Erasmus MC
University Medical Center Rotterdam

BIGR
projects
department of radiology & nuclear medicine

The BIGR (Biomedical Imaging Group Rotterdam) group is a research group of +/- 75 MSc and PhD students, postdocs, and scientific programmers in the Erasmus MC who perform research on a wide variety of topics in medical image analysis, applied to e.g. cardiology, oncology and neurology.

We are continuously looking for (MSc, BSc) students with a technical background and a medical interest or vice versa that would like to do a thesis project or internship in our group.

BIGR Research Groups

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Image Registration Group

Group leader: Stefan Klein
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Fully Automated Carnegie Staging of the Human Embryo

Supervisors: Wietske Bastiaansen, Stefan Klein, Melek Rousian (gynecologist, depart. Obstetrics and Gynecology), Anton Koning
Contact: w.bastiaansen@erasmusmc.nl

Background The introduction of virtual reality (VR) techniques and systems within the Erasmus University Medical Center made it possible to visualize the first trimester pregnancy in much more detail and precision when compared to the conventional ultrasound methods, see Fig. 1. Not only can we measure growth, but it is now also possible to assess the morphological development based on external morphological characteristics in-utero using the Carnegie staging system[1]. The Carnegie stages are a useful tool for monitoring growth (e.g., pregnancy dating) and morphological development, especially in association with maternal and paternal genetic/environmental factors[2,3]. Given that we want to use this morphological measure in research in large cohorts (>200 subjects) and also in clinical care, and determining the Carnegie stage takes minutes, there is a pressing need for automation of Carnegie staging[1,4].

Aim In this project, our aim is to develop a fully automatic Artificial Intelligence (AI) algorithm to determine the Carnegie stage based solely on three-dimensional ultrasound scans performed in the first trimester of human pregnancy.

Methodology In recent years, many AI algorithms were developed for image classification, we start the project by applying these algorithms for assigning the Carnegie stage. The algorithm will learn how to assign the Carnegie stage based on the already performed staging in VR. Next, we will analyze which morphological aspects visible in the ultrasound scans, were used by the algorithm to assign the stage.

Potential impact The development of this unique fully automatic framework for assigning the Carnegie stage will greatly support anomaly screening and diagnostics in the first trimester. This will lead to better prevention, diagnosis, and treatment of growth and developmental anomalies from the earliest moment in life. The impact may be enormous, since every pregnant woman receives one or more first-trimester ultrasound scans.

Interested?
Are you: an enthusiastic student with a clear interest in medical image analysis; looking for a master thesis or an internship; up for this challenge; has some experience with programming (preferably Python)? Then join this project! A visit to the clinic is part of this project!

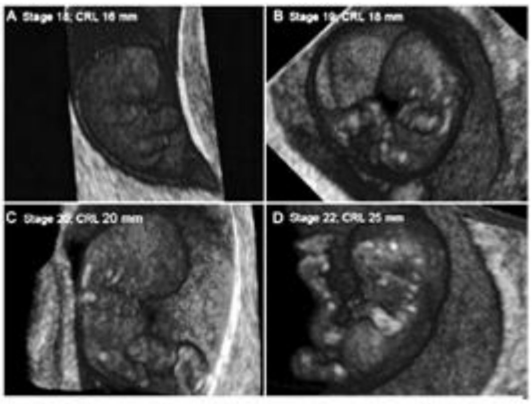


Fig 1. Examples of Embryo staging using VR.

[1]Rousian, M., et al. *Human Reproduction* 28.5 (2013): 1181-1189.
[2]Parisi, F., et al. *Human Reproduction* 32.3 (2017): 523-530. [3]Pietersma, C. S., et al. *Human Reproduction* 37.4 (2022): 696-707. [4]Rousian, M., et al. *International journal of epidemiology* 50.5 (2021): 1426-1427

Automatic calculation of the Crown-Rump Length (CRL) in first trimester ultrasound

Supervisors: Wietske Bastiaansen, Stefan Klein, Melek Rousian (gynecologist, depart Obstetrics and Gynecology), Anton Koning
Contact: w.bastiaansen@erasmusmc.nl

Background In clinical practise the growth and development of the embryo during the first trimester is world-wide montired by measuring the Crow-Rump Length (CRL), this is the longest distance between the top of the head (the crown) and end of the budy (rump). However, performing the measurement manually is time-concuming and prone to human errors. This measurement is of great importance, since it is used to determine the length of the pregnancy, and thus when the pregnancy should end. Wrong estimation of this length has direct impact on pregnancy outcome.

Aim In this project, our aim is enable automatic measurement of the CRL.

Methodology In previous work, we created a segmentation tool to automatically delineate the embryo. The CRL is now 'simply' the longest diameter within the segmentation mask, as shown in figure 1. However, nothing is ever that simple. Starting with the longest diameter, the goal of this project is to refine and improve the measurement. This means implementation and testing on a large database (> 10.000 images). But also visual inspection in Virtual Reality (the current way to measure manually).

Potential impact The development of this unique fully automatic framework for measuring the CRL will greatly support screening and diagnostics in the first trimester. This will lead to better prevention, diagnosis, and treatment of growth and developmental anomalies from the earliest moment in life. The impact may be enormous, since every pregnant woman receives one or more first-trimester ultrasound scans.

Interested?
Are you: an enthusiastic student with a clear interest in medical image analysis; looking for a master thesis or an internship; up for this challenge; has some experience with programming (preferably Python)? Then join this project!
A visit to the clinic is part of this project!

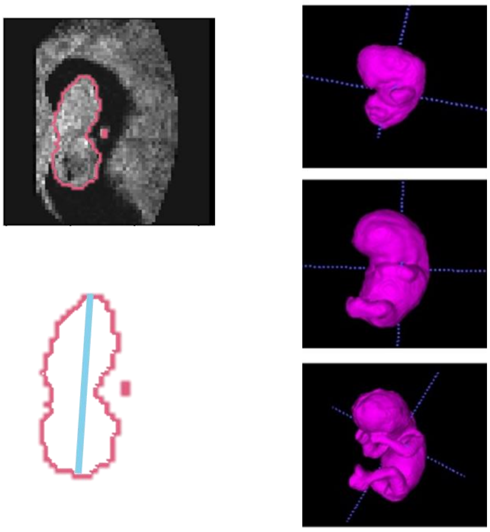


Figure 1: On top the already availiable segmentation mask is given (3D rending in pink), below the CRL is given in blue, however finding the longest diameter is challening due to the presence of the limbs (legs and arms).

Verification and improvement of standard plane detection in first trimester ultrasound

Supervisors: Wietske Bastiaansen, Stefan Klein, Melek Rousian (gynecologist, depart Obstetrics and Gynecology), Anton Koning
Contact: w.bastiaansen@erasmusmc.nl

Background In clinical practise the growth and development of the embryo during the first trimester is world-wide montired by visual in spection of standard planes, showing the brain and developing organs in great detail. Finding these standard planes is time-consuming and challenging. Especially given the wide variation in position and orientation of the embryo within the ultrasound image. Moreover, ultrasonography has typically limited quality.

Aim In this project, our aim is to verify standard plane detection of an already developed AI algorithm for spatial alignment.

Methodology In previous work, we created a algorithm for spatial alignment of the embryo. So far, only the mid-saggital plane has been verified, see Figure 1. The initial aim of this project is to verify the other standard plane and identify other relevant views. This will be done in close collaboration with a gynecologist. If time permits, the accuracy of the algorithm can be improved by including the available segmentation masks or make the standard plane detection work in case of abnormalities.

Potential impact The possiblity to automatically and accuralty detection standard planes will greatly support screening and diagnostics in the first trimester. This will lead to better prevention, diagnosis, and treatment of growth and developmental anomalies from the earliest moment in life. The impact may be enormous, since every pregnant woman receives one or more first-trimester ultrasound scans.

Interested?
Are you: an enthusiastic student with a clear interest in medical image analysis; looking for a master thesis or an internship; up for this challenge; has some experience with programming (preferably Python)? Then join this project!
A visit to the clinic is part of this project!

