BIGR Open Lab Day 2024

Student Projects

Contents

Early ex prediction of the human embryo using deep learning

Research Line: Applied Medical Image Analysis
Project type: Master Project
Approx. duration: 6 to 9 months

Project description
In clinical practice, sex of the developing embryo is not determined during the first trimester. Besides the fact that most parents want to know the sex, research has shown that there are developmental differences between boys and girls early in pregnancy, which are currently neglected[1]. The most well-known method to determine sex during the first trimester is using the orientation of the genital tubercle in the mid-sagittal plane, see **Figure 1**. This proves to be accurate in about 70 - 85% of the cases[2]. The orientation of the genital tubercle is inspected manually using 3D ultrasound. We hypothesize that a deep learning-based approach can be of help in this case since it can automatically extract complex image-based features of the entire embryo. These features could contain information and patterns, which may be more informative than a visual inspection of the genital tubercle.

Interested?
Are you: an enthusiastic student with a clear interest in medical image analysis; looking for a master thesis or an internship between 6 – 9 months (shorter can be discussed); up for this challenge; having experience with programming (preferably Python)? Interested in early human development?

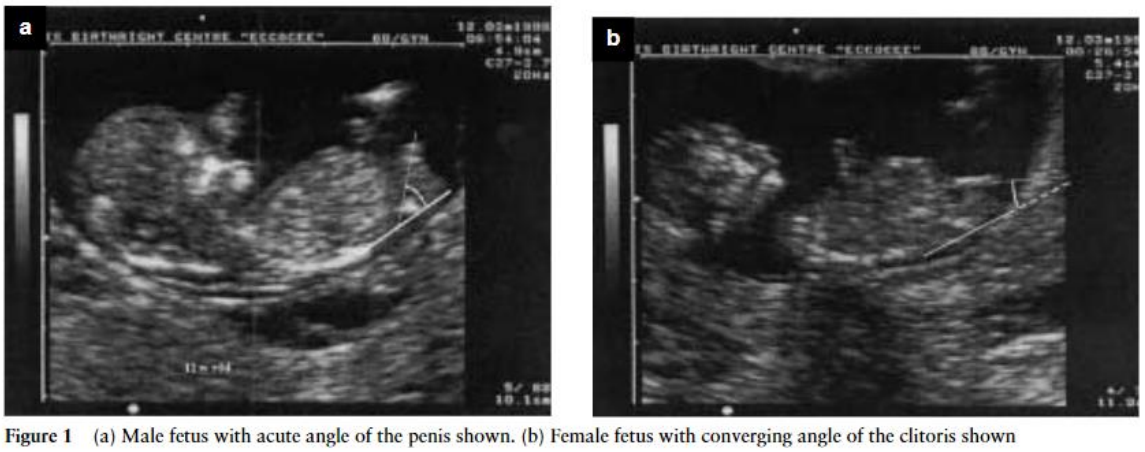

Figure 1 (a) Male fetus with acute angle of the penis shown. (b) Female fetus with converging angle of the clitoris shown

A visit to the clinic is part of this project.

[1]De Zegher, F., Devlieger, H., & Eeckels, R. (1999). Fetal growth: boys before girls. Hormone research, 51(5), 258-259.
[2]Efrat, Z., Akinfenwa, O. O., & Nicolaides, K. H. (1999). First-trimester determination of fetal gender by ultrasound. Ultrasound in Obstetrics and Gynecology, 13(5), 305-307.

Interested in this project?

Supervisor(s): Wietske Bastiaansen, collaboration with the Perioconception Epidemiology group of the department of Obstetrics and Gynecology.
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The influence of maternal BMI on brain development in the second and third trimester

Research Line: Applied Medical Image Analysis
Project type: Master Project
Approx. duration: 6 to 9 months

Project description

Brain growth and morphological development during pregnancy is of crucial importance for current and future health of the developing embryo and fetus. To address this, we created the 4D Human Embryonic Brain Atlas[1], which describes growth and development during the first trimester. Recently, the Fetal Brain Atlas was published[2], which covers the second and third trimester. Using the 4D Human Embryonic Brain Atlas, we studied the influence of maternal BMI (see **Figure 1**) and other important factors such as age, smoking and alcohol usage, on brain development. The aim of this project is to explore whether the Fetal Brain Atlas could be used in a similar fashion. Using groupwise image registration techniques, the deformation between the ultrasound images and the atlas can be determined, which in turn can be analyzed. A large dataset containing second and third trimester 3D brain ultrasound images is available.

Interested?

Are you: an enthusiastic student with a clear interest in medical image analysis; looking for a master thesis or an internship between 6 – 9 months (shorter can be discussed); up for this challenge; having experience with programming (preferably Python)? Interested in early human development?

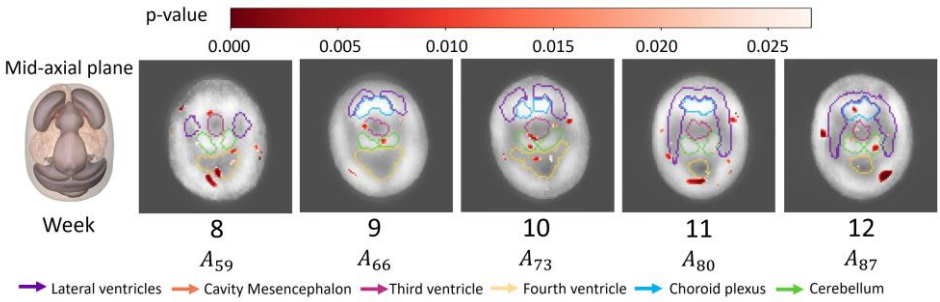

Figure 1: Important brain structures are outlined, in red the voxels are marked that significantly differ between the normal maternal and high maternal BMI group.

A visit to the clinic is part of this project.

[1]Bastiaansen, Wietske AP, et al. "Towards a 4D Spatio-Temporal Atlas of the Embryonic and Fetal Brain Using a Deep Learning Approach for Groupwise Image Registration." International Workshop on Biomedical Image Registration. Cham: Springer International Publishing, 2022.
[2]Namburete, Ana IL, et al. "Normative spatiotemporal fetal brain maturation with satisfactory development at 2 years." *Nature* 623.7985 (2023): 106-114.

Interested in this project?

Supervisor(s): Marcella Zijta and Wietske Bastiaansen, collaboration with the Perioconception Epidemiology group of the department of Obstetrics and Gynecology.
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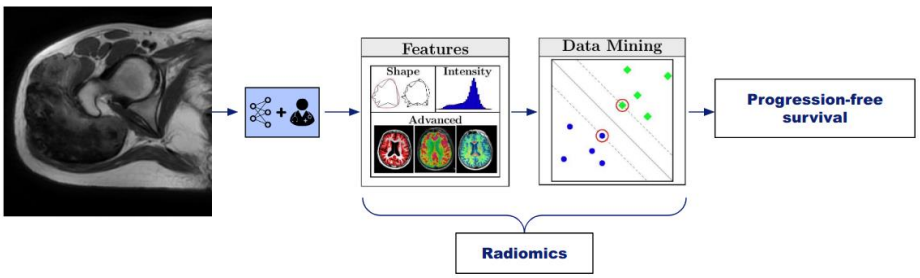
GRAFITI-study: predicting the progression of desmoid-type fibromatosis using radiomics.

Research Line: Applied Medical Image Analysis
Project type: Master Project
Approx. duration: 4 to 9 months

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 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) to determine if a desmoid patient is at risk for progression. For this purpose we have collected data from ~100 patients in various hospitals in the Netherlands, Canada and Italy. 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) to predict tumor progression from MR imaging.



