Polytech network form for PhD Research Grants from the China Scholarship Council

This document describes the PhD subject and supervisor proposed by the French Polytech network of 14 university engineering schools. Please contact the PhD supervisor by email or Skype for further information regarding your application.

Supervisor information	
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University name	University of Orleans
Country	France

PhD information	
Title	Full Professor, PhD
Main topics regards to CSC list (3 topics at maximum)	Biomedical engineering, Techniques of simulation and application

Required skills in science and engineering	Machine learning, Image processing, computer programming, matlab, mathematical background is a plus

Subject description (two pages maximum)

Title : Deep Learning-Based Approaches for Automatic Knee Osteoarthritis Diagnosis

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 [1], 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 [2]. 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 [3, 4].

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. Despite these advantages, it is well known that plain radiography is insensitive when attempting to detect early OA changes. This can be explained by several facts: first, the degeneration and wear of the articular cartilage is the main feature of OA – a tissue that cannot be directly seen in plain radiography; second, although the evaluation of the changes in the joint should be investigated as three-dimensional (3D) issue, the imaging modality uses only two-dimensional (2D) projection; and finally, the interpretation of the resulting image requires a significantly experienced practitioner. Eventually, the cartilage degeneration and wear are indirectly estimated by the assessment of joint-space narrowing and bony changes, that is, osteophytes and subchondral sclerosis. For these reasons, an early OA diagnosis is difficult in clinical practice. A part from the aforementioned limitations of plain radiography, OA diagnosis is also highly dependent on the subjectivity of the practitioner due to the absence of a precisely defined grading system.

With improvements in computer hardware it has become feasible to train more and more complex models on more data, and in the last few years, the use of supervised learning in image segmentation, recognition, and registration has accelerated.

Deep learning (DL), and in particular Convolutional Neural Networks (CNN), has recently shown ground-breaking results in a variety of general image recognition [5, 6] 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. CNN automatically learns relevant image characteristics to produce a specific output, for example, diagnosis, region of interest extraction, segmentation, etc.

Scientific objectives: In this thesis, machine learning in medical image classification will be investigated, and several fully automated frameworks will be proposed to better handle challenges in OA knee progression and initiation. The proposed frameworks should provide accurate classification results without human intervention. Our aim is to develop a new state-of-the-art automatic CADx method to diagnose knee OA from plain radiographs while simultaneously providing transparency in the physicians' decision-making process. This work aims to develop an efficient neural network architecture that learns highly relevant disease features compared to the baseline. Fine-tuned and pre-trained architectures on existing dataset (transfer learning) will be tested. Additionally, attention maps that can be used for supplementary diagnostic information will be provided for clinical use. Two main issues will be tackled in the pipeline of the proposed network: 1) automatic detection of the distal area (joint space) between the femur and the tibia and 2) extraction of relevant textural image characteristics to produce a specific output related to knee OA.

To prove the robustness of the proposed approach, dataset for training and model selection will be different than the one used for the final testing. Two public databases (OAI and MOST) as well as data from our internal network of hospitals will be considered for experimentations. Clinically, the proposed approach should complement the OA diagnostic chain and make radiographic knee OA grading more objective.

Position details: The candidate will work closely with clinicians, image processors, industrials, etc. The candidate should have at least skills in of one of the following areas: machine learning, image processing, programming, applied mathematics is a plus.

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References:

[1] Cross, M. et al. The global burden of hip and knee osteoarthritis: estimates from the global burden of disease 2010 study. Annals rheumatic diseases ann. rheumdis–2013 (2014).

[2] Puig-Junoy, J. & Zamora, A. R. Socio-economic costs of osteoarthritis: A systematic review of cost-of-illness studies. In Seminars in arthritis and rheumatism, vol. 44, 531–541 (Elsevier, 2015).

[3] T. Janvier, R. Jennane, et al. "Subchondral Tibial Bone Texture Analysis Predicts Knee Osteoarthritis Progression". Osteoarthritis and Cartilage, Elsevier, DOI: 10.1016/j.joca.2016.10.005.

[4] T. Janvier, R. Jennane, H. Toumi, E. Lespessailles. "Subchondral Tibial Bone Texture Analysis Predicts Knee Osteoarthritis Progression". Osteoarthritis and Cartilage, DOI: 10.1016/j.joca.2016.10.005.

[5] Simonyan, K. & Zisserman, A. Very deep convolutional networks for large-scale image recognition. arXiv preprint arXiv:1409.1556 (2014).

[6] He, K., Zhang, X., Ren, S. & Sun, J. Deep residual learning for image recognition. In Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, 770–778 (2016).