

Project ID : 25-26J-112

1. Topic

Knee Osteoarthritis Progression and Prediction using Multi-Modal Deep Learning.

2. Research group the project belongs to

CoEAI - Centre of Excellence for AI

3. Specialization of the project belongs to

Data Science (DS)

4. If a continuation of a previous project:

Project ID	
Year	

5. Brief description of the research problem including references

Knee Osteoarthritis (KOA) is a long-term (chronic) joint disease where the cartilage in the knee joint gradually breaks down. Cartilage is the soft, rubbery layer that covers the ends of the bones and helps them move smoothly without rubbing. When the cartilage becomes thinner or damaged, the bones start to rub against each other. This causes pain, stiffness, swelling, and difficulty moving the knee[1][6][11].

KOA is one of the most common types of arthritis and mainly affects people. However, it can also occur earlier due to injuries, excess weight, heavy work, or repeated stress on the knee joint. As people live longer and become less physically active, the number of people with KOA is increasing worldwide. This disease can seriously lower the quality of life by limiting mobility, causing constant pain, and leading to mental health issues such as depression and anxiety. It also puts a heavy burden on the healthcare system because of long-term treatments, doctor visits, and surgeries.

Currently, KOA is identified by doctors using several methods:

1. Clinical examinations: The doctor checks how well the knee moves, listens for joint noises (like grinding or popping), and asks about symptoms such as pain or stiffness[2].
2. X-rays: These show the space between the knee bones. If the space is narrow, it means the cartilage is wearing away[5][7].
3. MRI scans: These give detailed images of the cartilage and soft tissues and are useful in early KOA when X-rays don't show much damage yet[3].
4. Patient history: Doctors also consider the patient's age, lifestyle, body weight, previous injuries, and how long they've been feeling pain or stiffness[4].

Although current techniques like X-rays, MRIs, and clinical assessments are commonly used to diagnose and monitor KOA, they have several important limitations. These methods are often expensive and require specialized equipment and trained staff, which are usually found only in large hospitals. As a result, people living in rural or low-income areas may have limited access to these services. In addition, these diagnostic tools only capture the condition of the knee at a single point in time. Since KOA progresses slowly and changes over weeks or months, one-time imaging does not provide a complete view of how the disease is developing. Patients must also visit healthcare centers regularly for monitoring, which can be difficult for older adults or those with movement difficulties. Another challenge is that most tests focus on only one type of data, such as medical images or patient history, without considering other factors like joint movement, body weight, or daily activity. This limited view makes it harder to understand the full condition of the knee and reduces the accuracy of treatment decisions.

Existing Research Approaches

Researchers have developed models that focus on only one type of data, such as X-rays[2][12], MRI scans[3], or biomarkers[4], to detect and assess KOA. While some efforts try to combine different data types, most studies still rely on a single input source. These models often require expensive tools, are tested in limited environments, and do not support continuous real-life monitoring, making them hard to apply in everyday care.

Proposed Research and Its Uniqueness

This research aims to develop a low-cost, easy-to-use, and real-time solution for predicting, monitoring, and managing KOA, especially in non-hospital or low-resource environments. The approach combines medical imaging, such as X-rays and MRIs, to assess joint damage, along with clinical and lifestyle details like age, weight, physical activity, and medical history to better understand risk factors. It also incorporates real-time movement data collected during daily activities, such as walking patterns and joint function. By combining these types of information, the system can provide a more complete and personalized view of the patient's knee condition. Continuous monitoring allows for regular updates on disease progression, enabling timely intervention and better long-term care. In addition, the use of explainable AI improves trust by making predictions and decisions more transparent for both healthcare providers and patients.

Impact on Healthcare Providers and Patients

This research offers significant benefits for both doctors and patients. For doctors, it provides a tool that helps accurately detect the presence and stage of Knee Osteoarthritis, monitor the patient's progress over time, and receive alerts if the disease worsens. This supports better decision-making and timely interventions. For patients, the system enables easy tracking of their condition, allowing them to see if their symptoms are improving or getting worse. The alert system also notifies patients when their disease severity changes, encouraging early action and better self-management.