Main tasks:

- Under supervision of musculoskeletal radiologist (MSK) validate interactive segmentation method in desmoid-type fibromatosis.
- Create own radiomics model using WORC to predict tumor progression from MR imaging.

Project designed for: A *clinical* student interested in medical imaging analysis to improve healthcare for patients with a rare soft tissue tumor. This project is co-supervised between the radiology and nuclear medicine departments, and the oncological surgery departments. *Note for technical medicine students: project is registered at your master and includes multiple possibilities for clinical rotations, including sarcoma outpatient clinic (and MDO), viewing of surgery, and more!*

Interested in this project?

Supervisor(s): Douwe Spaanderman, Stefanie Hakkesteegt (PhD candidate, oncological surgery), Martijn Starmans, Dirk Grünhagen (surgeon, dept. oncological surgery), Stefan Klein
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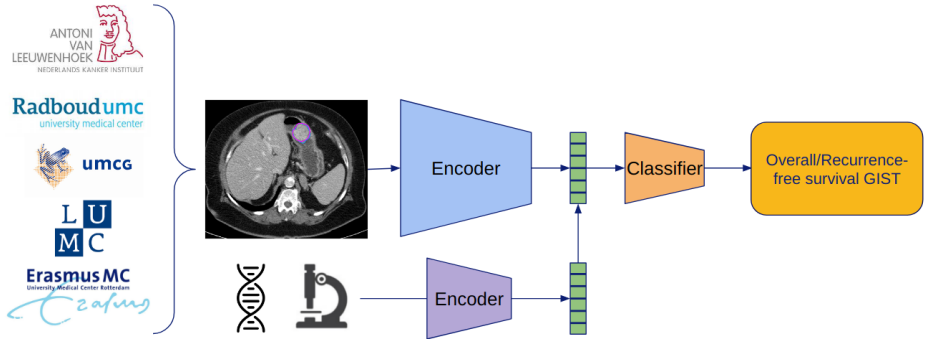
Computer-aided Prognosis for Gastrointestinal stromal tumor on CT using Deep Learning.

Research Line: Applied Medical Image Analysis
Project type: Master Project
Approx. duration: 4 to 9 months

Background:
Gastrointestinal Stromal Tumors (GIST) are a complex group of rare tumors with a broad range of differentiation. The subtypes of GIST differ in their clinical behavior, aggressiveness, molecular background, and preferred treatments given. In order to guide personalized medicine, identifying biomarkers for patient outcomes is essential. The use of features in radiology imaging ('radiomics') such as CT 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. Currently, genetic biomarkers such as the KIT mutations are used to stratify patients at risk. We hypothesize that deep learning can detect these genetic biomarkers as well as novel biomarkers from imaging features.

Aim: The aim of this research is to create a deep learning model identifying known biomarkers directly from CT scans, such as specific KIT mutations, as well as identifying novel imaging biomarkers which will let us directly infer patient survival and treatment response. In order to achieve this, we have already collected a huge multi-timepoint clinical and imaging database of 1400 GIST patients, in a multi-center setting.



Main tasks:

- Developing a deep learning approach to predict known and novel biomarkers.
- Focus on explainability and uncertainty measurement for deep learning

Project designed for: A *technical* student, with already (minimal) experience in deep learning (preferably PyTorch), interested in developing novel deep learning to improve healthcare for patients with a GISTs. Shorter projects than 4 months can be discussed.

Interested in this project?

Supervisor(s): Douwe Spaanderman, Martijn Starmans, Dirk Grünhagen (Dept. Oncological surgery), Stefan Klein
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Detection of incidental pulmonary embolisms in highly variable lung CTs.

Research Line: Artificial Intelligence for Integrated Diagnostics (AIID)
Project type: Master Project
Approx. duration: 6 to 9 months0

Project description
A pulmonary embolism (PE) is a blood clot in a lung artery. It is estimated that PE is the cause of death in 370.000 cases annually in Europe. Detection, especially early detection of PE is not trivial. PE is quite frequently incidentally detected on chest or abdominal computed tomography (CT) scans. In 1%-4% of chest or abdominal CT images with an indication other than PE, an incidental PE (IPE) is detected (1). Unfortunately, these are only a subset of all IPE's, as 44%-79% of visible IPE's on the CT are missed. The main cause of missed IPE is human error. It is not performed as accurately as for the primary indication of the CT image, resulting in this high rate of missed IPE. A robust deep learning model for detection of IPE can help reduce the number of missed indications, improve the earlier detection of PE and reduce deaths and reductions in the quality of life related to PE.

The objective of the project is to develop a clinically valuable deep learning model for the detection of IPE on chest CT.

Achieving high technical performances from the model is only part of the project. How to integrate the model into the clinical workflow is an similar important aspect. The model should be inherent trustworthy and practical. Therefore, there is a close cooperation with the clinic to verify idea's on explainability and usability (2).

You are free to define a strategy for IPE detection. IPE should be detected in a wide range of CT protocols which include lung. You're therefore dealing with various image quality, changing contrast and a highly variable field of view. Generating additional characteristics from an image could be helpful in the detection and trustworthiness. An example might be blood flow modeling with a physics-informed neural network (3) or using complementary labels for negative learning (4). An dataset of a few hundred CT images will be available to train, test and validate with.

(1) F. A. Klok, et al. "Management of incidental pulmonary embolism," *Eur. Respir. J.*, Jun. 2017, doi: 10.1183/13993003.00275-2017

(2) B.H.M. van der Velden, et al. "Explainable artificial intelligence (XAI) in deep learning-based medical image analysis," *Medical Image Analysis*, May 2022, doi: 10.1016/j.media.2022.102470

(3) M. Raissi, et al. "Physics-informed neural networks: A deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations," *J. Comput. Phys.*, Feb. 2019, doi: 10.1016/j.jcp.2018.10.045

(4) W. Ma, et al. "Semantic clustering based deduction learning for image recognition and classification," *Pattern Recognit.*, Apr. 2022, doi: 10.1016/j.patcog.2021.108440

Interested in this project?

Supervisor(s): Erik Kemper, Martijn Starmans, Frans Vos
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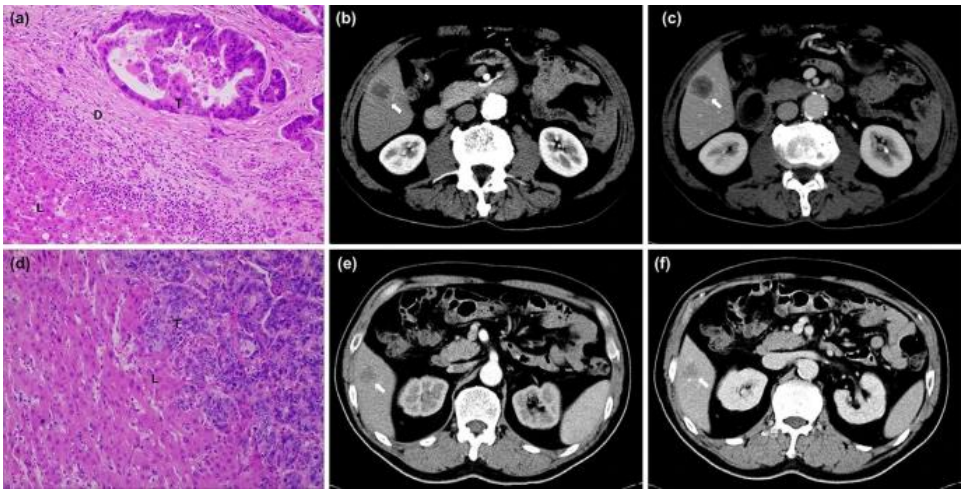
Automated scoring of histopathological growth patterns in colorectal liver metastases on radiology using AI

Research Line: Artificial Intelligence for Integrated Diagnostics (AIID)
Project type: Master Project
Approx. duration: 6 to 9 months



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 tumor 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.

