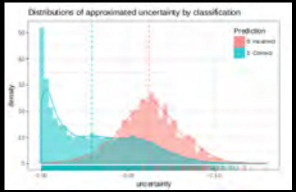


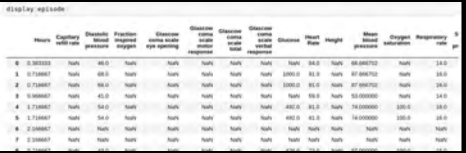


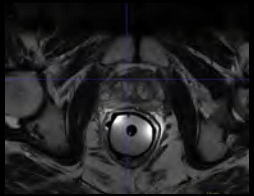


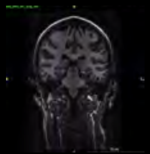












Recent publications in machine learning and computational medicine

ELSEVIER
Zeitschrift für Medizinische Physik
Volume 29, Issue 2, May 2019, Pages 102-127

Review

An overview of deep learning in medical imaging focusing on MRI

Alexander Selvikvåg Lundervold [a, b], Arvid Lundervold [a, c, d]
Show more

https://doi.org/10.1016/j.zemedi.2018.11.002

ELSEVIER
Computerized Medical Imaging and Graphics
Volume 63, January 2018, Pages 24-30

Intensity-based volumetric registration of magnetic resonance images and whole-mount sections of the prostate

Are Losnegård [a, b], Lars Reisæter [a], Ole J. Halvorsen [c, g], Christian Beisland [h, d], Aurea Castilho [f], Ludvig P. Muren [e], Jarle Rørvik [b, a], Arvid Lundervold [f, a]
Show more

Journals & Magazines > IEEE Transactions on Biomedic... > Volume: 66 Issue: 6

In Vivo Detection of Chronic Kidney Disease Using Tissue Deformation Fields From Dynamic MR Imaging

11 Author(s) Erlend Hodneland ; Eirik Keilegavlen ; Erik A. Hanson ; Erling Andersen ; Jan Ankar Monssen ; ... View All Authors

PLOS COMPUTATIONAL BIOLOGY

Hodneland et al.

A new framework for assessing subject-specific whole brain circulation and perfusion using MRI-based measurements and a multi-scale continuous flow model

JMRI

Original Research | Full Access

Preoperative tumor texture analysis on MRI predicts high-risk disease and reduced survival in endometrial cancer

Sigmund Ytre-Hauge MD, Julie A. Dybvik MD, Arvid Lundervold BSc, MD, PhD, Øyvind ... PhD, Camilla Krakstad PhD, Kristine E. Fasmer MSc, Henrica M. Werner MD, PhD ... See

First published: 13 August 2018 | https://doi.org/10.1002/jmri.26184 | Cited by: 5

PLOS ONE

Estimating the discretization dependent accuracy of ... coupled capillary flow measurements

PLOS ONE
PUBLISH ABOUT BROWSE
OPEN ACCESS PEER-REVIEWED
RESEARCH ARTICLE

Inattention in primary school is not good for your future school achievement—A pattern classification study

Astri J. Lundervold, Tormod Bøe, Arvid Lundervold

Published: November 28, 2017 • https://doi.org/10.1371/journal.pone.0188310

PLOS ONE
PUBLISH ABOUT BROWSE
OPEN ACCESS PEER-REVIEWED
RESEARCH ARTICLE

Lateral ventricle volume trajectories predict response inhibition in older age—A longitudinal brain imaging and machine learning approach

Astri J. Lundervold, Alexandra Vik, Arvid Lundervold

Published: April 2, 2019 • https://doi.org/10.1371/journal.pone.0207967

Dissemination

EUREKA!

FLSB

ECR 2018 DIVERSE & UNITED
February 28 – March 4
Vienna

Oslo universitetssykehus

Tekna

Realfagsdagene
@realfagsdagene

DELFT DATA SCIENCE

data

Den Norske Dataforening
Ditt kompetansenettverk i et digitalt Norge

SIEMENS Healthineers

NORDAHL GRIEG VIDEREGÅENDE SKOLE
HORDALAND FYLKESKOMMUNE

Norsk radiologisk forening
DEN NORSKE LEGEFORENING

19. oktober 2018

Norsk radiologisk Forenings standpunkt om «Bruk av kunstig intelligens i radiologi».