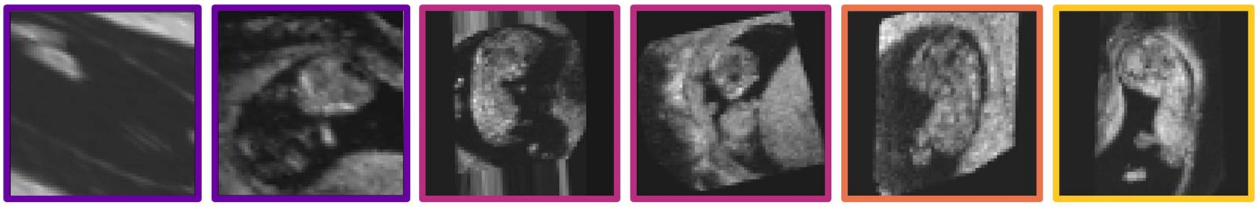


Figure 1: verification of the mid-saggital plane. Results on test set (1249 images) Purple: poor 13%, pink: landmarks aligned 26%, orange: acceptable 39%, yellow: excellent: 21%
More info: https://www.melba-journal.org/papers/2022:020.html

Computer-aided Diagnosis for Gastrointestinal Stromal Tumors on CT using Deep Learning

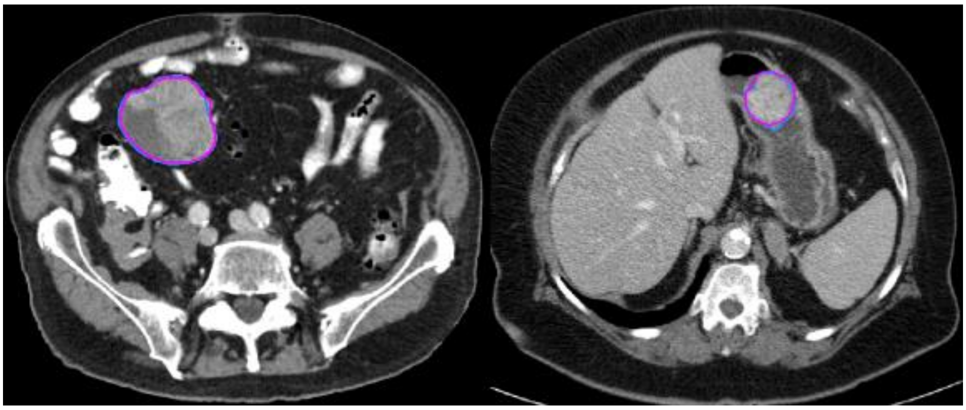
Supervisors: Douwe Spaanderman, Martijn Starmans, Dirk Grünhagen (Oncological surgeon), Stefan Klein
Contact: d.spaanderman@erasmusmc.nl

Background: Gastrointestinal Stromal Tumors (GIST) are a complex group of tumors with a broad range of differentiation. Currently, it is difficult for clinicians to determine the aggressiveness, clinical behavior, and best treatment for this disease. It is therefore important to identify new biomarkers for these patients. The use of features in radiology imaging ('radiomics') can be used to identify such biomarkers. These biomarkers have advantages as they can be retrieved from standard clinical practice, are non-invasive, and can be easily repeated to follow the patient in time.

Aim: The aim of this research is to create an AI method identifying known biomarkers, such as KIT mutations, as well as identifying novel imaging biomarkers which will let us infer patient survival and treatment response, directly from CT scans.

Methodology: Together with several hospitals in the Netherlands (GIST Consortium) we have already collected imaging and clinical data from ~1400 GIST patients. First, we will use this data to validate previous work to automatically segment GIST tumors. Next, we will use state of the art deep learning methods to create an end-to-end model for GIST biomarkers.

Project designed for: Master thesis, for a period of at least 6 months. No experience with medical image analysis is required, however, some programming experience is preferred. If you are interested in a technical challenge, please contact me!



Related research:

- https://doi.org/10.1038/s41572-021-00254-5
- https://doi.org/10.1016/j.humpath.2008.06.025

GRAFITI-study: predicting the progression of desmoid-type fibromatosis using radiomics

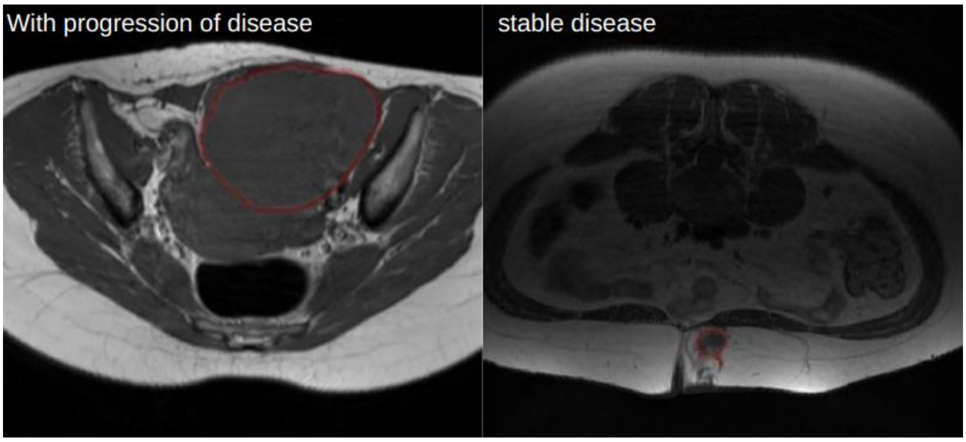
Supervisors: Douwe Spaanderman, Stefanie Hakkesteegt (PhD student oncological surgery), Martijn Starmans, Stefan Klein
Contact: d.spaanderman@erasmusmc.nl

Background: Currently, there is no standard treatment for patients with a Desmoid tumor. More and more doctors recommend wait-and-see treatment. This means that the tumor is monitored, but not treated with drugs, radiation, or surgery. This is safe because the tumor does not metastasize and sometimes shrinks spontaneously. While the wait-and-see treatment benefits most patients, some Desmoid tumors progress to a more aggressive state, and therefore require extensive treatment. To be able to provide appropriate treatment, it is important to be able to predict the behavior of a tumor.

Aim: In this study we want to use features in radiology imaging (radiomics) in order to determine if a desmoid patient is at risk for progression.

Methodology: We have collected data from ~100 patients in various hospitals in the GRAFITI study. First, we will use this data to validate previous work to interactively segment Desmoid tumors. Next, we will use the Workflow for Optimal Radiomics Classification (WORC) in order to predict tumor progression from MR imaging. Finally, depending on the length of the internship, we could investigate the use of deep learning instead of WORC for progression prediction.

Project designed for: A student who is interested in medical imaging analysis for the improvement of healthcare for patients with a rare soft tissue tumor. Both master thesis as well as shorter internships can apply for this project. This project is co-supervised between the oncological surgery department. If you are interested, you can contact me!



Related research:

- https://doi.org/10.1097/00000658-199905000-00002
- https://doi.org/10.1158/0008-5472.CAN-16-1536

Preoperative risk stratification for lung metastasis in soft tissue tumor using a radiomics model

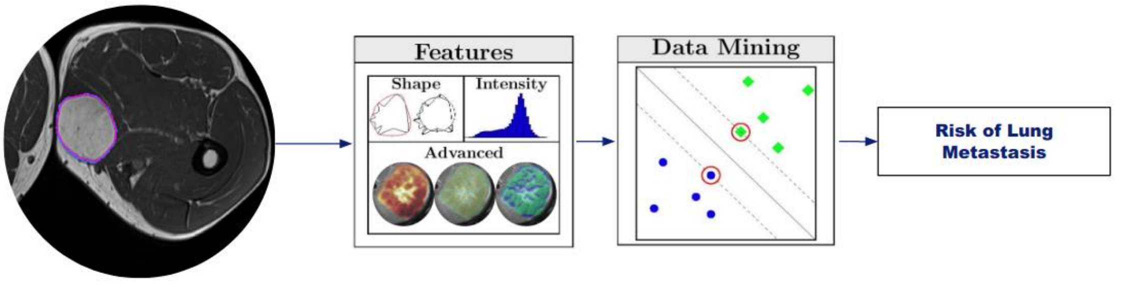
Supervisors: Douwe Spaanderman, Martijn Starmans, Dirk Grünhagen (Oncological surgeon), Stefan Klein
Contact: d.spaanderman@erasmusmc.nl

Background: For soft tissue tumors (STT), the lungs are the most common site of metastasis, occurring in 20% of all STTs. Preventing metastasis is essential as it greatly reduces the patient's chance of survival. Also, when metastasis occurs, it is of great importance to identify this as soon as possible. Therefore, identifying patients at risk for lung metastasis is essential for drawing up treatment plans and scheduling follow-up scans. It is difficult to predict which patients with a soft tissue tumor will develop lung metastasis. The phenotype, location, and tumor grade can already give a hint. For example, tumors in the extremities have a greater chance of metastasis to the lungs. In addition, we believe that image characteristics on MRI can provide an indication of the risk of lung metastasis.

Aim: The aim of this research is to develop a radiomics model that can predict, based on MRI images of the extremities, whether a patient with a soft tissue tumor is at risk of lung metastasis.

Methodology: We will use the pathology database to find patients with at least a follow-up of 5 years with a STT, and collect data from their patient records. Next, automatically generated segmentations, i.e., outlines of the tumor, have to be approved and interactively annotated on the MR images. Finally, general database statistics and interpretation of radiomics results. During this project, it is possible to watch the OR during complex operations and to walk along in the outpatient clinic.

Project designed for: (technical) medicine student, Dutch proficiency is required as we will be using patient records. Both master thesis as well as shorter internships can apply for this project. If you are interested in learning more about the clinical aspects of developing a radiomics study, you can contact me!



Related research:

- https://doi.org/10.1097/00000658-199905000-00002
- https://doi.org/10.1158/0008-5472.CAN-16-1536

A systematic review reporting quality of radiomics research in the diagnosis and prognosis of soft-tissue sarcoma.