Aim
The aim of this project is to preoperatively predict HGPs based on computed tomography images using deep learning. Previously, we have already distinguished pure HGPs (100% of one type) (see first paper below) and piloted predicting mixed HGPs on 400 patients. These models will never be perfect, e.g., when tumors are very small, there is just 1% of a specific growth pattern, or low scan quality. Your task will therefore focus on dealing with this problem, for example by employing selective classification to balance between coverage (e.g., using the model on a large number of patients) and performance. This project will be conducted in close collaboration with the Department of Surgery.

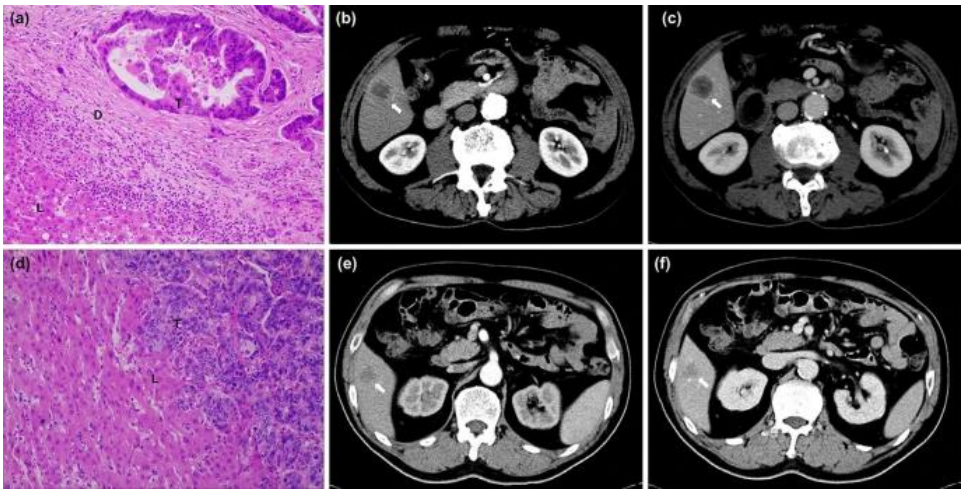
Related research
- https://doi.org/10.1038/s41416-022-01859-7
- https://doi.org/10.1016/j.semcancer.2020.07.002
- https://proceedings.mlr.press/v97/geifman19a/geifman19a.pdf

Interested in this project?

Supervisor(s): Martijn Starmans, Zhen Qian, Stefan Klein
Email: m.starmans@erasmusmc.nl

Automated scoring of histopathological growth patterns in colorectal liver metastases on pathology using AI

Research Line: Artificial Intelligence for Integrated Diagnostics (AIID)
Project type: Master Project
Approx. duration: 6 to 9 months



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 tumor tissue. Patients with more aggressive growth patterns have a far worse prognosis and may benefit from preoperative neo-adjuvant chemotherapy. Currently, HGPs are manually scored on H&E stained pathology slices, where a pathologist needs to count all cells of the tumor border to determine the HGP mixture. As this is time consuming and requires expert knowledge, this substantially hampers both research and transition to clinical practice.

Aim
The aim of this project is to create a deep learning model based on histopathology slides of the CRLM to predict the HGP. How we get there is quite open, e.g., a (semi-)supervised approach using the limited available segmentations we have, or weakly supervised approach, where you train end-to-end models that determine CRLM HGPs directly from the image using only the HGP scores. Explainability to highlight which cell correspond to which HGPs should be a key component. This project will be conducted in close collaboration with the Department of Surgery and Department of Pathology.

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

Interested in this project?

Supervisor(s): Martijn Starmans, Zhen Qian, Farhan Akram, Stefan Klein
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Diffusion Models for Counterfactual Explanations in Soft-tissue Tumor Diagnosis

Research Line: Artificial Intelligence for Integrated Diagnostics (AIID)
Project type: Master Project
Approx. duration: 4 – 9 months

Introduction: Understanding the decision-making processes of deep learning models is crucial, especially for their deployment in healthcare settings. A generative AI approach [1], as reported in skin image analysis, has shown promise in revealing features learned by AI classifiers using counterfactual images. Counterfactual images describe the changes to the current input that result in arriving at the alternative decision by AI models. Extending this workflow to complex clinical questions like soft-tissue tumors (STT) holds significant potential. However, STT image formats and clinical features can pose greater complexity. Recent advancements in diffusion models offer another way to tackle such challenges. Therefore, this project aims to leverage generative AI techniques to comprehensively understand current AI classifiers in STT, and assess the counterfactual images from generative methods quantitatively and qualitatively.

Methods: 1) Implement diffusion models [2] to generate counterfactual tumor images (MRI). 2) To investigate methods for evaluating counterfactual images and explore avenues for incorporating human experts into the process

Aims: In this project, our aim is to enhance the understanding of the key features to be used to distinguish benign and malignant tumors by the use of counterfactual images generated by diffusion models, which can add interpretability to the current STT AI classifiers and establish a groundwork for further improvements.

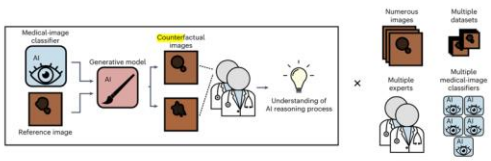

Fig 1. Overview of joint expert, XAI auditing procedure and audited AI classifiers [1].

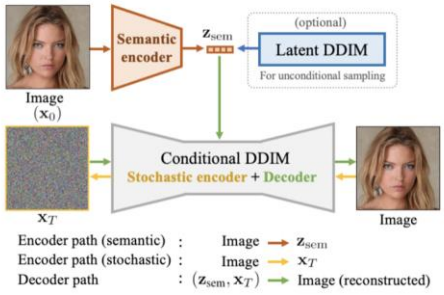

Fig 2. Overview of the diffusion encoder [2].

[1] DeGrave, A.J., Cai, Z.R., Janizek, J.D. *et al.* Auditing the inference processes of medical-image classifiers by leveraging generative AI and the expertise of physicians. *Nat. Biomed. Eng* (2023). https://doi.org/10.1038/s41551-023-01160-9

[2] Preechakul, K., Chatthee, N., Wizadwongsa, S., & Suwajanakorn, S. (2022). Diffusion autoencoders: Toward a meaningful and decodable representation. In *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition* (pp. 10619-10629).

Interested in this project?

Supervisor(s): Xinyi Wan, Shishuai Wang, Martijn Starmans, Stefan Klein
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Uncertainty-Aware Deep Learning Networks for MRI-Based Diagnosis of Differentiated Liposarcomas and Lipomas

Research Line: Artificial Intelligence for Integrated Diagnostics (AIID)
Project type: Master Project
Approx. duration: 4 – 9 months

Project description

Introduction: Accurate diagnosis of lipomatous tumors, especially distinguishing between well-differentiated liposarcoma (WDLPS) and benign lipomas, presents a significant clinical challenge. Deep learning models show promise in this area, but their tendency to produce overconfident predictions on out-of-domain (OOD) inputs is usually neglected. In this proposal, we aim to address this problem by employing the Spectral-normalized Neural Gaussian Process (SNGP) approach to enhance robustness and quantify uncertainty in lipomatous tumor diagnosis [link].

Methods: Integrate SNGP into a deep residual network architecture, leveraging its uncertainty quantification capabilities to improve model reliability and detect out-of-domain (OOD) inputs.

Aims: 1) Develop a deep learning model incorporating SNGP to accurately differentiate between differentiated liposarcoma and lipoma using MRI. 2) Quantify uncertainty by utilizing OOD datasets, such as desmoid or a subtype of liposarcoma not encountered during model training.