References

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- [3] P. Panwar, S. Chaurasia, J. Gangrade, A. Bilandi, and D. Pruthviraja, "Optimizing knee osteoarthritis severity prediction on MRI images using deep stacking ensemble technique," *Scientific Reports*, vol. 14, no. 1, Art. no. 26835, Nov. 2024.
- [4] W. Chen, H. Zheng, B. Ye, T. Guo, Y. Xu, Z. Fu, X. Ji, X. Chai, S. Li, and Q. Deng, "Identification of biomarkers for knee osteoarthritis through clinical data and machine learning models," *Scientific Reports*, vol. 15, no. 1, Art. no. 1703, Jan. 2025.
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- [8] Pi, S.-W., Lee, B.-D., Lee, M. S., & Lee, H. J. (2023). Ensemble deep-learning networks for automated osteoarthritis grading in knee X-ray images. *Scientific Reports*, 13, 22887.
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- [11] S. Glyn-Jones et al., "Osteoarthritis," *The Lancet*, vol. 386, no. 9991, pp. 376–387, 2015.
- [12] S. S. Lee et al., "Explainable AI for knee osteoarthritis diagnosis using radiographs," *Computers in Biology and Medicine*, vol. 141, 105076, 2022.

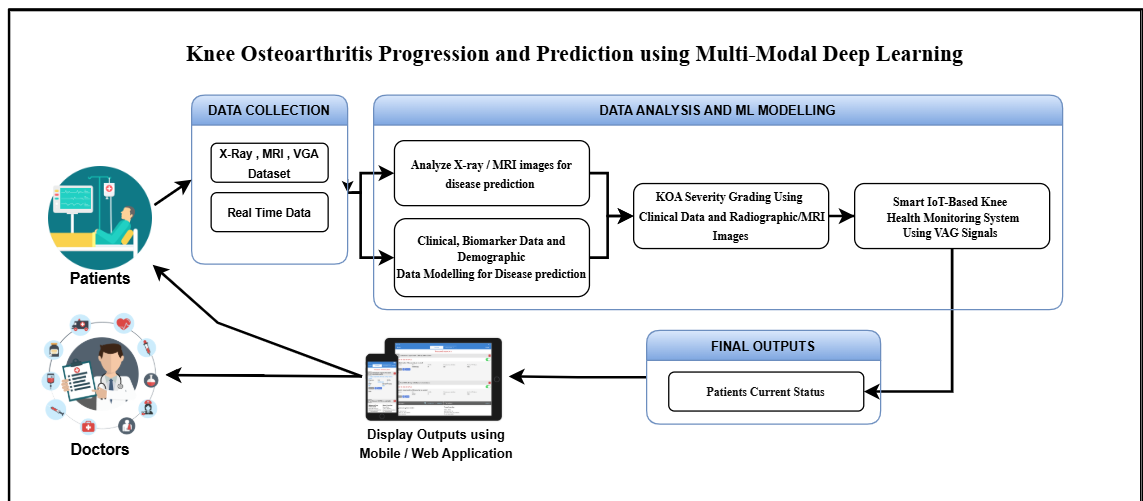
6. Brief description of the nature of the solution including a conceptual diagram.

The proposed solution is an end-to-end intelligent system for predicting and monitoring KOA progression through the integration of diverse data sources and advanced data-driven techniques. It begins with the collection of multi-modal data, including radiographic images (X-ray/MRI), clinical records, demographic information, and real-time knee joint signals. These datasets are analyzed using methods such as correlation, distribution, and time-series analysis to uncover patterns related to KOA severity and progression.

Following the analysis, the system processes the data to develop predictive insights regarding the current state and likely progression of KOA in individuals. By combining information from imaging and non-imaging sources, the system ensures a comprehensive understanding of the patient’s condition.

A central KOA prediction module consolidates these insights, supporting severity assessment and progression forecasting. The solution is further enhanced by a smart, wearable health monitoring system that captures real-time knee vibrations, enabling continuous, non-invasive observation and personalized tracking of the disease over time.

The final output is delivered through user-friendly application software, including mobile interfaces, allowing patients and healthcare providers to access predictions, track disease status, and support timely clinical decisions. The system emphasizes accuracy, reliability, and accessibility, making it effective for both clinical and remote monitoring environments.



7. Brief description of specialized domain expertise, knowledge, and data requirements

This project requires specialized expertise across several domains. Medical and clinical knowledge is essential to understand the pathology of Knee Osteoarthritis (KOA), its diagnosis, and grading systems such as the Kellgren–Lawrence (KL) scale[1]. Expertise in interpreting medical imaging, understanding joint biomechanics, and evaluating vibration-based joint sounds is critical. Medical professionals also play a key role in validating the datasets and ensuring clinical relevance throughout the development process.

In terms of technical knowledge, the project demands skills in medical image processing to work with X-ray and MRI data-this includes preprocessing, feature extraction, and region-of-interest detection. Machine learning knowledge is required to build predictive and severity classification models that can handle multi-modal data. Signal processing expertise is important for analyzing Vibroarthrography (VAG) signals captured from the knee during movement. Additionally, embedded systems and IoT expertise are needed to design a wearable sensing device capable of real-time data acquisition and wireless transmission. Mobile application development skills are also required to create a platform for visualization, alerts, and remote monitoring.