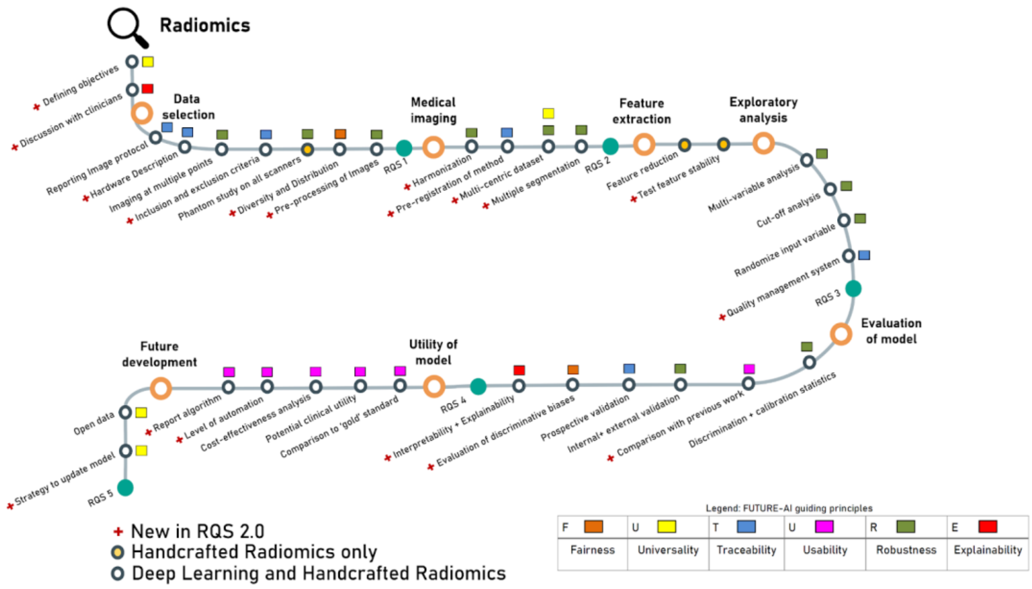
Supervisors: Douwe Spaanderman, Martijn Starmans, Stefan Klein
Contact: d.spaanderman@erasmusmc.nl

Background: Soft tissue tumors (STT) are a rare and complex group of tumors with a broad range of differentiation. In order to guide personalized medicine, identifying biomarkers for patient outcomes is essential. The use of features in radiology imaging ('radiomics') such as CT and MRI can be used to identify such biomarkers. These biomarkers have advantages as they can be retrieved from standard clinical practice, are non-invasive, and can be easily repeated to follow the patient in time. As we are also developing radiomics methods for STT, it is of high priority to create an in-depth overview of the clinical applications radiomics has been used for in STT. This can guide the field towards relevant clinical questions. Additionally, it is an opportunity to show the field what has been achieved in recent years, and where the focus should be on.

Aim: The aim of this research is to qualitatively and quantitatively score radiomics studies in soft-tissue sarcoma. Additionally, we would like to create an overview of all the clinical applications for which radiomics has been applied in STT and discuss possible clinical endpoints which should be investigated.

Methodology: We will use the PRISMA 2020 guidelines for reporting systematic reviews. Next, together with the EMC's medical library we will do a literature search to find all the relevant articles. Finally, we will score these articles based on the Radiomics Quality Score (Figure 1) and report our findings.

Project designed for: 1 or 2 students, perfect if a literature study is required for your study. Finally, for you, this will be an opportunity to get a (Co-)authorship of an impactful review for radiomics in soft-tissue sarcoma.



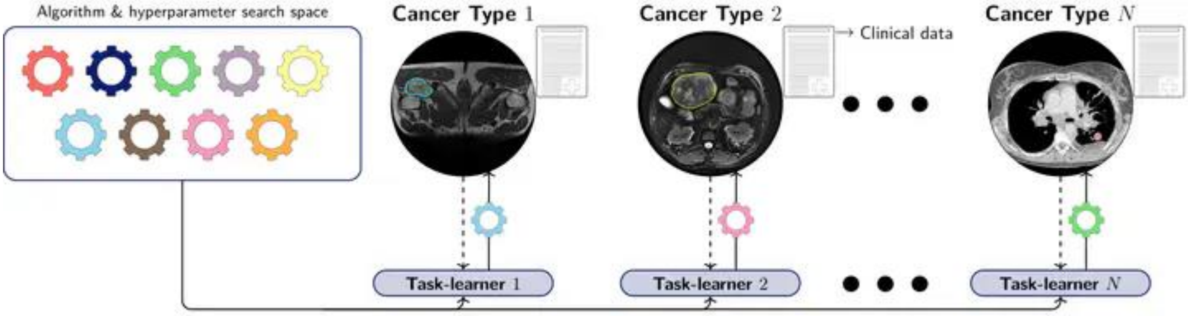
[i]

Related research:

- https://doi.org/10.3322/caac.21605
- https://doi.org/10.1186/s13643-021-01626-4
- https://doi.org/10.1038/nrclinonc.2017.141

Adaptive deep learning in oncology classification through automated machine

Supervisors: Martijn Starmans
Contact: m.starmans@erasmusmc.nl



Background Oncology is a major focus of precision medicine, with medical imaging, e.g., Magnetic Resonance Imaging (MRI) and Computed Tomography (CT), gaining an increasingly important role. Artificial Intelligence (AI), particularly deep learning, has made significant advances in developing predictive models from medical imaging. Currently, in medical imaging, AI models are manually constructed through a heuristic trial-and-error process, which suffers various drawbacks (e.g. time consuming, requiring expert knowledge, low reproducibility, sub-optimal performance).

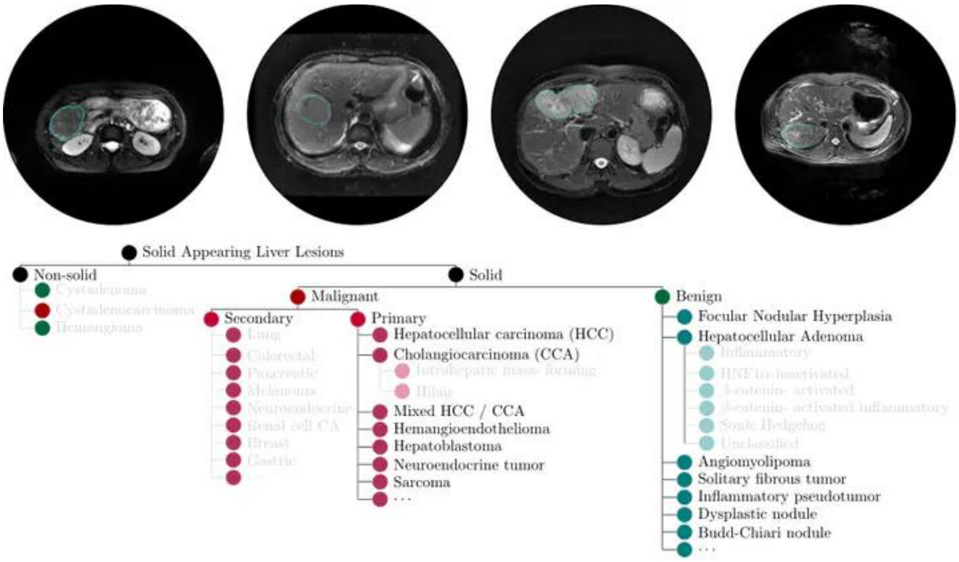
Aim The aim of this research is to overcome these drawback by developing AutoML methods to automatically optimize model construction per oncological application. You will work on a variety of oncological diseases, with a focus on rare cancers (e.g. sarcoma, primary liver cancer, colorectal cancer, melanoma, glioma), where in each application there is a classification task to be solved. You will have to design a search space of promising deep learning solutions (e.g. CNNs, transformers) and develop an AutoML algorithm to optimize model construction. We aim to make the optimization strategy model- and task-agnostic, such that various deep learning models can be tried, and other tasks besides segmentation such as classification can be used. The project is quite technical: however, the resulting biomarkers can have substantial clinical impact.

Related research:

- https://automl.org/automl/literature-on-neural-architecture-search
- https://doi.org/10.48550/arXiv.2108.08618
- https://doi.org/10.1109/TPAMI.2021.3067763

Diagnosis of solid appearing lesions based on MRI and deep learning

Supervisors: Martijn Starmans, Maarten Thomeer (Radiologist), Stefan KleinContact: m.starmans@erasmusmc.nl



Background Differential diagnosis of solid appearing liver lesions (groups of abnormal cells in the liver, either malignant or benign) based on magnetic resonance imaging (MRI) is one of the most important challenges for abdominal radiologists. Based on their interpretation, patients are referred back with no need for follow-up or they may undergo further analysis with subsequent treatments including surgery or chemotherapy. In current practice, the differential diagnosis of liver lesions is based on subjective and qualitative assessment, relying vastly on the experience of the local radiologist. More objective and quantitative approaches are therefore urgently needed.