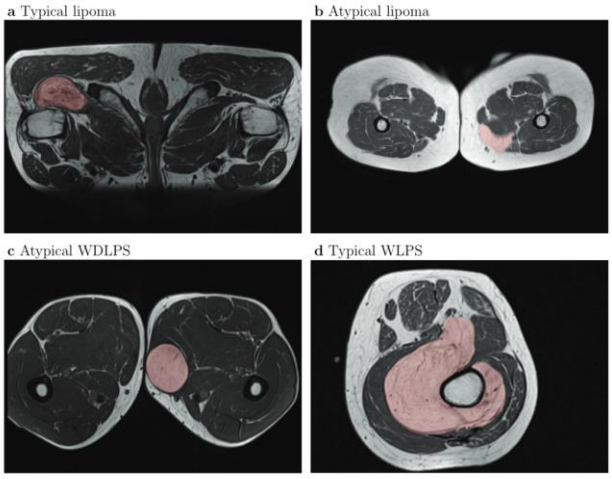

Fig 1. Examples of typical and atypical lipomas and well differentiated liposarcomas.

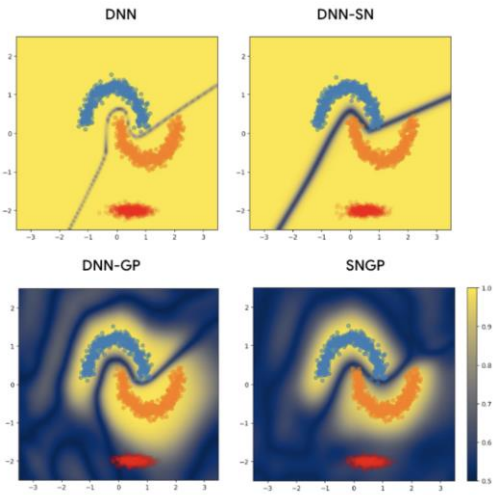

Fig 2. Two moon examples showing the confidence levels in OOD problem using different models

Liu, Jeremiah Zhe, et al. "A simple approach to improve single-model deep uncertainty via distance-awareness." *Journal of Machine Learning Research* 24.42 (2023): 1-63.

Interested in this project?

Supervisor(s): Xinyi Wan, Martijn Starmans, Stefan Klein
Email: x.wan@erasmusmc.nl

Matching of facial shape between mother and offspring

Research Line: Computational Population Biology
Project type: Master thesis
Approx. duration: 9 months

Project description
Objective:

The goal of this study is to identify features of facial similarity between mother and offspring. Furthermore, this study will explore if it is possible to match the facial shape between a mother and her offspring. For example, given a facial image of a mother, what is accuracy in matching the correct offspring among the study population.
If the matching is possible, then try to explain the matching with genetic insights.

Data sets:

- 3D facial image of mother-and-child pairs from the Generation R Study [1];
- SNP-based genotype data of subjects

Tasks:

- To develop an AI-based facial matching algorithm for mother-and-child pairing;
- To identify facial features based on the similarity between mother and offspring with the study population, and then calculate a similarity map;
- To explore if there are sex-related patterns in the similarity map by stratifying the analysis for boys and girls;
- To compare the similarity map with a heritability map, which has been previously generated by our research group;

References:
[1] X Liu, et al. Association between prenatal alcohol exposure and children's facial shape: a prospective population-based cohort study, Human Reproduction, 2023

Interested in joining our research group?

Supervisor(s): Xianjing Liu, Gennady Roshchupkin
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Analysis of photoreceptor density in patients using an automatic segmentation tool

Research Line: Eye Image Analysis Group Rotterdam
Project type: Bachelor or Master Project
Approx. duration: 3 to 6 months

Project description

Adaptive Optics (AO) is a technique that enables super-resolution imaging by correcting aberrations in the light pathway during acquisition. In ophthalmology, it can be used to visualize retinal structures, such as photoreceptors and capillary vessels, on a microscopic level. On a previous project, we developed in-house software for the location and analysis of cones (photoreceptors in charge of color vision) in images acquired with the rtx1 AO retinal camera (Figure 1). This software has been validated in healthy subjects, but we would like to extend its applicability further, to patients that show healthy-looking cell mosaics (e.g., initial stages of a disease or unaffected regions). In the context of the AO-Vision project, we have acquired a dataset of >100 patients of different inherited retinal dystrophies (IRDs), a family of diseases that damage the cells.

The goal of this project is to select the images that are measurable from the IRD patient set (the regions that have sufficient quality and have not been severely damaged by the disease), analyze them using the automatic analysis tool, review and correct the model output if needed, and refine the algorithm so that it can be applied to track the subtle changes due to disease progression.

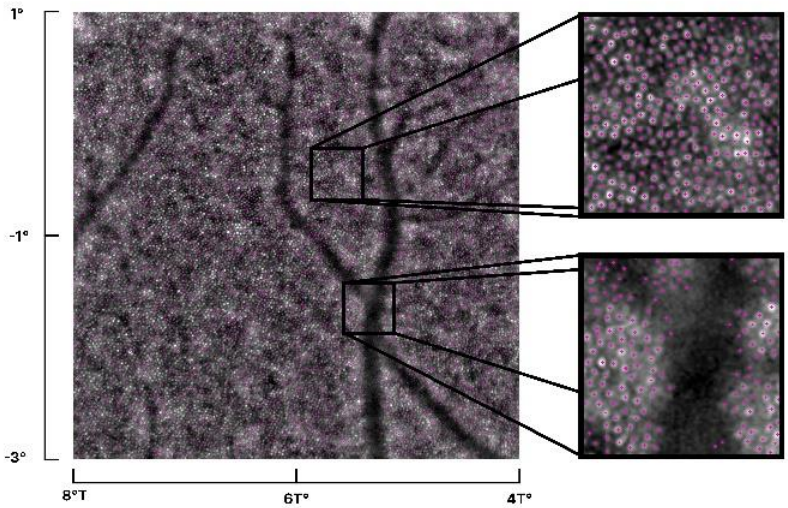

Figure 1. Example of automatic cone detection in an AO image

Interested in this project?

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Email: d.andradedejesus@erasmusmc.nl , m.sanchezbrea@erasmusmc.nl

Automatic analysis of optic nerve sheath diameter in ultrasound data

Research Line: Eye Image Analysis Group Rotterdam
Project type: Master Project
Approx. duration: 4 to 9 months

Project description
The optic nerve is a key structure in our eyes, responsible for sending the electrical stimuli towards the brain. Within the eye, the optic nerve starts at the optic disc and travels towards the skull. Between the eye and the skull, the nerve is "covered" in the optic nerve sheath. This structure can exhibit changes in diameter derived from changes in the intracranial pressure (ICP). In other words, the optic nerve sheath diameter (ONSD) can be used to indirectly monitor changes in ICP over time. This is done by the clinician by manually marking and measuring the sheath in an ultrasound (US) image (Figure 1). However, current ONSD measurements contain errors due to inaccurate placement of the markers (leading to intra- and inter-observer variability). Automated quantification may help to reduce this type of error to the target ranges of tenths/hundreds of millimeters.

Thus, the goal of this project is to develop a model to automatically measure the OSND in US images. These measurements will then be used to monitor changes in ONSD and, therefore, ICP. A retrospective dataset of several hundred US images is already available. The images are not always of optimal quality (Figure 2), and only a subset have pixel-wise segmentations, but sheath measurements are available for the complete dataset. This project is a collaboration with the Anesthesiology department, who can also facilitate additional data collection and pixel-level labelling.