Springbrettet

NORSK RADIOGRAFFORBUND
Norwegian Society of Radiographers

(NoRafo ønsker å takke Alexander Lundervold ved Mohn Medical Imaging and Visualization Centre for nyttige innspill).

Courses

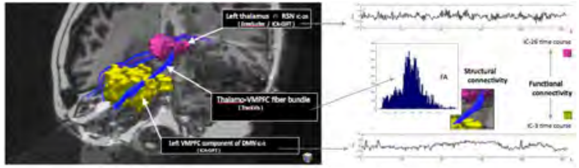
Kurset tilhører Institutt for biomedisin og er assosiert med Mohn Medical Imaging and Visualization Centre .

ELMED219

Summer school 2019 in Computational Biomedicine – Imaging, machine learning and precision medicine

DAT253 Practical deep learning

BMED360



HELIKT620

ETTER- OG VIDEREUTDANNING

Helseinformatikk

ELMED223

MASTEREMNE

Innovasjon og entreprenørskap

Courses

Summer school 2019 in Computational
Biomedicine – Imaging, ma
learning and precision medi

ERASMUS+
Enriching lives, opening mi

European Commission

OPEN EDUCATIONAL RESOURCES IN COMPUTATIONAL BIOME

4 Participating countries:

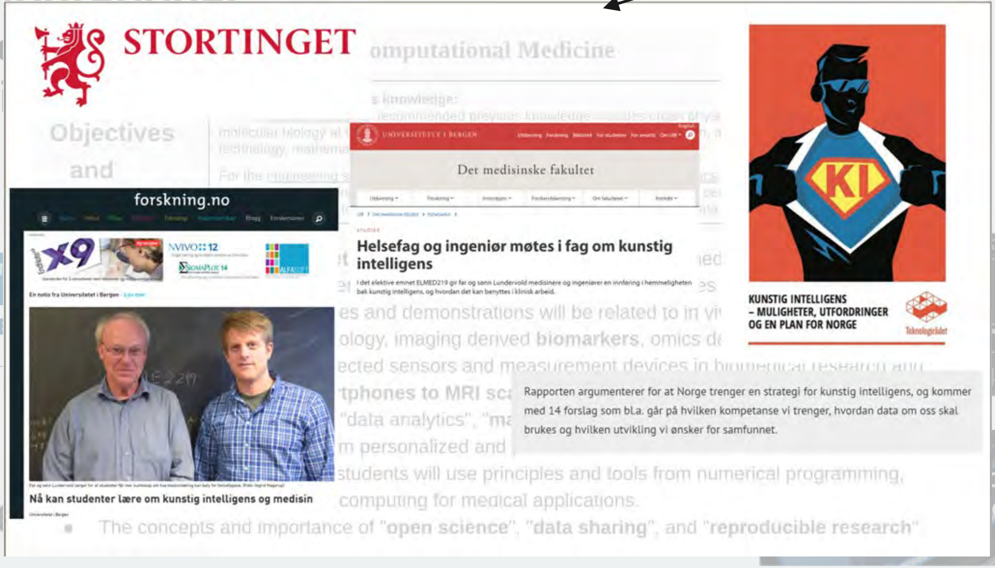
MASTEREMNE

ELMED223

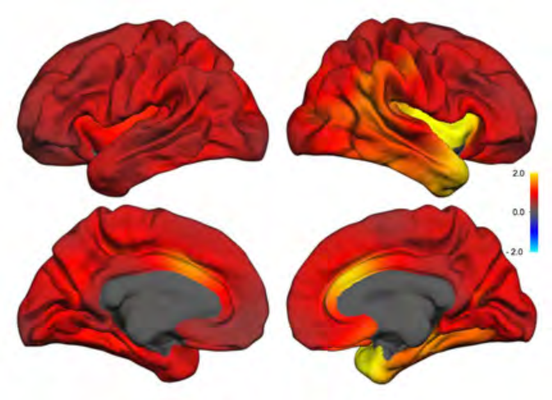
Innovasjon og entrepr

Kurset tilhører Institutt for biomedisin og er assosiert med Mohn Medical Imaging and Visualization Centre .