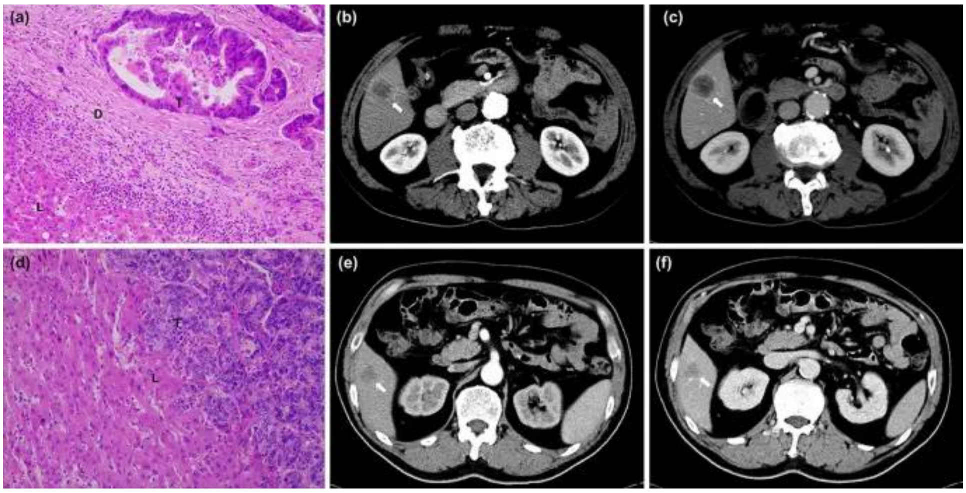
Aim The aim of this research is to create a deep learning model for comprehensive liver tumour phenotyping based on MRI. We already have a database of 500 patients from various centres for you to start with four different liver tumours. You first task will be to extend this database by including more patients from the EMC with other liver lesion phenotypes. Using this dataset, you main task is to develop a multi-parametric MRI (e.g. T1, T2, DWI, contrast enhanced T1) deep learning model for the classification of these liver lesions. The main challenge is how to optimally combine the information from the different MRI sequences, while dealing with missing data and substantial heterogeneity. Optionally, we might also want to create a segmentation model, as this is something the radiologists would like to use in the clinic as well to quantify therapy response. You can focus on the more clinical aspects of the project in close collaboration with the radiologists, or the more technical aspects on how to construct such a model.

Related research:

- https://doi.org/10.1101/2021.08.10.21261827
- https://doi.org/10.48550/arXiv.2108.08618

Preoperative prediction of colorectal liver metastases aggressiveness using pathomics

Supervisors: Martijn Starmans, Zhen Qian (Department of Surgery), Mitko Veta (TU Eindhoven), Stefan Klein
Contact: m.starmans@erasmusmc.nl



Background The prognosis of colorectal liver metastases (CRLM) is highly influenced by the so-called histopathological growth pattern (HGP), i.e. the interaction between the liver and tumour tissue. Patients with more aggressive growth patterns have a far worse prognosis and may benefit from preoperative neo-adjuvant chemotherapy. Unfortunately, the HGP can currently only be determined based on surgery and thus post-operatively. Our clinicians are therefore looking for a pre-operative alternative. Previously, we have already shown that histopathological characteristic of the primary tumour relate to the HGP (link 1 below).

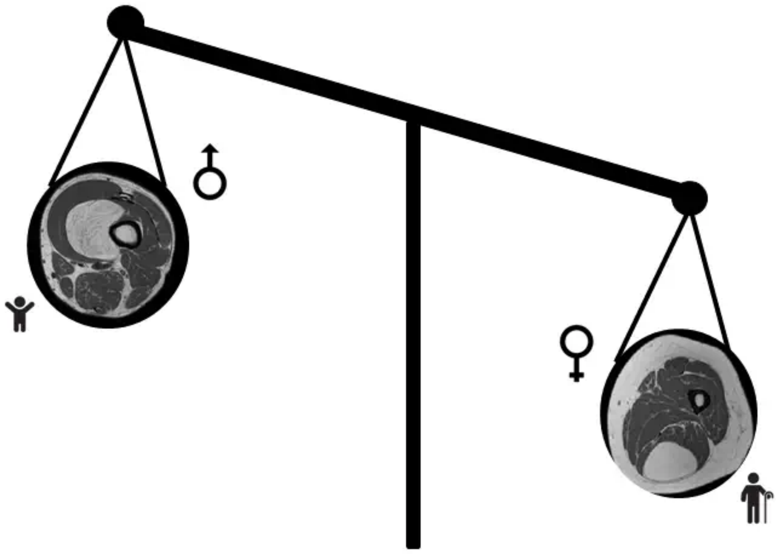
Aim The aim of this research is to create a deep learning model based on histopathology slides of the primary tumor to predict the CRLM HGP. We will take a two-fold approach: 1) automate the scoring of the characteristics that were previously found to be predictive. This will result in a highly explainable model, but performance might nog be ideal. 2) Take an agnostic approach, where you will use recent advances in AI models for whole slide image representation to train end-to-end models that determines CRLM HGPs directly from the primary tumour image. This project will be conducted in close collaboration with the Department of Surgery, Department of Pathology, TU Eindhoven, and GZA Antwerp.

Related research:

- https://doi.org/10.1186/s12885-022-09994-3
- https://doi.org/10.1038/s41416-022-01859-7
- https://doi.org/10.1016/j.semcancer.2020.07.002
- https://openaccess.thecvf.com/content/CVPR2022/papers/Chen_Scaling_Vision_Transformers_to_Gigapixel_Images_via_Hierarchical_Self-Supervised_Learning_CVPR_2022_paper.pdf

Optimizing the Fairness-performance trade-off of oncological radiomics biomarkers

Supervisors: Martijn Starmans, Stefan Klein
Contact: m.starmans@erasmusmc.nl



Background AI has revolutionized the development of predictive models in oncology based on medical imaging. However, only a small fraction is actually used in clinical practice. This may be attributed to development focussing on performance only, which is not sufficient for healthcare. To overcome this gap, I recently worked on the FUTURE-AI guidelines for trustworthy and deployable AI in healthcare (see link 1 below). The first principle of the guidelines, Fairness, currently a hot topic, means that medical AI algorithms should maintain the same performance when applied to similarly situated individuals and subgroups, independent of e.g., sex, ethnicity, and age. While methods have been proposed to ensure algorithmic Fairness, this usually hurts performance.

Aim The aim of this project is to develop a method to optimize the Fairness-performance trade-of of AI classification methods in medical imaging. You will develop generalizable methods, but we will focus on sarcoma on this project. The first step will be to evaluate the Fairness of current biomarkers in sarcoma. Second, you will have to implement various Fairness methods (see link 3 below) in our existing radiomics framework (see link 2 below) to evaluate how these impact Fairness and performance. Third, you will study how automated machine learning can be used to optimize the Fairness-performance trade-off of radiomics biomarkers, and which type of biomarkers are most suitable for this. In this project, we will collaborate with the BCN-AIM lab of the University of Barcelona.

Related research:

- https://doi.org/10.48550/arXiv.2109.09658
- https://doi.org/10.48550/arXiv.2108.08618
- https://doi.org/10.48550/arXiv.1810.01943
- https://doi.org/10.1002/bjs.11410

Photon-counting detector CT for assessment of bone microarchitecture and bone strength

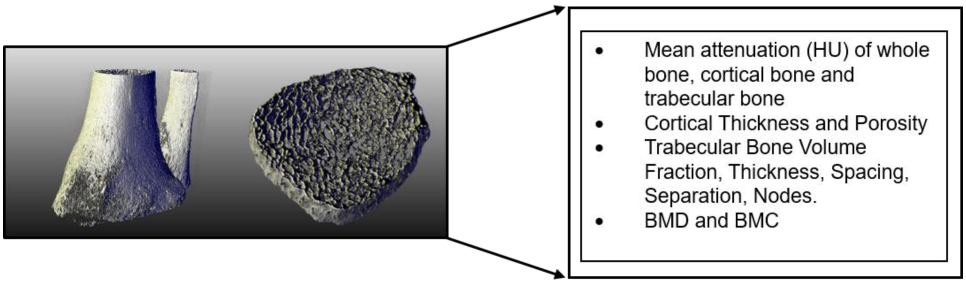
Supervisors: Jukka Hirvasniemi, Ronald Booij, Edwin Oei (radiologist)
Contact: j.hirvasniemi@erasmusmc.nl, r.booij@erasmusmc.nl

Background: Osteoporosis is the most common bone disease and is a risk factor for fractures as the disease is characterized by disruption in the microarchitecture of bone, compromising bone strength. Determining the bone strength is essential for treatment planning and monitoring. Micro-CT offers high spatial resolution and allows visualization of the microarchitecture but is limited to ex-vivo imaging of humans only. Therefore, assessment of quantitative in-vivo imaging biomarkers such as bone mineral density (BMD) and bone strength are often performed by DEXA scans or (HR)-pQCT scanners but are limited by its spatial resolution or imaging of the extremities, respectively. A new CT technology, photon-counting detector CT (PCD-CT), has recently been introduced into clinical practice. PCD-CT has a superior spatial resolution than conventional CT and has demonstrated strong correlations with micro-CT for determining bone microarchitecture parameters. Therefore, PCD-CT might be a valuable asset for accurate assessment of bone strength. Before in-vivo imaging and analysis can be performed, quantitative variables related to the bone microarchitecture should be extracted from clinical PCD-CT and their association with bone microarchitecture from micro-CT and HR-pQCT needs to be demonstrated for different body parts. Radiomics has been successfully applied on analysis of bone on MRI and X-rays in previous studies. Radiomic features from clinical PCD-CT could potentially provide accurate information about bone strength.