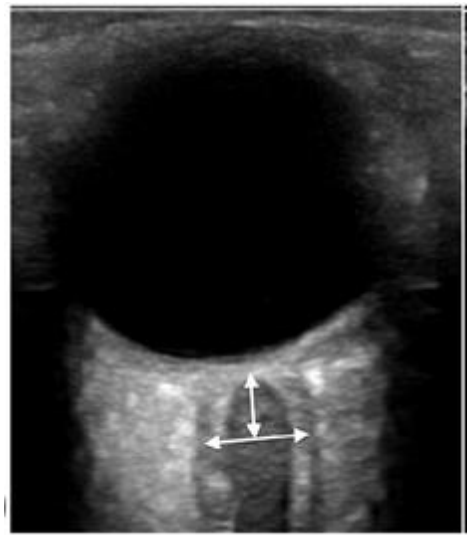

Figure 1. High-quality US image showing the ONSD markings

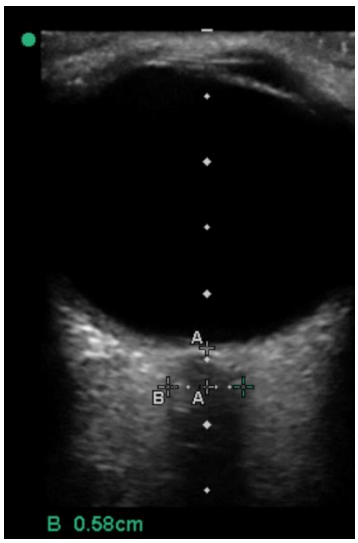

Figure 2. Low-quality US

Interested in this project?

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Automatic analysis of Optical Coherence Tomography Angiography images of the retina

Research Line: Eye Image Analysis Group Rotterdam
Project type: Master Project
Approx. duration: 4 to 9 months

Project description
Optical coherence tomography angiography (OCTA) is an imaging modality computed from the differences of several optical coherence tomography (OCT) scans taken at the exact same location. These differences are mainly due to the blood flowing through the vessels and, hence, OCTA depicts in great detail the vasculature, as long as there is blood flowing through it. In ophthalmology, OCTA has been used to assess and monitor different diseases with known vascular components, such as diabetes and glaucoma. However, OCTA images have a series of associated challenges, namely they are very difficult to interpret visually and prone to acquisition artifacts (Figure 1). Furthermore, the few objective parameters that are used in clinics are provided by the device manufacturers through closed and private software, which makes these markers obscure and not widely applicable through different datasets. Thus, there is a need for objective and open quantification tools.

The goal of this project is to segment the vasculature and other regions of interest in the data (e.g., optic disc), and to compute features relevant to monitor disease progression in different use cases. There is a variety of both public and in-house datasets available for this project, which is a collaboration with Porto University and UK Leuven.

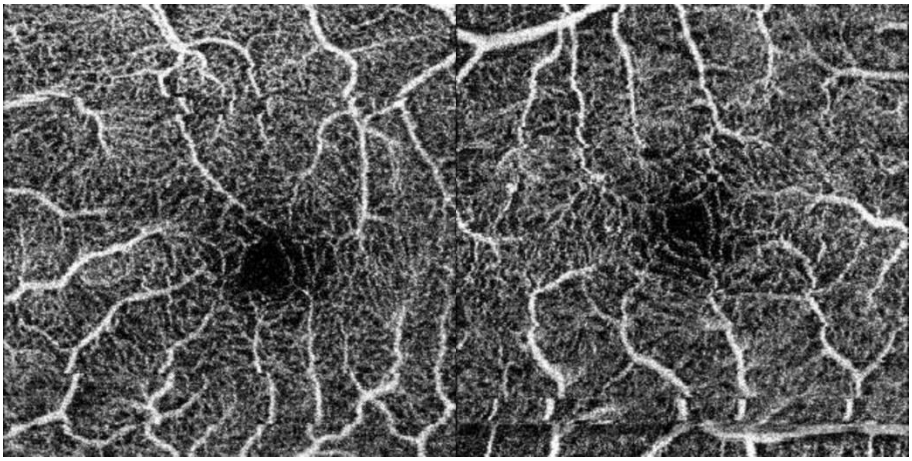

Figure 1. OCTA images (superficial vascular plexus slab) of representative quality, including some motion artifacts – observable where the vessels are not “continuous”, such as in the bottom half of the images.

Interested in this project?

Supervisor(s): Danilo Andrade de Jesus, Luisa Sánchez Brea
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Fovea localization in high-resolution retinal images

Research Line: Eye Image Analysis Group Rotterdam
Project type: Master Project
Approx. duration: 4 to 9 months

Project description

Adaptive Optics (AO) is a technique that enables super-resolution imaging by correcting aberrations in the light pathway during acquisition. In ophthalmology, it can be used to visualize retinal structures, such as photoreceptors and capillary vessels, on a microscopic level.

The human retina has the highest concentration of cones (photoreceptors in charge of color vision) in the fovea (the central part). The acquisition device used for this project, the rtx1 AO retinal camera, obtains 1500 by 1500 pixels images that represent approximately 1.2mm by 1.2mm in real-world units. However, the density and size of the cones in a healthy fovea is so high that this resolution is not enough to observe individual cells. Thus, if automatic measurement tools are used in the complete image, they produce an (incorrect) low density measurement on the fovea. Therefore, we want to exclude this region from computations. Currently, the acquisition device provides an initial estimation of the location of the fovea center, which is accurate in healthy controls, but becomes less trustworthy in patients, especially those with fixation issues. The goal of this project is to develop and validate an algorithm that automatically locates the fovea center and the edges of the region around it where cells cannot be distinguished (white circle in Figure 1).

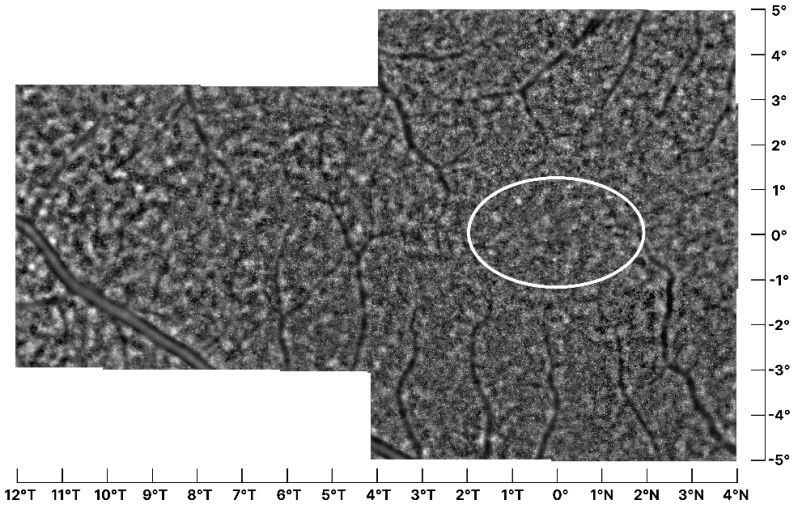

Figure 1. AO-FIO montage with the fovea position marked in white

Interested in this project?

Supervisor(s): Danilo Andrade de Jesus, Luisa Sánchez Brea
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Deep Learning in Acute Ischemic Stroke Therapy

Research Line: Image guidance in interventions and therapy
Project type: Master Project
Approx. duration: 6 to 9 months

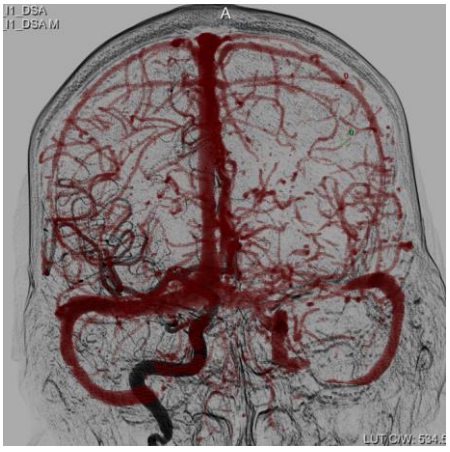
Project description
Acute ischemic stroke (AIS) is one of the leading causes of death and disability in the Western world. In this disease, a thrombus is blocking one of the intracranial arteries, depriving the distal brain tissue of oxygen and essential nutrients.

