Research Proposal of Machine Learning in Detection OF Osteoarthritis.

Osteoarthritis

Osteoarthritis (OA) is a joint disease which can occur in any joint of the human body (mostly found in hip joints and knee joints) [1]. OA affects cartilage and surrounding structure of the entire joint including trabecular bone, femoral head, bone tissues ligament, synovial fluids, hyaluronic acid (which helps synovial fluid lubricate the joint), subchondral bone (located underneath the cartilage).

Osteoarthritis (OA) has stage I-IV stages. **Stage 0** (Pre-OA) has no clinical sign of the joint pathology but is characterized by an appearance of cellular changes. No other surface lesion is observed but MRI might detect pre-OA. Treatment involves change in lifestyle. Early stage of OA, also referred to as **Stage 1**, exhibits negligible cartilage injury and development of bone spurs but patients rarely complain of pain. It is usually diagnosed by physical examination or imaging studies, and its treatment does not involve surgery; instead, it may involve modified diet and regular exercises or change in weight. Mild OA at **Stage 2** involves more the formation of bone spur as well as slight narrowing space in joint as well as frequent pain frequently. Diagnosis is done through X-ray and the treatment as suggested includes NSAIDs, braces and exercises. Moderate osteoarthritis (OA) is categorized in **Stage 3** characterized with major cartilage loss and worsening pain during and after the exercise. It may be diagnosed using MRI or arthroscopy or through a surgical procedure; the treatments are through drugs, physical therapy and administration of injections for patients in severe pain. **Stage 4** severely limits their movement and has constant pain and stiffness coupled with very minimal or no cartilage at all. This is diagnosed using images and osteotomy or joint replacement may be needed since cure usually necessitates intervention [2].

Introduction

Osteoarthritis (OA) is a complex and disabling condition that led to $140 billion in healthcare expenses and $164 billion in lost wages in the United States in 2013 alone [3]. Additionally, with an aging global population, the prevalence of osteoarthritis (OA) is continuing to increase [5]. AI and Machine Learning can help clinicians to detect OA and its pathology where ML can also help with personalized treatments. This method allows us to use multidimensional and multi-source data to understand the nature of OA [4].

The complexity and diversity in both the structural and clinical aspects of **osteoarthritis (OA)** have made it challenging to develop effective treatments to slow or stop the disease's progression. Due to this challenge, the focus on AI driven technology to detect OA at its earliest stage has been a considerable topic to discuss and explore. I have researched through such similar articles and my findings were.

AIML Driven Methods to detect OA

The study done by Widera and his colleagues, tried to determine patients with osteoarthritis (OA) who are likely to develop their disease more quickly. This is important because it will increase understanding of the factors that may affect the treatment efficacy through enrolment of these "rapid progressors" in RCTs. Cohort Hip and Cohort Knee which contained 1002 patients and Osteoarthritis Initiative (OAI) which contained 3465 patients were used on which Six types of ML

algorithms are examined. These datasets were comprised of clinical data, X-Rays, and results including Total Joint Replacement (TJR). The study established that the trained models outperformed conventional approaches to predicting OA progression in terms of pain, or structural alterations, or both. The lesson showed that the current methods of analysis had an accuracy of 20 percent, while the ML models had approximately 45 percent accuracy. This indicates that the designed ML models should be more effective in identifying patients who are likely to develop the worsening OA symptoms. However, the approach has not been validated for independent use and needs further testing in future RCTs to establish its practicality in the external environment [7].

Dorraki and his team (2023) came up with a unique idea to detect OA by using Novel Network Approach inspired by Graph Theory. They focused on trabecular bone structures and their changes. They compared bones from people who have HOA (Hip Osteoarthritis) to healthy bones with no history of bone disease in the same age group of the people. Then they created a Machine Learning model to classify between OA affected to healthy bone. They used CNN architecture for image processing and to identify the pathology of OA. This approach helped to explain how certain patterns are linked to the occurrence of OA [6].