Aim: The aim of this project is to extract bone microarchitecture from ex-vivo human body parts using PCD-CT and correlate those variables with the bone microarchitecture parameters of micro-CT and HR-pQCT.

Methods: Images will be obtained from ex-vivo specimen of the distal tibia and radius, part of the spine and hip with HR-pQCT, micro-CT, and clinical PCD-CT. Different open access analysis tools (e.g., ImageJ, 3D Slicer) and Python-based scripts to assess the bone microarchitecture will be explored and compared.

Related research:
https://doi.org/10.1186/s41747-022-00286-w
https://doi.org/10.1016/j.bonr.2020.100711



Automatic detection and grading of osteoarthritis-related changes on MRI using deep learning

Supervisors: Jukka Hirvasniemi, Edwin Oei (radiologist), Stefan Klein
Contact: j.hirvasniemi@erasmusmc.nl

Background: More than 300 million people worldwide have osteoarthritis, making it the most common joint disease. It is a leading cause of disability, representing a tremendous burden for both patient and society. Osteoarthritis affects all tissues in the joint, e.g., causing progressive degeneration of articular cartilage and changes in the subchondral bone. Alterations in the subchondral bone include formation of osteophytes (Figure 1), bone sclerosis, bone marrow lesions, and cysts.

MRI is the most comprehensive imaging modality for osteoarthritis. Osteoarthritis-related changes can be visually graded, for example using the MRI Osteoarthritis Knee Score (MOAKS). However, visual grading of knee MRIs is time-consuming and subjective.

Aim: In this project, automatic methods for detection and grading of osteoarthritis-related changes (e.g., osteophytes, bone marrow lesions) on knee MRI will be developed. Various deep learning methods for detecting and grading of the features will be tested.

Methods: An open access Osteoarthritis Initiative dataset (number of knees over 500) and clinical MRI datasets in the Erasmus MC (number of knees around 100 per dataset) will be utilized in this project.

References/related research:
https://doi.org/10.1016/j.joca.2011.05.004
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC8166108/

Figure 1. Knee MRI showing an osteophyte at the tibia.

Neuro Image Analysis Group

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Computational Population Biology

Group leader: Gennady Roshchupkin
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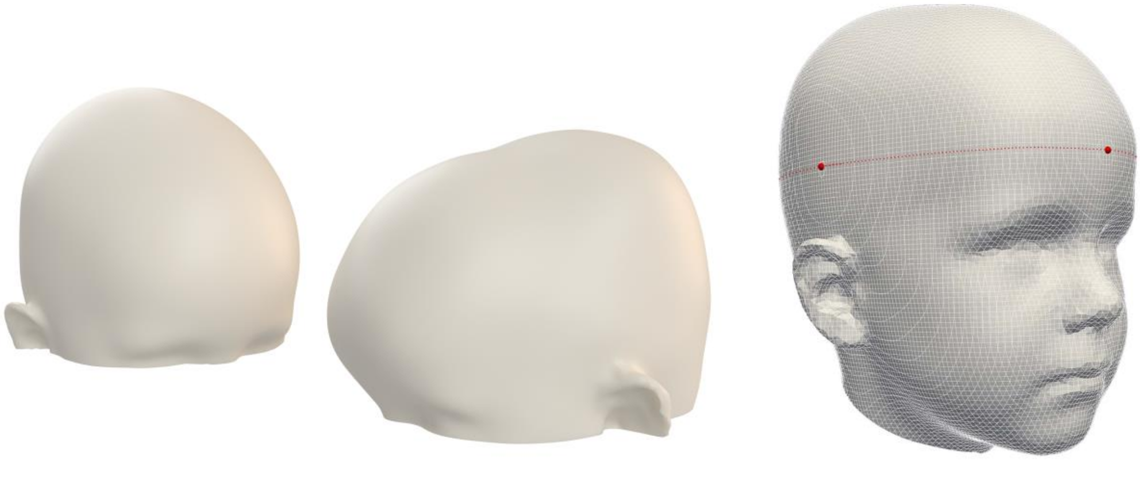
Project: Quantification of cranial deformations using 3D photogrammetry

Supervisors: Tareq Abdel Alim, Gennady Roshchupkin, Marie-Lise van Veelen,
Contact: t.abdelalim@erasmusmc.nl g.roshchupkin@erasmusmc.nl m.l.c.vanveelen@erasmusmc.nl

Background: Craniosynostosis is a congenital condition that involves premature fusion of one or more of the cranial sutures. The result is a reduction in growth at the site of the affected suture with compensatory growth occurring at the open sutures. When left untreated, the resulting abnormal cranial morphology can lead to functional problems in addition to cosmetic concerns. In order to determine (1) how severe the deformation of the head is, and (2) how effective the surgery was, a comprehensive metric is required that can objectively express the deformation of the head.

In accordance to treatment protocol, these patients receive a 3D photogrammetry image of the head before and after surgery. These 3D reconstructions of the subjects' surface contain important information about the cranial shape and may provide useful in quantifying the initial deformation and progress that was made after treatment.

Project Goal: The aim of this project is to develop a new metric based on these 3D images that can be used to describe and quantify these 3D shapes and shape changes. Ideally, such a shape descriptor can express the deformation with respect to it's healthy or ideal cranial shape.



Project: Detection and quantification of beaten copper appearance from skull radiography

Supervisors: Tareq Abdel Alim, Marie-Lise van Veelen, Gennady Roshchupkin

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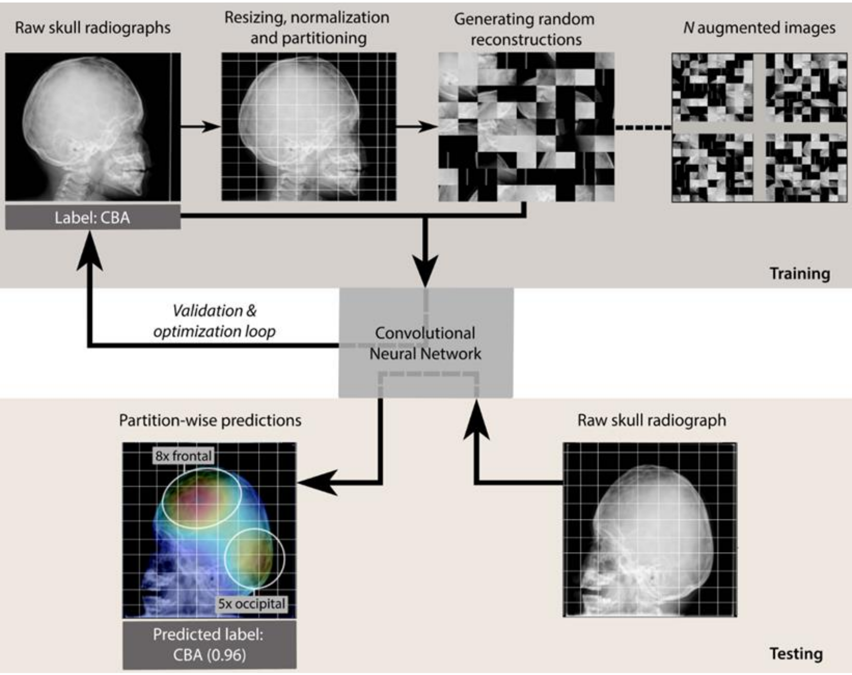
Background: Children who are born with craniosynostosis, a congenital condition that involves premature fusion of one or more of the cranial sutures, may face problems such as an inhibition of brain growth and raised intracranial pressure (ICP), for which early detection is critical. Unfortunately, there are still few reliable, non-invasive indicators that point to the presence of raised ICP. The most frequently reported non-invasive indicators that have been associated with the presence of raised ICP include subjective clinical symptoms, ventricular dilation from computed tomography (CT), swelling of the optic nerve (papilledema) from optical coherence tomography (OCT) and the manifestation of prominent convolutional markings on skull radiographs, also known as the beaten copper appearance (CBA).

The presence of these convolutional markings, however, does not necessarily indicate raised ICP as these markings are also observed in healthy children. To enable convolutional markings to serve as a reliable indicator for raised ICP, it is essential to understand the differences between healthy and pathological convolutional markings. This requires an objective measure for the severity of the convolutional markings present in a skull radiograph.

Project Goal: The aim of this project is to (further) develop and test a patch-wise convolutional neural network (CNN) in its ability to detect and quantify these convolutional markings from plain radiography images, or propose a promising alternative. The output is a severity metric that provides information about the location and intensity of the convolutional markings. This resulting severity measure can facilitate further studies into the clinical relevance of this poorly understood appearance.