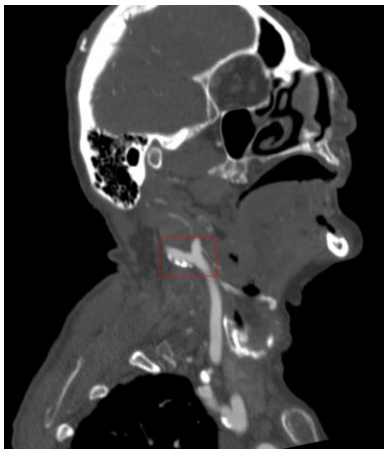
In recent years, mechanical thrombectomy has shown great promise as a novel treatment for AIS. In this procedure, a guidewire-catheter system is advanced through the arteries from the groin to the brain. Using the guiding catheter, a stent-retriever is positioned inside the thrombus. The stent retriever is pulled back, hopefully taking the thrombus with it. The entire procedure is performed under fluoroscopic guidance ("real-time X-ray imaging").

Along the entire stroke care pathway, myriad patient data are generated, but they are relatively unused. At the IGIT group and the ICAI Stroke Lab, we want to unlock the potential of the collected stroke data, harnessing the power of AI. This MSc thesis will contribute to this overarching goal by improving the automated analysis of stroke imaging.

The project has a flexible definition, and we have multiple suitable ideas. One interesting direction is the detection of vessel occlusions on fluoroscopy imaging using Deep Learning. Another idea is automated roadmapping using the preprocedural images to facilitate catheter guidance. Please feel free to contact me to discuss potential projects!

This project is a collaboration between IGIT and the ICAI Stroke Lab, and the prospective student will be embedded in both groups.





Interested in this project?

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Image guidance in surgery with the HoloLens

Research Line: Image guidance in interventions and therapy
Project type: Bachelor or Master Project
Approx. duration: To be discussed

Project description
The Microsoft HoloLens is a head mounted display (HMD) device that allows the visualization of virtual objects in the real world. It can help surgeons during their intervention by providing an overlay of the preoperative data directly on the patient, without the need to switch attention between the patient and a 2D display, as is the case for conventional navigation systems.

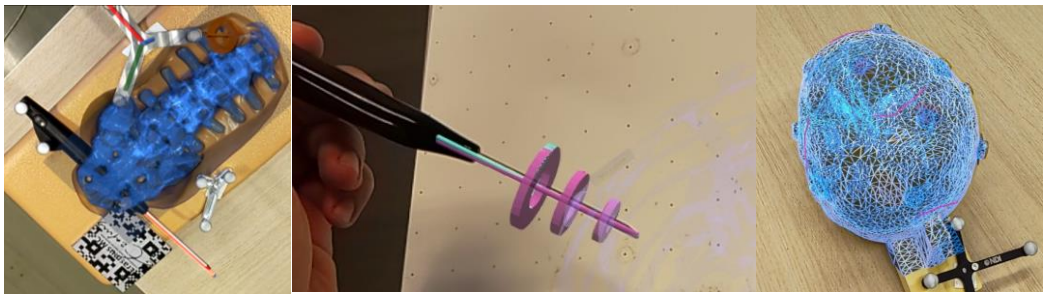
The HoloLens is equipped with a number of sensors and cameras, making it suitable for stand-alone navigation. It can track reference markers in the operative field that allows for tracking the patient and surgical instruments. The virtual overlay can be registered with the patient with multiple approaches such as point-based, surface or depth-based registration.

In our group, we investigate the different tracking and registration approaches for aligning the preoperative data with the patient. Furthermore, we also look at how to optimally visualize the virtual models and navigation data for optimum perception.

We have multiple projects that can fit BSc and MSc thesis projects. We offer more technical projects that focus on improving the current navigation frameworks we have in our lab, as well as technical-clinical projects that focus on validating the systems for the target surgical applications. The projects can be adjusted based on the interest of the students as well as background.

Example of possible projects:

- Reflective spheres tracking for HoloLens stand-alone navigation
- Dynamic visualization of virtual extension in needle insertion
- Feasibility of AR navigation in Zygomatic implant placement



Interested in joining our research group?

Supervisor(s): Mohamed Benmhdjoub, Abdullah Thabit
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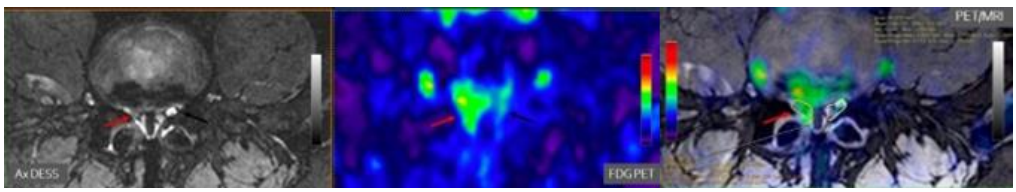
Automated lesion detection in PET/MR imaging of chronic pain

Research Line: Musculoskeletal Image Analysis
Project type: Master Project
Approx. duration: 3 to 9 months

Background: The diagnosis of chronic painful conditions with unknown causes is a challenging task. Functional imaging techniques may help identify pain generators by providing functional information in addition to anatomical information, where the presence of inflammation is an important parameter. Metabolic activity can be identified with Positron Emission Tomography (PET) and the tracer 18F-FDG, an application that is now also expanding beyond oncology to detect and quantify inflammation. A prospective research project is being conducted currently at Erasmus MC - one of the first studies in the world - with the application of 18F-FDG PET/MRI in patients with chronic pain. The unique dataset collected in this study is the serving the basis of this project. Despite the sensitivity of 18F-FDG, diagnosis remains difficult and time consuming even for medical specialists with several years of experience. This project aims to build an AI-based application to aid the identification of inflammation-related lesions on 18F-FDG PET/MR images.

Aim: The specific aims of this project are 1.) to build and train deep learning models (e.g. convolutional neural networks) for identification of inflammation related lesions on PET/MRI scans and 2.) to evaluate the performance of the networks with real patient scans. Beyond the specific application and project, our goal is to establish a modular, well documented and transferable pipeline for later synthetic medical imaging projects.

Methods: This project will use data from healthy PET/MRI scans collected from our patient database and PET/MRI scans from patients participating in our pain project. To create training data for the developed models, lesions will be digitally inserted in healthy PET/MRI scans. The model will be trained on the dataset with synthetic lesions introduced into healthy PET/MR images and evaluated on the patient dataset. Various deep learning architectures, such as YOLO [1-2] and U-Net [3-4], will be trained and compared for identification of inflammation related lesions on PET/MRI scans.



References:

[1] Redmon et al., CVPR, 2016. https://doi.org/10.48550/arXiv.1506.02640. [2] Sobek et al., arXiv preprint arXiv:2312.07729, 2023. https://doi.org/10.48550/arXiv.2312.07729. [3] Ronneberger et al., MICCAI, 2015. https://doi.org/10.48550/arXiv.1505.04597. [4] Isensee et al., Nature methods, 2021. https://doi.org/10.1038/s41592-020-01008-z.

Interested in this project?