ELMED219



Core MMIV project: Advanced neuroimaging



Data from Bergen sample, n = 19

Oltedal et al. (2017) *Neuroimage: Clinical*

DAGENS Medisin

Nyheter Debatt DM Arena DMTV

LETER ETTER SVAR: Renate Grüner og Leif Oltedal ved Haukeland universitetssjukehus sammenligner MR-bilder tatt før og etter elektrosjokk-behandling. Foto: Silje Robinson

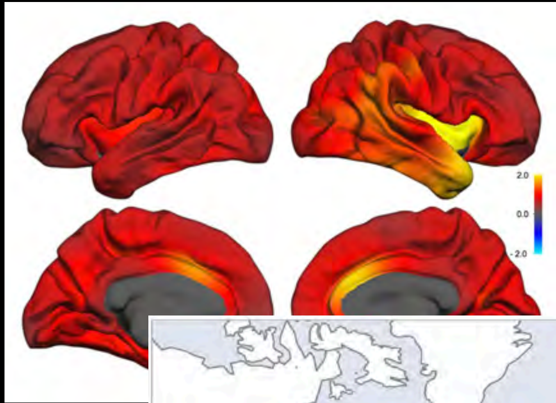
FORSKNING

Bruker MR på jakt etter elektrosjokk-svar

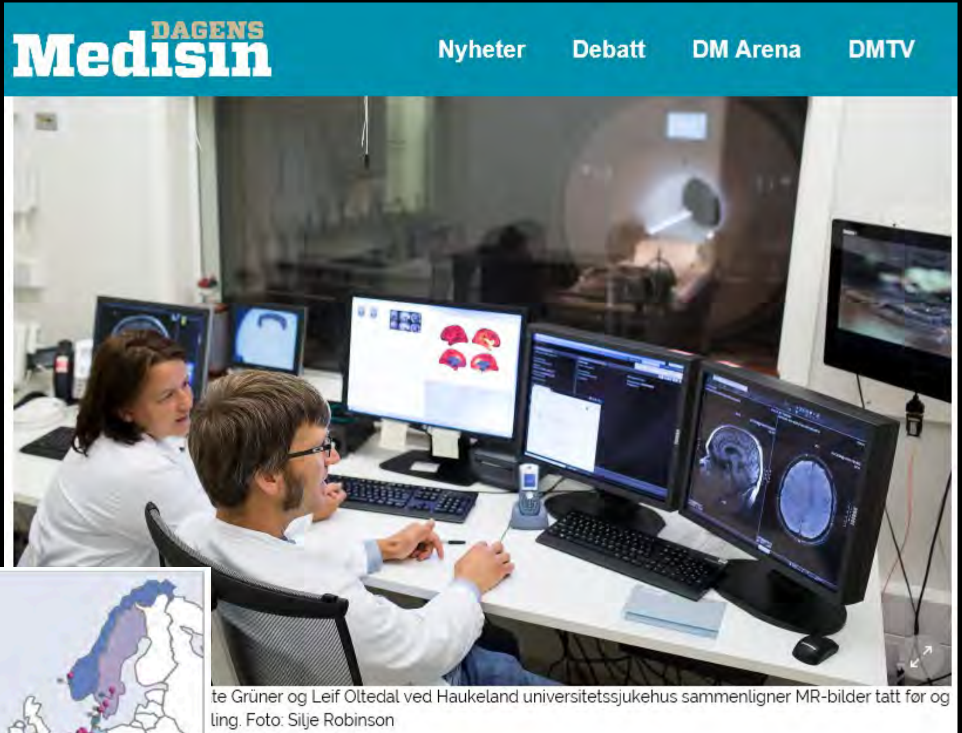
Fra Bergen leder overlege Leif Oltedal verdens største MR-studie på elektrosjokk-