Oncology and Machine learning in the ICU

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Unveiling new scleral morphological features to be used at clinical practice

1 position

Clinical supervisors: *Josianne ten Berge and Daphne Vergouwen*

The sclera forms around 85% of the outer tunic of the human eyeball. It is a collagen fiber structure, consisting of three sub-layers: sclera, episclera, and conjunctiva. Optical Coherence Tomography (OCT) is an imaging technique that can provide high-resolution cross-sectional images of the eye, including the scleral tissue. However, at the moment, OCT is not widely used in clinical or research settings for scleral imaging, possibly since a comprehensive description of the normal scleral morphology on anterior segment OCT is lacking. Providing this comprehensive overview would highly advance research into the role of scleral tissue in ocular disorders, and could play an important role in the diagnosis and follow-up of patients in the clinical setting.

In this project, the aim is to quantify the scleral, episcleral, and conjunctival thickness, as well as novel scleral morphologic features, including the amount of hyporeflective spaces. The tasks proposed in this project include 2D image analysis involving segmentation, feature extraction, and regression using machine learning techniques. A set of OCT images from healthy subjects and scleritis patients are available (300 subjects, four quadrants imaged). Additionally, a subset of the data has been manually segmented by two independent graders.

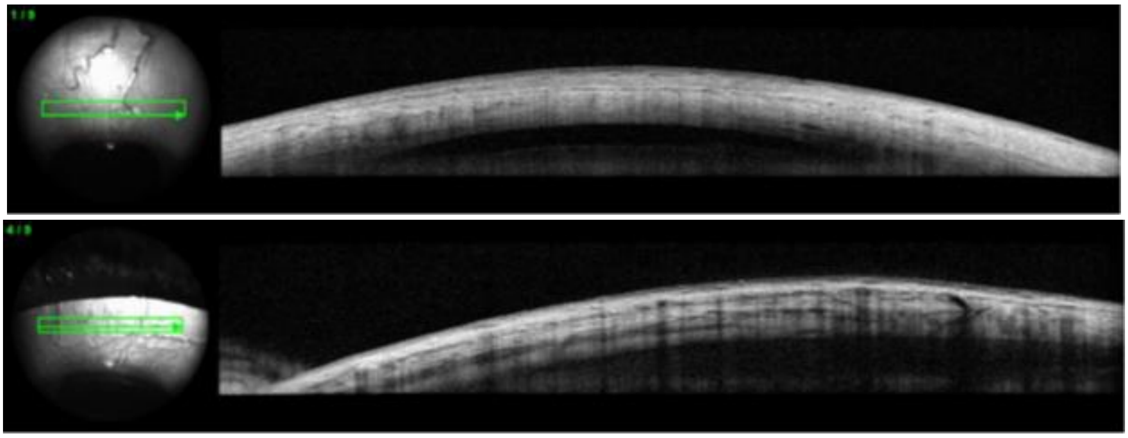

Figure. Anterior segment OCT of scleral tissue. The upper image is of a healthy volunteer, the lower image shows a patient with scleritis (inflammation of scleral tissue), with presence of hyporeflective spaces.

Automatic analysis of epiretinal membranes using OCT images

1 position

Clinical supervisors: Emine Kilic and Fahriye Hakan-Groen

Epiretinal membranes (ERM), also known as macular puckers, are a frequent clinical finding in an aging eye. They are creases or bulges of tissue that form in the macula (Figure 1), where the central vision is located, and sometimes result in decreased and/or distorted vision conditions, such as metamorphopsia. The incidence of developing ERM is 1.1% per year, with a high chance of the fellow eye to also develop it. The visual prognosis remains uncertain in many cases, even after surgical treatment with vitrectomy and peeling of the membrane.

Optical Coherence Tomography (OCT) is a noninvasive and fast imaging system that is routinely used in clinical practice to visualize the human retina in 3D. OCT imaging is used to diagnose, differentiate, manage, and follow several retinal conditions, among which is ERM. Visually analyzing the OCT data, a clinician can observe the different retinal structures that are affected by the disease, and evaluate good or bad prognostic signs. Additionally, to study the preoperative OCT data can also help the surgeons to identify any free edges of the ERM that may help in starting membrane peeling with reduced trauma.

The purpose of this project is to develop deep learning models for classification and progression analysis of ERM patients using OCT data. The dataset consists of 600 ERM patients, which have been manually categorized according to a clinical grading scale. Furthermore, data from three timepoints is available for each patient: at 6 weeks, 6 months, and 1 year after surgical treatment. The project has two main goals: to automatically classify ERM patients in the different morphologic groups, and to predict the treatment outcome at the earliest point, relating the OCT data with the visual acuity at the different timepoints.

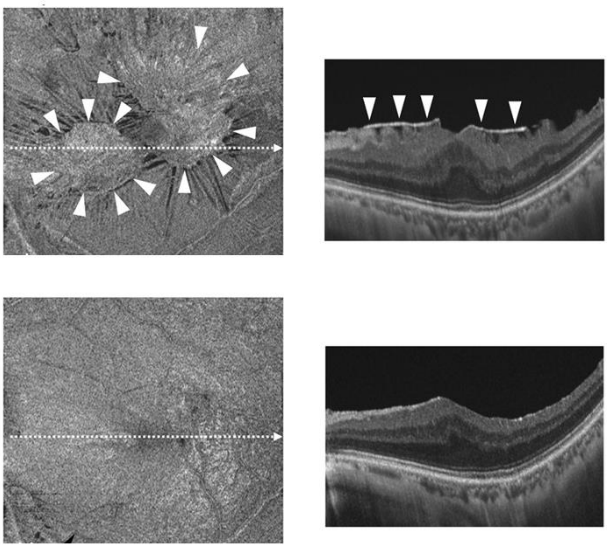

Figure 1. Representative case of a 71-year-old woman who underwent ERM surgery. OCT en-face images (left column) and B-scans (right column) obtained before (upper row) and at 6 months (lower row) after the surgery

are shown. The white dotted arrow indicates the position in the en-face of the B-scan images, and the white arrowheads indicate ERM.

Automatic quantification of microvasculature in OCTA for glaucoma

1 position

Clinical supervisors: Wishal Ramdas and Victor de Vries

Glaucoma is the leading cause of irreversible blindness worldwide. On its early stage, the disease affects only the peripherical vision, so the patient does not notice the symptoms until a later stage, when the damage has progressed towards the central vision. Unfortunately, there is no cure for glaucoma, and the vision that has been lost cannot be recovered. Therefore, treatment is focused on limiting disease progression. Despite having a high incidence and devastating consequences for the patient, may aspects of glaucoma remain unclear, and novel approaches to understand the mechanisms of the disease progression are needed.

Optical Coherence Tomography Angiography (OCTA) is a non-invasive and fast imaging system that enables the visualization of microvasculature in the human eye. Previous research has shown that OCTA parameters, such as vessel density in different regions or size of the macular avascular zone (Figure 1), can be linked to glaucoma onset and progression. Furthermore, these parameters can be used to assess the outcome of treatments.

The purpose of this project is to automatically quantify and analyze image features derived from OCTA which can be used in clinical practice in glaucoma management and treatment evaluation. The available dataset consists of 600 subjects, including patients and healthy controls, and cases with and without medication. The goal of the project is to compute relevant features in the whole dataset, enabling the study of the effect of medication and to characterize the changes that glaucoma produces at different disease stages.

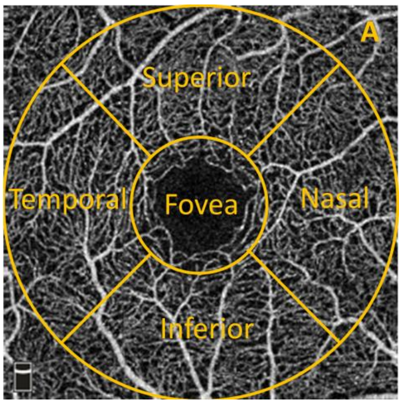

Figure 1. OCTA image showing the different sectors that can be considered in the macula region. In the center there is an avascular zone at the fovea.

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Embedding anatomical priors to image semantic segmentation through high-level descriptor

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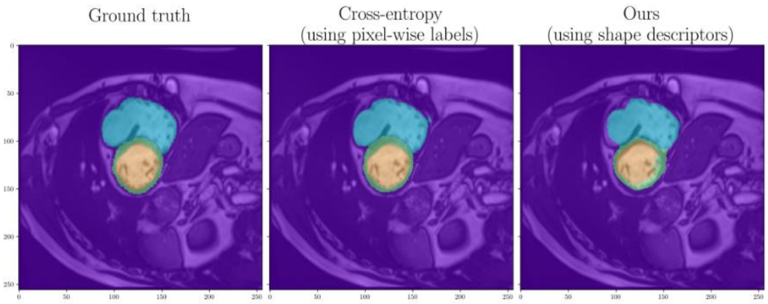
Background: Automatic image semantic segmentation has made tremendous progress over the last few years, mainly due to new deep-learning based methods. However, they require troves of (manually) annotated data during training, which is time-consuming and expensive to produce. Recently, it has been shown that a viable way to train segmentation networks was not necessarily through exhaustive pixel-wise supervision, but rather through a higher-level description (location, size, shape) of the organ to be segmented:



(a) A visual comparison of the different supervision methods on the ACDC dataset.