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Development of an imaging biomarker for genetic frontotemporal dementia using deep learning

Research Line: Neuroimage Analysis & Machine Learning
Project type: Master Project
Approx. duration: 6 to 9 months

Project description

Frontotemporal dementia (FTD) is the third most common type of dementia, characterized by brain shrinkage in the frontal and temporal lobes. About 10-40% of the patients have a genetic form of FTD, often involving either the *GRN*, *C9ORF72* or *MAPT* gene. Currently, biomarkers for genetic FTD are still lacking, whereas they could play an important role in gaining a better understanding of the disease process, and in future clinical trials.

Within Erasmus MC, genetic FTD is studied in the FTD-RisC cohort, which is a longitudinal study that follows mutation carriers and non-carriers over time. Previous studies in this cohort (Jiskoot et al., 2019; Panman et al. 2019) have shown that brain MRI changes are already perceivable before the start of symptoms. Brain MRI is therefore a promising source for the development of new biomarkers.

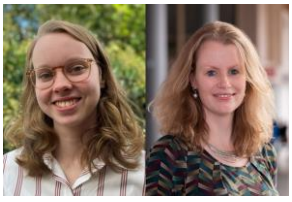
In this project, we aim to explore the development of an FTD imaging biomarker by employing deep learning. We will first train a model to recognize FTD atrophy patterns by classifying MRI scans of FTD, pre-symptomatic mutation carriers and controls. The FTD-likeness score provided by this model is a potential disease biomarker, which is then validated by correlating it to the time to symptom onset in patients who developed FTD within the timeframe of the FTD-RisC study.

If you are interested in image analysis, dementia and machine learning: feel free to contact us! Other future projects might also be possible. A clinical programme (e.g. for Technical Medicine) can also be included.

References

Jiskoot LC, Panman JL, Meeter LH, Dopper EGP, Donker Kaat L, Franzen S, van der Ende EL, van Minkelen R, Rombouts SARB, Papma JM, van Swieten JC. Longitudinal multimodal MRI as prognostic and diagnostic biomarker in presymptomatic familial frontotemporal dementia. Brain. 2019 Jan 1;142(1):193-208. doi: 10.1093/brain/awy288. PMID: 30508042; PMCID: PMC6308313.

Panman JL, Jiskoot LC, Bouts MJRJ, Meeter LHH, van der Ende EL, Poos JM, Feis RA, Kievit AJA, van Minkelen R, Dopper EGP, Rombouts SARB, van Swieten JC, Papma JM. Gray and white matter changes in presymptomatic genetic frontotemporal dementia: a longitudinal MRI study. Neurobiol Aging. 2019 Apr;76:115-124. doi: 10.1016/j.neurobiolaging.2018.12.017. Epub 2019 Jan 7. PMID: 30711674.



Interested in this project?

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End-to-end cardiovascular disease risk prediction using deep learning techniques

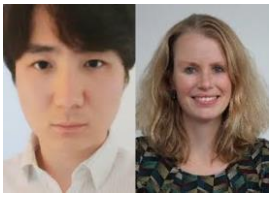
Research Line: Neuroimage Analysis & Machine Learning
Project type: Bachelor or Master Project
Approx. duration: 3 to 6 months

Project description
Cardiovascular disease (CVD) is a leading cause of morbidity and mortality worldwide. It has been known that most cardiovascular diseases can be prevented. Thus, It is important for individuals to monitor and predict their risk of CVD events so that management with counselling and medicines can begin as early as possible.

The MyDigiTwin (www.mydigitwin.nl) is a scientific initiative to develop a platform in which individuals can obtain personalized risk evaluation based on centralized health data in a digital personal health environment (PHE). The project entails the development of CVD risk prediction models to achieve early detection and risk self-management; as one of the partners of the MyDigiTwin consortium, we are trying to realize an end-to-end model that could provide the risk predictions to end users when they upload their heart CT scans to the platform.

Specifically, we implemented a deep learning model (in particular, a convolutional neural network) that can recognize patterns in the CT scans and make the risk predictions based on them. The following projects are available to extend this work.

- We developed deep learning-based CVD risk prediction models combining images and tabular information. Specifically, the models can extract visual features of coronary calcium and combine them with the measurement of risk factors (i.e., tabular information) by concatenating them after the last convolutional layer. We are interested in finding a better way to combine them in the direction of improving discrimination performance.
- On the other side, we are also actively working on adding AI interpretation to the above prediction model. we plan to employ and test some deep learning visualization methods, such as Grad-CAM and Occlusion sensitivity, explaining the network's decision on a given task. The methods will be used for our deep learning-based CVD risk prediction models so that we can offer AI interpretation highlighting what part of the input CT scans are relevant to the risk predictions.
- In addition, you can contribute to find out an association of calcification on a specific heart region (e.g., coronary artery, aortic valve or mitral valve) shown in the CT scans with CVD risk. The previous works have analyzed the association via calcium scoring, which might cause a loss of information regarding calcific lesions when calculating the score, while we aim to employ deep learning techniques that exploit more information directly from the imaging data.



Interested in this project?

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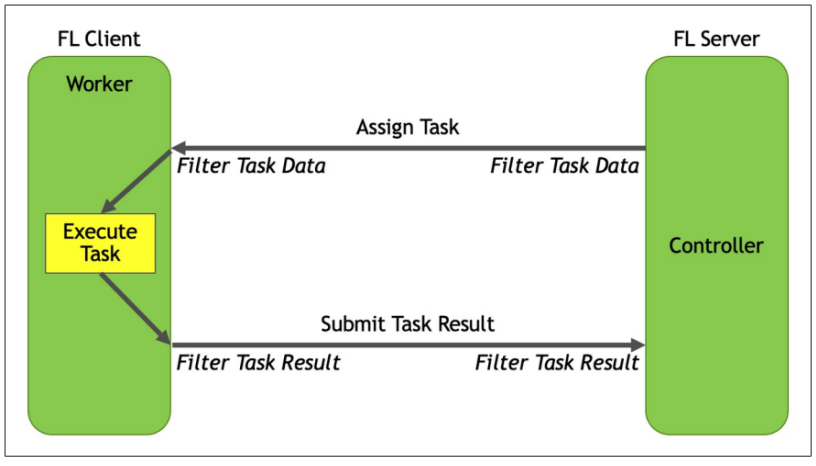
Extension of NvFlare/Flower for compliance with Erasmus MC's infrastructure.

Research Line: Neuroimage Analysis & Machine Learning
Project type: Bachelor or Master Project
Approx. duration: 3 to 6 months

Project description
Federated Learning (FL) is a machine learning paradigm that aims to train models between decentralized centers without sharing the data to a central location. This techniques is particularly useful in the medical field where the data is highly sensitive as it encodes patient information. FL trains local models at each center, then sends the resulting local model's weights to a centralized server. The server then aggregates the results to build a single global model and dispatches the updated weights to each center. The process is repeated until convergence. There is currently no standard framework for training federated models. Two of the most widely used frameworks are NvFlare and Flower. Despite their popularity in research and simulated studies, these frameworks cannot be used in a real-world FL application within Erasmus MC due to architectural reasons. An example issue is that the hospital does not allow ingoing connections, whereas the framework design requires the server to initiate the connection to the client (the hospital) to assign a task (such as training) as seen in the figure below.

The aim of this project is to implement a practical solution, such us the extension of one of the frameworks to comply with the network characteristics of Erasmus MC. The project will be co-supervised by a memeber of BIGR's infrastructure team. A successful implementation of this project will allow the hospital to participate in a wider range of international networks for training federated models.

This project is suitable for HBO students. The student idealy has experience with Python Programming and Computer Networks.



Interested in this project?