Oct 2018

Core MMIV project: Advanced neuroimaging



Data from B
sample, n =
Oltedal et a
Neuroimag

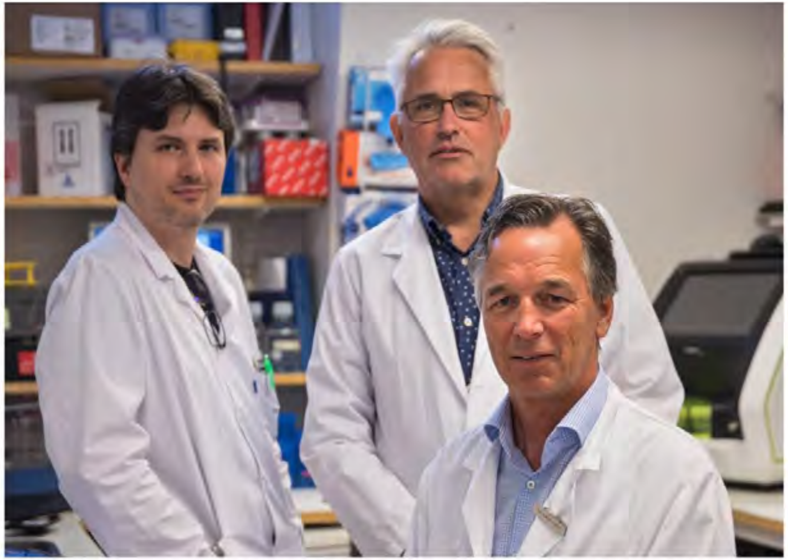


Current data (n = 550)

- 341 patients (15 sites)
- 100+ healthy controls
- 50+ other controls
- MRI and clinical data; before and after ECT

-> **aiming at increasing to N= 2000**

Computational medicine in the clinic



NYTT HÅP: Et nytt forskningssenter i Bergen skal forske på sykdommer som ALS. Forsker og professor Charalampos Tzoulis, nevrolog og overlege Kjell-Morten Myhr og professor og overlege Ole-Bjørn Tysnes skal lede forskningen. Foto: Gisle Oddstad