Pixel	Label
0	RV
1	Background
2	LV
⋮	
65536	Background

(b) Pixel-wise labels (**65k** discrete values)

Shape descriptor	Class		
(in pixels)	RV	Myo	LV
Object volume $\mathfrak{V}$	3100	800	1600
Centroid location $\mathfrak{C}$	(125, 80)	(125, 125)	
Avg. dist. to centroid $\mathfrak{D}$	(20, 15)	(15, 20)	(10, 10)
Object length $\mathfrak{L}$	750	1000	500

(c) Shape descriptors (**16** continuous values)

This new supervision paradigm enables a more natural way to describe the segmentation tasks, that could "encode" textbook knowledge; which in turn would require less newly labeled images.

Aim: This project can focus on different sub-topics, depending on the student interest and background. This can include (but not limited to):

- developing new descriptors for more complex shapes and organs (orientation, organs with holes, multiple connected components...);
- benchmarking optimization methods and implementation details for performances and stability;
- focusing on a specific application, pushing the performances to a new state-of-the-art;
- investigating time and/or patient independent descriptors.

Related research:
https://2021.midl.io/papers/a3
https://arxiv.org/abs/1805.04628
https://arxiv.org/abs/1904.04205

Image guidance in Interventions and Therapy Group

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Project: HoloLens standalone navigation in craniosynostosis surgery

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Background: Craniosynostosis is the premature closure of one or more of the cranial sutures causing a deformed skull shape. It is important to treat craniosynostosis as it can lead to many health complications. A surgical procedure is usually performed between the ages of 6 months and 2 years to correct the deformed head shape and allow for normal brain growth. In minimally invasive spring-assisted craniosynostosis surgery, surgeons plan the surgery by feeling the patient's head to locate the cranial sutures and mark them for positioning the incision lines (see figure below). However, locating the cranial sutures by manual palpation is prone to error due to the presence of skin and hair. Conventional navigation systems could potentially be used to help planning the surgery and locating the cranial sutures, but given the complexity of the system and the long setup time, surgeons usually choose not to use them in craniosynostosis. A standalone HoloLens based AR navigation system is a potential alternative for surgical navigation, as it is faster to setup, in addition to its ability to provide the suture visualization on the surgical site right in front of the surgeons' eyes.

In an earlier work we conducted a feasibility study for a hybrid AR navigation system that uses an electromagnetic tracking system and a Microsoft HoloLens AR device to be used in locating cranial sutures for craniosynostosis surgeries. However, the system has a limitation of being complex and takes long time to setup. Alternatively, the HoloLens can be used as a standalone navigation system by utilizing its camera sensors for tracking 2D markers to create reference points in the real world and position the virtual models with respect to these reference points (see figure below).

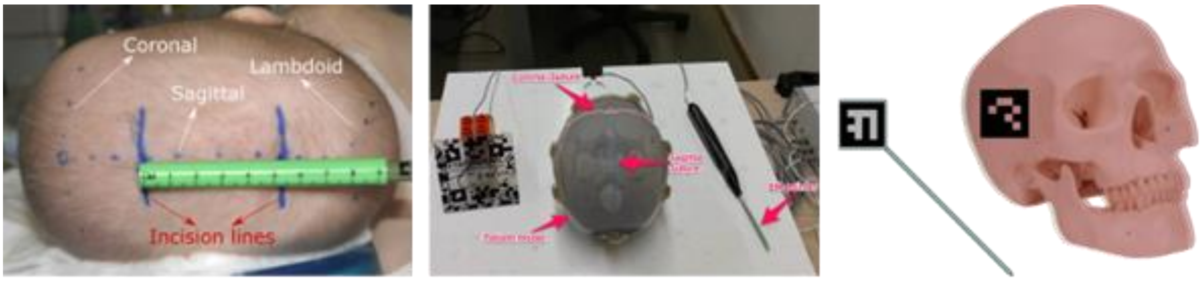

Figure: craniosynostosis surgery planning (left), AR hybrid setup (middle), HoloLens 2D marker tracking (right)

Project Goal: The goal of this project is to use the HoloLens to track 2D markers, one attached to the patient and one attached to a calibrated pointer in order to perform patient alignment and real-time patient tracking. The performance of the developed system will be compared with the previously developed hybrid system.

If you have any questions or interested in knowing more about the project, feel free to get in touch.

Further information: **https://doi.org/10.1007/s11548-022-02634-y**

Project: Feasibility of an AR-based spine surgical system
Supervisors: Mohamed Benmahdjoub, Abdullah Thabit, Theo van Walsum
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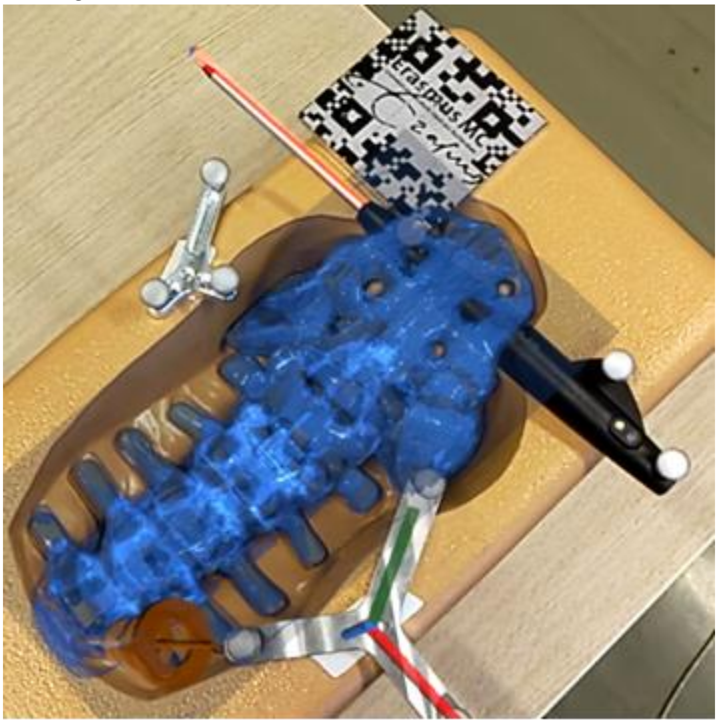
Background: Conventional navigation systems allow the alignment of patient specific data (CT, MRI…) on the patient. It helps in locating anatomical structures, surgical instruments, and preoperative planning. However, these systems fail to show the 3D aspect of the anatomy, as they are visualized on 2D screens, require familiarity with the hand-eye coordination, and forces the user to look back and forth between the screen and the surgical target.



Augmented reality (AR) has been suggested to overcome this problem.
In this project, we want to investigate the use of the Microsoft HoloLens to perform pedicle screw placement. This procedure is generally performed for patient with scoliosis to straighten the shape of the spine. This initially consists of inserting screws in the pedicles.

Project goal:

1- Investigate and find the correct way to perform image-to-patient registration given an initial AR system developed in the group.
2- Define the limitations of use in an operating room context.
3- Run pilot studies where participants are involved to perform AR-based pedicle screw placement.

Further information: **https://doi.org/10.1007/s10055-022-00653-3**

Project: Virtual extensions for needle insertion

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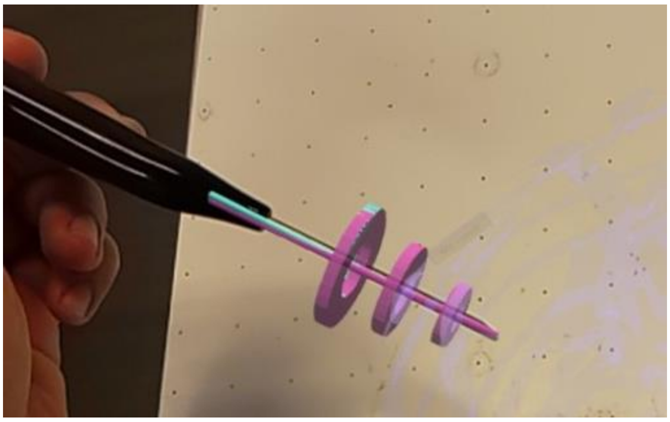
Background: Depth perception is important in surgical navigation. However, it is absent when using conventional surgical navigation: the surgeons have to reconstruct the 3D aspect of the anatomy and the trajectory of their needle/drill mentally.

An augmented reality system has been developed in our group to allow for the overlay of 3D anatomical targets/preoperative planning on the patient. It provides the surgeon with a view allowing for an intuitive interaction with the 3D objects. However, 3D perception using augmented reality head-mounted displays (HMDs) do not provide sufficient depth cues to locate 3D objects in space accurately: the depth can be overestimated/underestimated using AR glasses due to the lack of occlusion. This effect can be noticed to a high extent during the use of small/thin objects such as during needle insertion, or during drilling.

Virtual extensions (VE) were suggested in a previous study (see below) as a solution to improve the depth perception for a better localization of thin surgical instruments in space. They were used through a user experiment to visualize a pointing (black) device and the planning in AR with additional virtual elements. In this case, the planning showed the final position that the pointer should reach: when the representation of the pointer (pink) and of the planning (cyan) are fully matching.



