Opportunistic Diagnosis of Knee Osteoarthritis from a Plain Radiography

Knee OsteoArthritis (OA) is a prevalent degenerative joint disease that significantly impacts the quality of life by limiting mobility and causing chronic pain [1]. The progression of knee OA is typically slow and insidious, making early diagnosis challenging yet critical for preventing severe degeneration and managing symptoms effectively. The literature shows that hip and knee OA are the eleventh highest global disability factor [2], 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 [1]. 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 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. Finally, the interpretation of the resulting image requires a significantly experienced practitioner. For these reasons, an early OA diagnosis is difficult in clinical practice. Apart 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.

MRI is recognized as the gold standard for assessing knee OA, surpassing traditional X-ray methods that primarily capture bone abnormalities [5]. Unlike X-rays, MRI provides a comprehensive view of the entire knee joint, including cartilage, bone, ligaments, and soft tissues. This detailed imaging capability allows for the detection of early signs of OA not visible in X-rays, such as cartilage degradation, bone marrow lesions, and synovitis, offering a deeper understanding of the joint's structural integrity and the nuanced pathological changes associated with the condition.

MRI not only fills this gap by providing detailed and high-resolution images but also offers the unique advantage of non-invasive, multi-planar imaging capabilities. This enables a more thorough assessment of the knee joint from multiple perspectives (also known as views), which is crucial for a comprehensive analysis of the disease's progression. Nevertheless, the vast amount of data produced by MRI scans requires sophisticated processing techniques to extract diagnostically relevant information effectively, highlighting the importance of advanced computational models in enhancing the diagnostic process.

Unfortunately, the high cost of MRI means that most patients with knee OA only have access to plain radiograph (X-ray). To address this problem, in this thesis we aim to introduce a new approach to improve the diagnosis of knee OA in its early stages. More specifically, the aim of

this thesis is twofold: (i) to develop an approach to synthesize an MRI for a given patient from a plain X-ray; (ii) to introduce efficient models for extracting OA-related features from plain X-rays and synthetic MRIs for the early detection of knee OA.

Scientific objectives:
In this thesis, computer vision methods will be investigated, and several fully automated frameworks will be proposed to better handle challenges in knee OA 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 for early detection of knee OA from plain radiographs while simultaneously providing transparency in the physicians' decision-making process.

This thesis aims to develop an efficient approach that learns highly relevant disease features compared to the baseline. Additionally, several features 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 thesis. As the MR imaging modality is expensive and not widely available, the proposed approach will include: (i) the development of a method for MRI generation using one plain radiography and (ii) the introduction of innovative fusion classification techniques to aggregate relevant features from X-ray and generated MR images.

To prove the robustness of the proposed approach, several publicly available databases as well as private ones will be investigated for experimentations. Clinically, the proposed approach should enable and make early detection of knee OA grading more objective.

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

Contact:
Rachid JENNANE (email : Rachid.Jennane@univ-orleans.fr, tel : +33 2 38 49 45 38)

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