Åpner nytt forskningssenter i Bergen: Slik skal de løse ALS-gåten

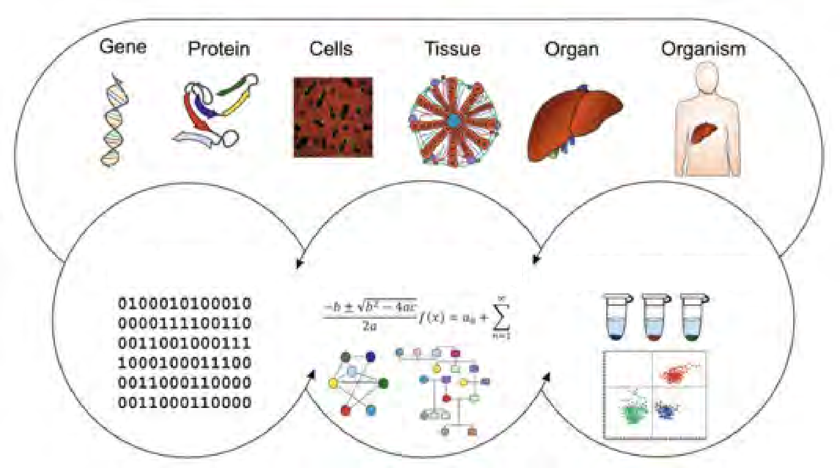
worms

fish

flies

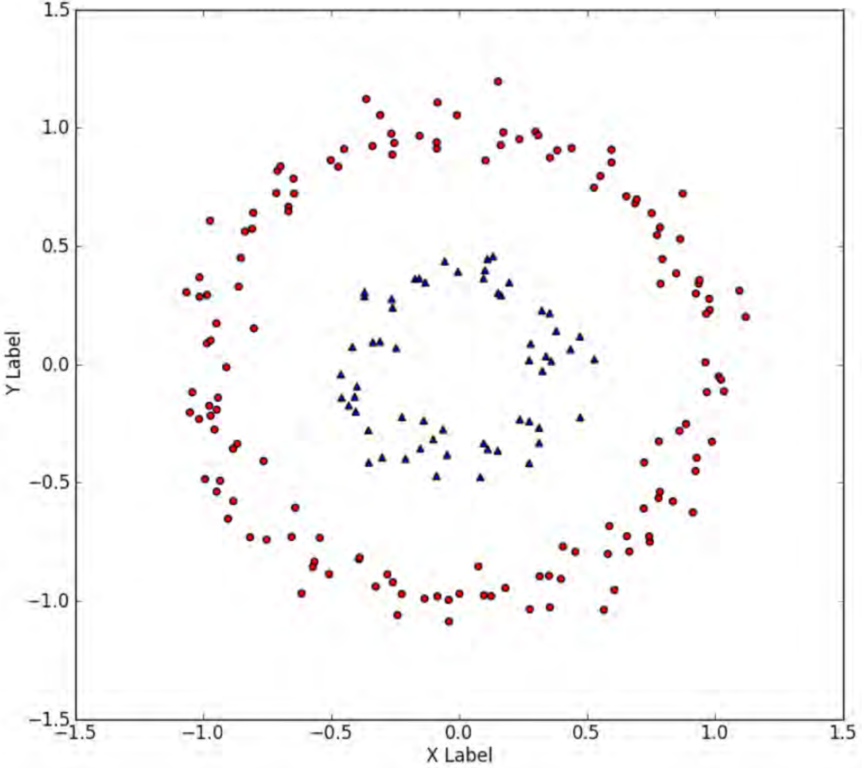
. . .

man



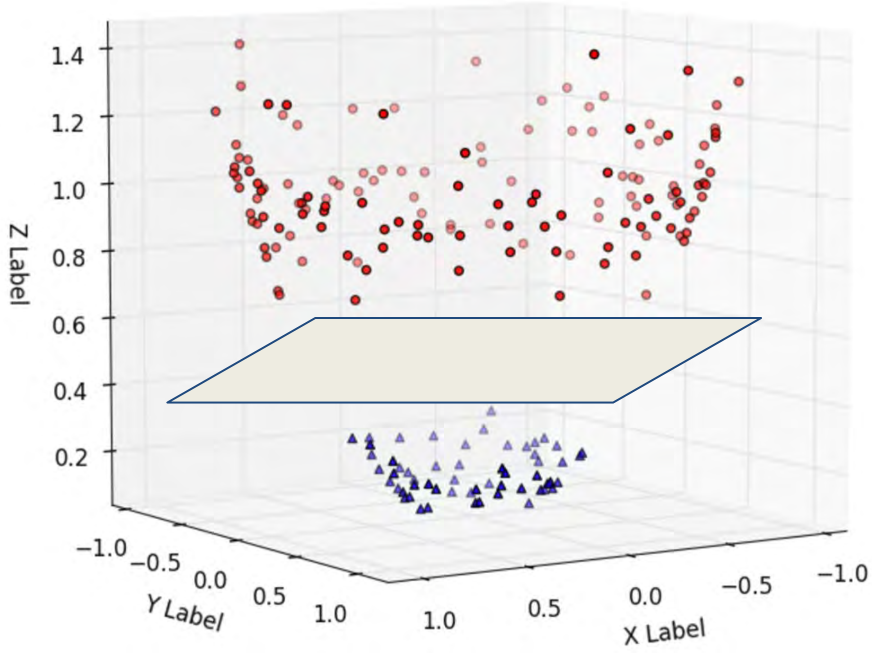
Wet-lab **Dry-lab** **Moist-lab**

Data in R^2 linear separable ?



Data linear separable R^3 !