However, it provided less guidance during the insertion and the user would not know if the insertion is going in the right direction. Positioning the pointer at all time at the right path with the right orientation is important to avoid causing any unnecessary damage.

Project goal:

1. Think of a dynamic paradigm of guidance during needle insertion and implementing it.
2. Evaluate this approach through a user experiment.

Further information: 10.1109/TVCG.2021.3106506

Project: Augmented reality registration for liver ablation: feasibility study on registration and targeting accuracy.

Supervisors: Mohamed Benmahdjoub, Abdullah Thabit, Theo van Walsum
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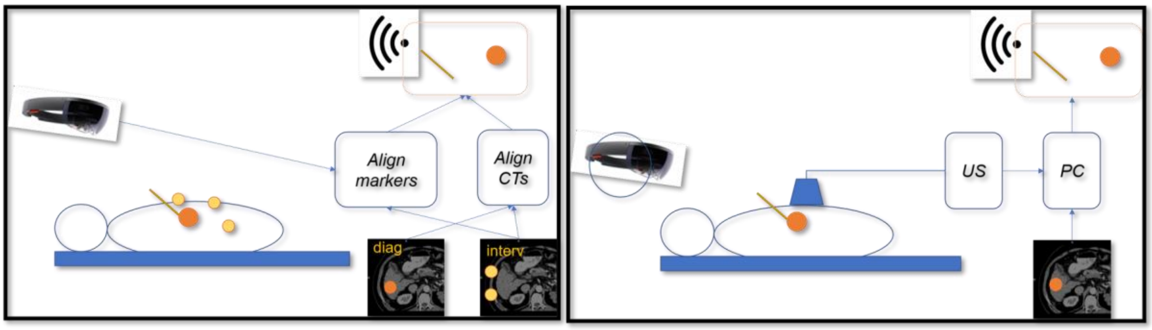
Background: liver ablation is a minimally invasive procedure that is used to target and destroy small tumors in the liver without having to surgically remove them. In this procedure, a needle is inserted through the skin and into the tumor to destroy it by the means of radiofrequency or microwaves. The procedure is usually guided using CT imaging, where a preoperative CT image is taken to locate the tumor and identify the needle insertion point. Sometimes, more CT images are needed during the procedure to make sure the needle is inserted into the correct location. The multiple use of CT scanning, however, interrupts the procedure and exposes the patient to more harmful radiation.



Project goal:

For this project, we are aiming to reduce the use of CT imaging by investigating the use of augmented reality (AR) in locating the tumor and guiding the needle insertion intraoperatively. There are multiple approaches that can be investigated in this project such as:

1. To investigate the use of our current AR system that uses an external tracking system to track the patient and instruments.
2. To investigate a combined approach of Ultrasound tracking and HoloLens visualization (figure below on the left).
3. To investigate approaches allowing image-to-patient registration using the HoloLens only, such as by detecting markers attached to the patient's skin (figure below on the right).

Project: Improved localization of lumbar hernia in surgical hernia repair.
Supervisors: Sieger Leenstra, Theo van Walsum
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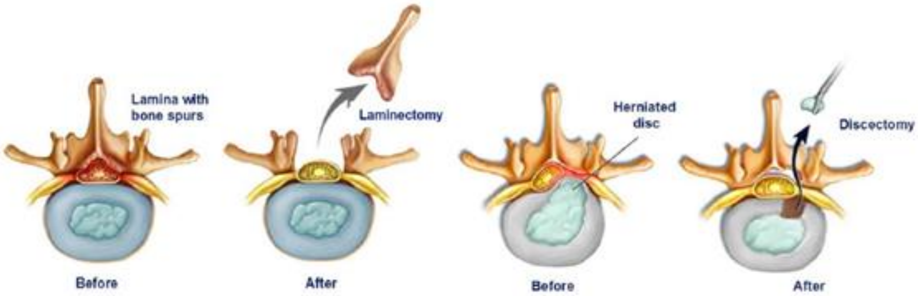
Background: : Surgical repair of hernia in the lower back and laminectomy for lumbar stenosis is frequently performed in the Netherlands, and also worldwide.. In the Netherlands, for these indications is performed ca 11.000 times per year. A common complication of this intervention is that it is applied at the wrong level (e.g. intervertebral disk that is not causing the hernia or laminectomy on wrong level). In literature, error rates of 1% - 3% are reported.



Laminectomy and surgical hernia repair

Project goal:

Currently, localization at the OR is done using X-ray imaging, which is expensive, cumbersome and uses ionizing radiation. At the Erasmus MC, a localization approach based on ultrasound has been developed, based on matching spinous processes contours from pre-operative images (X-ray and MRI) to contours in sagittal ultrasound images. Whereas this approach has demonstrated to be feasible, it is logisticaly inconvenient to acquire sagittal images at the OR. A better approach would be to use axial scanning. Purpose of this project is develop an imaging approach where axial ultrasound images can be used to infer the spinous contour shape. In this project, two challenges are the determining the 3D position of the individual 2D ultrasound images, and the automated detection of the spinous contours in these images.

We are looking for at TM or engineering student, with experience in image processing. In this project, you are expected to also do the image acquisition yourself (using a research ultrasound machine). An optical (and electromagnetic) position tracking system is available.

Further information: 10.1109/TMI.2017.2738612

Brain vessel analysis in DSA using deep learning

Supervisors: Ruisheng Su, Theo van Walsum

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Stroke is one of the worldwide leading causes of death and permanent disability. Recently, endovascular therapy (EVT) has been proven effective in recanalizing the occluded vessels and brain territory, leading to improved outcome for patients suffering from acute ischemic stroke. Digital Subtraction Angiography (DSA) is the imaging modality for visual procedural guidance and reperfusion assessment in EVT. Such DSA image sequences (2D+Time) provide information on vasculature, perfusion profile and brain anatomy, which are valuable for treatment quality assessment, therapeutic decision making, as well as outcome prediction (See figure). However, such information is mainly captured visually and interpreted subjectively by interventional neuroradiologists so far, which can be error-prone and time consuming. Therefore, *this project aims to assist clinicians to maximize patient benefits in an automated manner leveraging the power of artificial intelligence*.

Vasculature analysis in DSA images forms the basis of many biomarker extraction and quantitative analysis applications. In this context, graduation projects are available on (a combination of) the following subjects:

- Deep learning method for artery-vein separation in DSA sequences;
- Accurate vessel segmentation in DSA using deep learning techniques;
- Vessel centerline extraction in DSA based on deep learning;

During the projects (6-9 months), you will be working on developing deep learning methods for solving specific tasks, as well as comparing the proposed methods with state-of-the-art solutions. In this project, you will further consolidate the following skills: deep learning, python programming, image/video processing, computer vision, statistical analysis, scientific writing, etc.

Figure: Left: minimum intensity map of a DSA acquisition; right: DSA perfusion imaging showing contrast flow time information in brain vessels and tissues.

Brain vessel analysis in CTA using deep learning

Supervisors: Ruisheng Su, Theo van Walsum

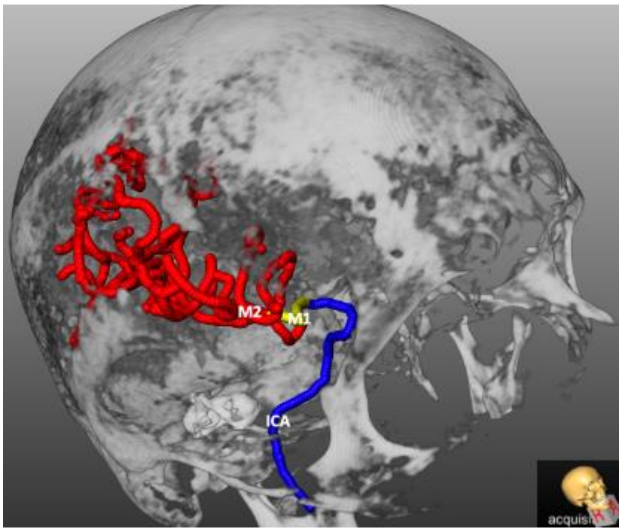
Contact: r.su@erasmusmc.nl, t.vanwalsum@erasmusmc.nl

Stroke is one of the worldwide leading causes of death and permanent disability. Recently, endovascular therapy (EVT) has been proven effective in recanalizing the occluded vessels and brain territory, leading to improved outcome for patients suffering from acute ischemic stroke. Baseline imaging such as CT and CTA are performed on these images. Extracting relevant information from these images (such as quantitative vessel information, thrombus characteristics) may help in better understanding the pathology and improve therapeutic deciscion making. Therefore, *this project aims to assist clinicians to maximize patient benefits in an automated manner leveraging the power of artificial intelligence*.

In this context, graduation projects are available on (a combination of) the following subjects:

- Deep learning method for artery-vein separation in CTA images;
- Thrombus characterization in CT/CTA images
- Distal occlusion detectin in CTA images

During the projects (6-9 months), you will be working on developing deep learning methods for solving specific tasks, as well as comparing the proposed methods with state-of-the-art solutions. In this project, you will further consolidate the following skills: deep learning, python programming, image/video processing, computer vision, statistical analysis, scientific writing, etc.



Vessels segmented in a CTA image

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