Supervisor(s): Kaouther Mouheb
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Automatic data extraction from radiology reports using NLP

Research Line: Neuroimage Analysis & Machine Learning
Project type: Master Project
Approx. duration: 1 to 3 months

Project description

Within the TAP-Dementia consortium, the TAP-Dance project aims to develop novel Artificial Intelligence (AI) techniques to enhance the differential diagnosis of Dementia. The process of training AI models necessitates substantial amounts of data. To optimize the model's performance, our goal is to leverage multi-modal data, encompassing imaging data such as MRI scans, and tabular data including genetic information and psychological assessments. An important source of data is the radiology reports of patients that enable the extraction of important image-based biomarkers, such as the presence of microbleeds or infarcts in the scans. However, the task of data structuring and curation poses particular challenges in the case of radiology reports due to their free-text format, lack of predefined structure, and considerable variability in the language and structure used across different radiologists (see the figure below). Currently, researchers must manually extract this information from the reports, a process that is both time-consuming and highly prone to human error. In this context, advancements in AI, particularly in natural language processing (NLP), can facilitate the automation or semi-automation of this labor-intensive task.

In this project, our objective is to investigate the application of recent advancements in NLP, including Large Language Models (LLMs) like GPT, in constructing an automated pipeline for extracting information from radiology reports of the Alzheimer's Center Erasmus MC cohort (ACE). This project will be developed as an extension of a previous initiative aimed at extracting information from Pathology reports at the Biomedical Imaging Group Rotterdam. The project is expected to last for at least 8 weeks. Github: https://github.com/Douwe-Spaanderman/MedicalRecordNLP

Procedure Performed: MRI Brain with and without contrast

Technique: Multiplanar T1-weighted, T2-weighted, FLAIR, and gradient echo sequences were obtained.

Findings:

- General: The brain parenchyma demonstrates diffuse cortical atrophy, particularly prominent in the bilateral temporal lobes.
- Temporal Lobes: Significant volume loss and cortical thinning are noted in both temporal lobes, consistent with atrophy. This is indicative of underlying neurodegenerative processes, correlating clinically with the patient's history of dementia.
- Microbleeds: Four focal areas of susceptibility artifact consistent with microbleeds are identified within the cerebral hemispheres. These are distributed as follows:
    1. Right frontal lobe
    2. Left parietal lobe
    3. Bilateral occipital lobes
    4. Right thalamus These microbleeds are suggestive of small vessel disease, often associated with vascular risk factors.

Interested in this project?

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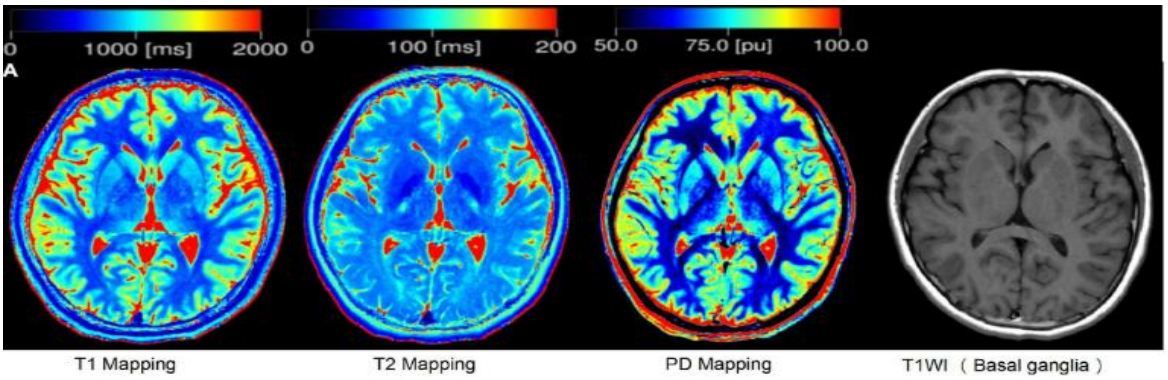
Deep Learning based Super Resolution Quantitative MRI for Precision Medicine

Research Line: Quantitative MR reconstruction
Project type: Master Project
Approx. duration: 3 to 6 months



Background: In clinical MRI, conventional images provide valuable information but lack a direct relation to tissue properties. Quantitative MRI (qMRI) addresses this by measuring tissue properties as illustrated in the figure enabling unbiased comparisons over time and scanners. However, integrating qMRI into clinical practice is hindered by long acquisition times for the required high resolution. Our study aims to overcome this by using deep learning to synthesize high-resolution qMRI from low-resolution qMRI in combination with high-resolution conventional images.

Aim: In our previous work, we implemented an algorithm to simulate rapid acquisition of low resolution synthetic qMRI images. These images are then combined with high resolution conventional images to generate high resolution qMRI. The primary aim of this Master's project is to develop an AI algorithm so it is applicable to the data acquired through the actual scanning. The student will engage in understanding the underlying theory, refining the exciting methodology and optimizing the AI algorithm for this particular application.

Project strategy: The project involves preparing a newly collected dataset of qMRI scans and corresponding high-resolution conventional images. Image registration techniques may be required to align the scans properly. We will then train the deep learning model to synthesize high-resolution qMRI from the low-resolution inputs and high-resolution weighted images. Validation will be conducted to assess performance of the method.

Potential impact: The rapid acquisition of low-resolution qMRI scans, followed by their enhancement using routinely acquired weighted images, holds the potential to advance methods for detecting abnormalities in patients. The incorporation of such techniques into clinical protocols could enable online abnormality detection, thereby improving patient care and diagnosis.

Interested in this project?

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Diffusion Model-based Denoising for Radial-sampled MR Images

Research Line: Quantitative MR reconstruction
Project type: Master Project
Approx. duration: 6 to 9 months

Project description
Background: Zero echo-time (ZTE) MRI is a novel imaging technique that utilizes ultrafast readouts, offering advantages such as capturing unique contrast information and facilitating silent scanning. Currently, our group is investigating a modified version of ZTE, called DL-MUPA, to generate parametric maps of tissue properties such as T1, T2, and proton density. These maps are generated voxel by voxel from weighted images acquired with DL-MUPA. However, the acquired weighted images often exhibit high (structured) noise level due to the rapid radial sampling scheme employed. This noise propagates into the resulting quantitative maps (see Figure 1), thereby impeding their clinical applicability.

Aim: In this project, our objective is to build a deep learning-based method to denoise the weighted images acquired with DL-MUPA, which is crucial for ensuring the accuracy and reliability of the generated parametric maps, and hence improve the applicability of this novel imaging technique.

Methods: Our investigation will focus on applying diffusion model, a novel and potent generative AI technique, for denoising weighted images. Leveraging the diffusion model, we approach denoising as a conditional generation problem, aiming to generate clean weighted images conditioned on their noisy counterparts.

Project designed for: An enthusiastic technical student with interest in medical image analysis and looking for a master thesis or an internship between 6 – 9 months (shorter can be discussed); having experience with Python and (minimal) MR physics knowledge is desirable.

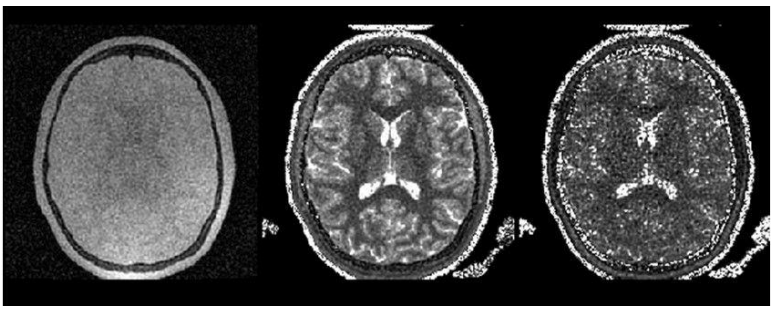

Figure 1: Noisy quantitative maps (PD, T1 and T2) created based on the weighted images acquired using DL-MUPA

Interested in this project?

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