The need to predict cartilage loss in the knee as a manifestation of OA progression was the aim of the study by Bonakdari et al. They focused on assessing bone curvature using MRI scans. The researchers paid particular attention to eight areas of the knee and employed gender-related simulation data. According to their outcomes, researchers discovered that cartilage degeneration most likely affect the medial condyle region, the interior portion of the knee. The results were highly accurate, with an R value of 0.78 in the test as well as in the validation sets. The best ML algorithm deployed was an “adaptive neuro-fuzzy inference system”; however, it required many input variables (10 in this case) to increase the computational cost [7].

In the further study conducted by Bonakdari et al., now the aim was to know whether structural knee OA could be accurately forecasted with other factors such as, SNPs and mtDNA haplogroups in combination with age and BMI (OA damage) which are the two main predictors of knee OA. In this study, the bonakdari focused on 901 participants from the OAI database to perform machine learning studies, where hybrid models helped boost prediction capability. These models were internally and externally validated on the data from the Tasmanian Older Adult Cohort Study. The outcome demonstrated excellent validity of the models as they scored above 95% in the initial experimental trials and 85% in the external test. This underscores the genetic factors in hitch with clinical findings as promising biomarkers for prediction of OA progressiveness. And the current research points to the development of a more focused, individualized approaches to OA treatments in the future, opening the door for similar studies in other populations and multiple other genetic risk factors. In his research, Bonakdari draws attention on biomolecular data applicability to inform the development of machine learning algorithms in complexity of OA progression and treatment [8]

In the DNA Methylation and Biomarkers Study, the researchers aimed to identify biomarkers for osteoarthritis (OA) progression by analysing DNA methylation patterns, which are chemical changes in DNA that can impact gene expression. The study focused on predicting different types of OA progression, such as pain-only, radiographic-only (joint damage seen in X-rays), or both. The team used data from three independent groups: a subset of 554 patients from the Osteoarthritis Initiative (OAI), 128 individuals from the Johnston County

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OA Project, and an additional 56 participants from the OAI. The researchers applied elastic net regularized logistic regression to correlate methylation patterns with progression outcomes. They found that models based only on clinical features (like symptoms or X-rays) did not perform well, with an AUC of 0.54–0.68. However, when methylation data was included, either alone or combined with clinical data, the models performed much better, particularly in identifying patients with pain-only or pain plus radiographic progression. They identified 13 CpG sites (regions of DNA where methylation occurs) as reliable predictors of OA progression in both the original test and independent groups. The study is significant because it was validated with both internal and external data, making the results more reliable. These methylation biomarkers could serve as stable, time-independent indicators of OA progression, offering potential for more targeted and personalized treatment approaches in the future [9].

Challenges faced by AI driven methodologies in OA

In case of OA, the application of AI and ML is useful predicting the patterns and progression of the disease but there are challenges faced by researchers. That is; the AI models could be biased in many ways. This is possible where the data we use to train the AI belongs to a set of people or have some missing information. For example, electronic health records (EHRs) often have gaps or are designed for billing, not for detailed medical analysis, which can lead to inaccurate predictions [4]. That is why when AI systems are developed in a particular population, applying it to a different or real patient population may not be effective.

Another challenge is that most AI models are not validated with other datasets. Notably, without this external validation, the results cannot always be trusted which limits the use of AIML in practical life [4].

Research Proposal

Here I introduce an idea built around Reinforcement Learning, Active Learning, doctor feedback, and Cloud Computing to overcome certain deficiencies of current AI/ML models for OA. **Reinforcement learning** allows the system to improve through the results given to it, thus minimizing the biases and increasing the correct answers' rates as time goes by [10]. **Active learning** makes certain that the model pays attention to the most difficult instances, and when in doubt, it seeks advice from doctors, which enhances the learning process through the integration of knowledge from the experts [11]. This feedback loop also helps maintain a human-in-the-loop again that keeps the model up to date and clinically sound. Additionally, **cloud computing** enables a combination of big databases and increases the system's adaptability and applicability; at the same time, it supplies the necessary computational resources for the processing of extensive medical data [12].

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