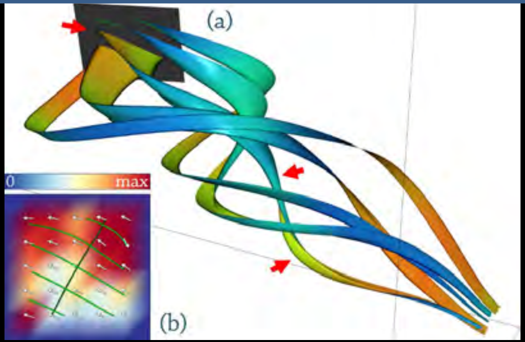
$Z = X^2+Y^2$

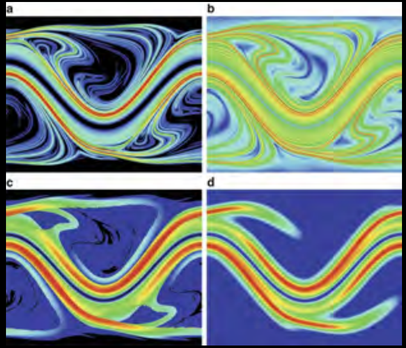


Courtesy Prof. A Lundervold, UIB

Flow visualization

PI: Prof H Hauser



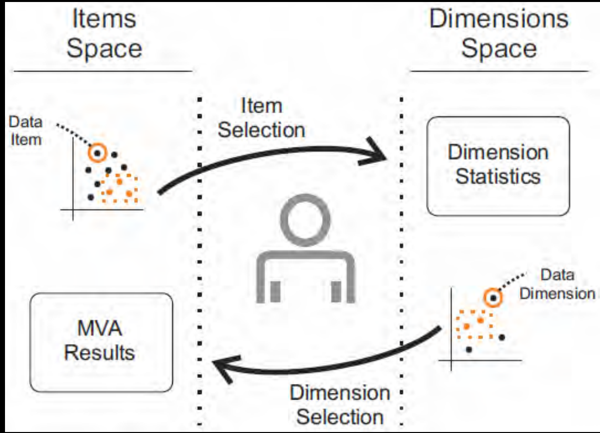


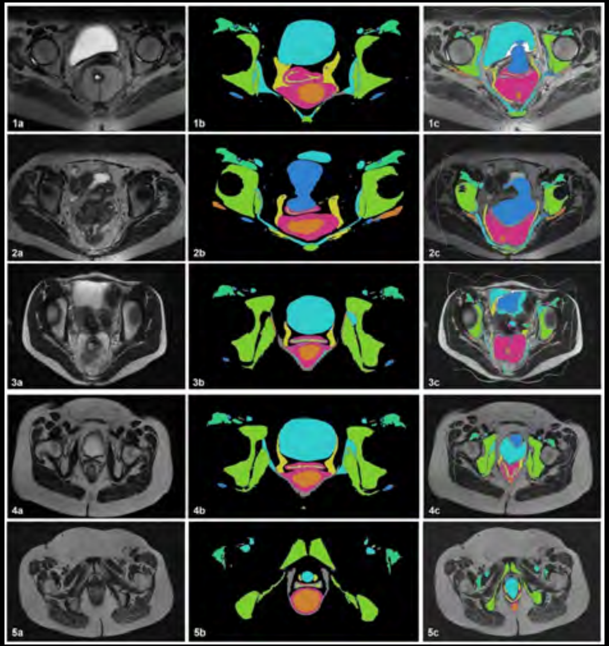
Core MMIV project: Medical Visualization

Research directions:

- Interactive visual analysis
- Visual parameter space analysis
- Visual integration and comparison
- Quantitative visualization
- Smart visual interface

