Thesis Position in Orléans, France

Deep Learning for Knee Osteoarthritis Prediction: Texture Analysis and Generative Networks for 3D Reconstruction

Contract: PhD Position (that can be preceded with a Master internship in Spring 2022)

Key words: Machine learning, statistical and texture analysis

Duration: 3 years

Employer: University of Orléans

Research Laboratory: Institut Denis Poisson, University of Orléans, France

Funding: ANR MIMOSA project (https://anr.fr/Projet-ANR-20-CE45-0013)

Salary: 2 135 € gross per month (+ 2600 € per year for optional teaching duties)

Start date: November 2022

Official application website:

https://emploi.cnrs.fr/Offres/Doctorant/UMR7013-ROMABR0-002/Default.aspx

Context

OsteoArthritis (OA) is the most common form of arthritis and is now considered as a disease of the whole joint organ involving not only the articular cartilage, subchondral bone and synovial membrane but also the menisci and ligaments. The literature shows that hip and knee OA are the eleventh highest global disability factor, causing a large economic burden to the society. It has been reported that the estimated overall costs per patient for OA treatments reach 19,000 €/year. Costs mainly arise from the current clinical inability to automatically diagnose the disease at an early stage, or to slow down its progression and reduce the impact of its future disability. Because there is no effective cure for OA besides total joint replacement surgery at the advanced stage, an early diagnosis and behavioral interventions remain the only available options to prolong the patients' healthy years of life. Clinically, early diagnosis of OA is possible; however, currently, it requires the use of expensive magnetic resonance imaging (MRI) available only at specialized centers or in private practice. Moreover, this modality does not capture the changes in the bone architecture, which might indicate the earliest OA progression.

The current gold standard for diagnosing OA, besides the always required routine clinical examination of the symptomatic joint, is X-ray imaging (plain radiography), which is safe, cost-efficient and widely available (see Figure 1). Despite these advantages, it is well known that plain radiography is insensitive when attempting to detect early OA changes. For these reasons, early OA prediction is difficult in clinical practice. OA diagnosis is also highly dependent on the subjectivity of the practitioner due to the absence of a precisely defined grading system.

Deep Learning (DL) networks have recently shown ground-breaking results in a variety of general image recognition and also in knee OA and CADx (Computer Aided Diagnosis) tasks. These powerful models already can reach human-level performance, which clearly indicates the possibility for using them in clinical practice in the near future.

Currently, there is an urgent need to accurately detect the presence and quantify the severity of OA. Fully automatic knee severity grading can provide objective and reproducible prediction. The

development of Artificial Intelligence (AI) based predictive models is essential to improve the prediction of OA.

The aim of this thesis is to develop effective machine learning methods combining hand-crafted knowledge-based features and deep learning features for the early detection of knee OA. Different public and private databases will be investigated.

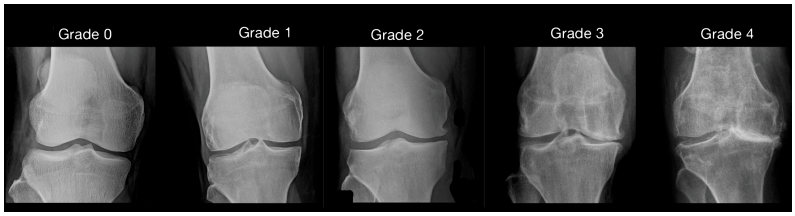

Figure 1: Radiological grades of osteoarthritis according to the Kellgren & Lawrence scale.

Scientific objectives

For the diagnosis of knee osteoarthritis two main informations are of interest: The trabecular bone microarchitecture and the 3D geometry of the knee joint.

Bone texture analysis using 2D X-ray radiographies for the early detection of knee osteoarthritis: Ever since the seminal work of (Gatys et al 2015) for texture synthesis, texture modeling has seen exciting developments by using pre-trained deep Convolutional Neural Networks (CNN) statistics. This approach has impacted all texture-related applications in computer vision and computer graphics (Liu et al 2019). To the best of our knowledge, the benefits of this approach for the characterization of X-ray images has yet to be fully explored and evaluated. Indeed, radiographic bone textures are not visually comparable to the natural textures present in real-life pictures used to train the CNN for computer vision tasks. Another relevant alternative is to use scattering transforms (Bruna & Mallat 2013) that are not learned from image databases. The main goal of this task would be to explore the adequacy of these numerous CNN statistics for OA scoring and confront/combine these new measures with the efficient and application-tailored classical texture features, notably the Trabecular Bone Score developed by Medimaps and the score based on 3D fractional Brownian motion (Jennane et al 2007, El Hassouni et al 2016).

Generative networks for conditional MRI generation given 2D radiographic data: A major open question tackled by the MIMOSA project is how to exploit the rich information of academic databases of combined 2D X-ray and 3D MRI knee images in a clinical situation where only 2D X-ray are available. In this context, we wish to elaborate a new network architecture for the generation of fake 3D MRI images conditioned on one or several knee 2D X-ray images. This very challenging task consists in proposing and training Generative Adversarial Networks generating 3D volumes consistent with 2D input X-ray images using the pairs of images from public databases (OAI: The Osteoarthritis Initiative: https://data-archive.nimh.nih.gov/oai/). Several recent contributions, e.g. (Ying et al 2019) and (Kasten et al 2020), tackles similar 2D to 3D reconstruction problems for medical imaging but are too limited in term of resolution for the purpose of knee joint inspection. We will investigate techniques that allow for generating high-resolution volumes as already achieves in computer graphics applications (Gutierrez et al 2020). In case of success, the generative network will be of direct interest for the MIMOSA partners, namely the Medimaps company as well as the other researchers of the project that will use all available imaging modalities for knee OA grading.

Position details & key skills

The candidate will work within the mathematics laboratory Institut Denis Poisson and will collaborate closely with scientists from different fields (clinicians, data scientists, industrials, etc.).

The candidate should have skills in the following areas: applied mathematics, image processing, machine learning, deep learning.

Computer skills: python, an experience with PyTorch and GPU programming will be appreciated.

Contact

Send a detailed CV and a cover letter **via the official application website**:

https://emploi.cnrs.fr/Offres/Doctorant/UMR7013-ROMABR0-002/Default.aspx

Feel free to also contact us by email:

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References

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