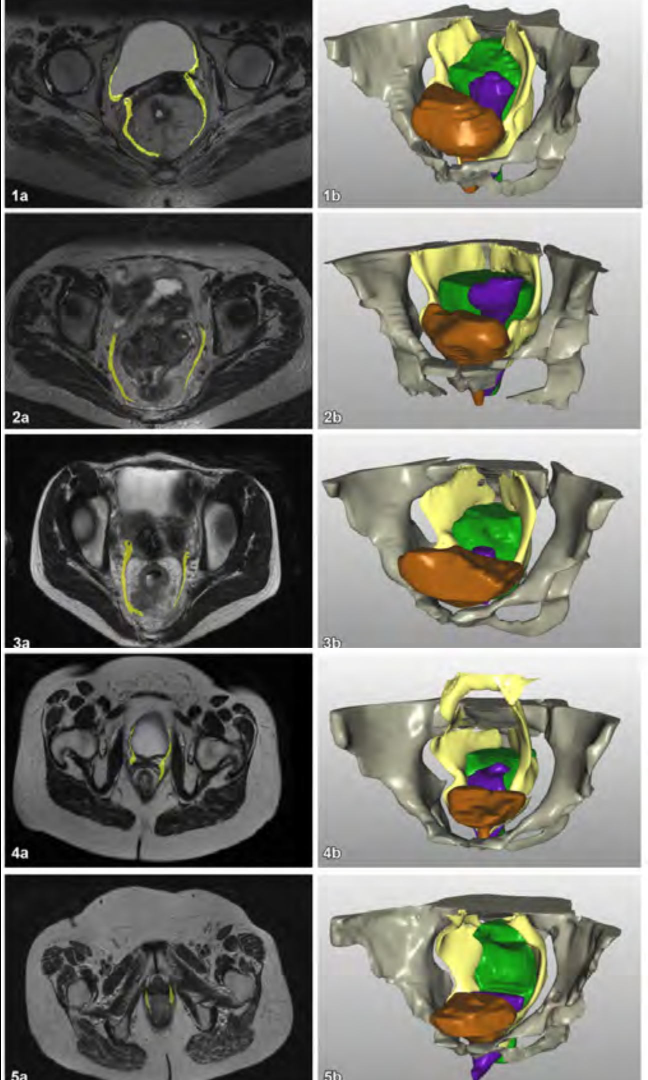
Higher dimensional data visualization





Presurgical:
patient specific 2D/3Dmodels

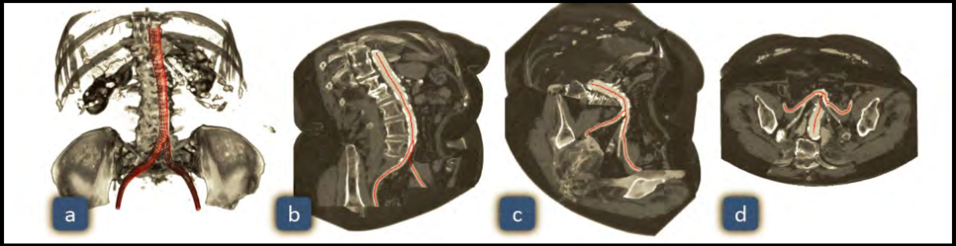
Medical education:
The online anatomical human
18000users worldwide



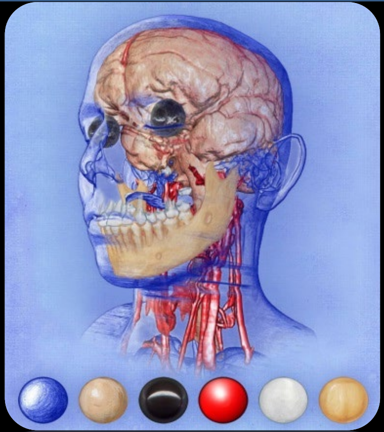
Core MMIV project: Medical Visualization

Medical visualization

PI: Prof S Bruckner



Illustrative visualization

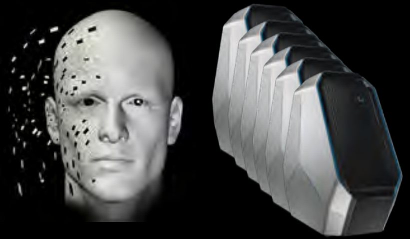


«The amount of change in 20 years is unimaginable, and we need to keep our finger on the pulse of this.»

Bradley Erickson, Mayo Clinic

Summary/ comments

- There is a gap between clinical imaging and research imaging
- Combination of imaging, advanced visualization and machine learning approaches may help bridge this gap. Requires and interdisciplinary agenda
- eInfrastructure limitations (data integration, system integration, HPC). Information from registries, clinical information, extractions from EPJ.
- Limitations in regulatory framework (ethical and social risk/benefit assessment). Optimize solution for deIdentification/ Safe handling of data. Share technical solutions (eg training in machine learning) rather than data?



URL: http://www.mmiv.no

Thank you for your attention!

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Bergen fMRI group, Research group leader
Norwegian Cancer Society Reserach group MALIGN, Research group leader
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Assoc Prof
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Bergen, Norway

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BERGEN fMRI GROUP

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