The project depends on multiple data sources. These include X-ray and MRI images labeled with KOA severity grades [2][3], structured clinical records relevant to KOA assessment, and labeled VAG signal data for detecting mechanical joint abnormalities [4]. To ensure reliability, all datasets must be reviewed or verified by medical professionals. The combination of these diverse, validated datasets supports the development of accurate, clinically applicable models and systems for real-time KOA prediction, grading, and monitoring.

References and Datasets

- [1] M. W. Brejnebøl, M. Skougaard, P. M. Boesen, M. T. Sørensen, and M. Hansen, “Kellgren-Lawrence grading of knee osteoarthritis using deep learning,” *Scientific Reports*, vol. 13, no. 1, p. 22887, Dec. 2023.
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- [5] A. Bahga and V. Madisetti, *Internet of Things: A Hands-On Approach*, 1st ed., VPT, 2014. A practical, project-driven introduction covering IoT architecture, hardware, software, and protocols.
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8. Objectives and Novelty

Main Objective:-

Design a multi-modal deep learning and IoT-based system for accurate prediction and monitoring of Knee Osteoarthritis progression.

Name/ RegNo	Sub Objective	Tasks	Novelty
Fernando W.D.A. IT22223708	Analyze X-ray / MRI images for disease prediction	The project aims to develop an automated image classification system that predicts the presence or absence of KOA using both X-ray and MRI images. To ensure clinical relevance and accuracy, the imaging data will first be reviewed and validated by medical experts. The system involves preprocessing the images to enhance quality and isolate the knee joint region, followed by leveraging deep learning techniques to automatically learn and extract relevant features indicative of KOA. Separate classification pipelines are created for X-rays and MRIs, allowing each to specialize in the unique information each modality provides-X-rays focusing on bone structure and joint space, and MRIs capturing soft tissue details like cartilage condition. To improve overall diagnostic accuracy, the system explores combining insights from both modalities. The models are trained and evaluated using clinical metrics such as sensitivity and specificity, ensuring robust performance that supports early KOA detection and can be integrated into broader disease monitoring solutions.	Dual-Modality Image Classification: Unlike typical models trained on X-rays alone, this system uses both X-ray and MRI imaging for more accurate KOA detection, leveraging the complementary nature of both modalities.

Name/ RegNo	Sub Objective	Tasks	Novelty
Jayasinghe J.M.N.S. IT22582942	Clinical, Biomarker Data and Demographics Data Modelling for Disease Prediction	<p>The task involves building a machine learning-based predictive model to determine whether an individual is likely to have KOA based on clinical, biomarker, and demographic data. The process begins with collecting and preprocessing structured data, ensuring consistency, handling missing values, and normalizing the inputs. Clinical records may include details related to medical history, symptoms, and functional limitations. Biomarker data reflects underlying physiological or biochemical conditions relevant to joint health, while demographic attributes capture population-based risk factors such as age, weight, or activity levels.</p> <p>Feature engineering is then performed to create meaningful inputs that capture complex relationships among the data types. Once prepared, these features are used to train a binary classification model that categorises patients as KOA-positive or KOA-negative. The model undergoes systematic evaluation using appropriate performance metrics to assess its reliability and ability to generalize to unseen data. To ensure transparency and trust in decision-making, feature importance analysis and interpretability tools are applied to understand how various factors contribute to the final prediction. This task supports the creation of a non-invasive, cost-effective diagnostic aid for KOA risk prediction, particularly useful in early detection and in environments with limited access to advanced imaging.</p>	<p>Multi-Source Predictive Modeling: Combining clinical records, biomarker values, and demographic information often studied in isolation into a single cohesive model for KOA disease prediction</p>

Name/ RegNo	Sub Objective	Tasks	Novelty
Perera B.B.A.R. IT22606792	KOA Severity Grading Using Clinical and X- Ray / MRI Images	<p>The task is to design and implement a multi-modal deep learning system to automatically grade the severity of KOA using both imaging data (X-ray and MRI) and structured clinical data. The system will classify KOA severity according to a recognized grading standard, such as the Kellgren-Lawrence (KL) scale ranging from Grade 0 to Grade 4. The process involves extracting meaningful features from X-ray and MRI images that reflect structural changes associated with KOA. These imaging features are then combined with structured clinical data to provide a more comprehensive representation of the patient's condition.</p> <p>The integrated data is used to train a classification system capable of predicting the correct severity level. The system will be evaluated using appropriate performance measures to ensure accuracy and consistency in grading. By utilizing both medical images and clinical records, this approach aims to enhance the precision of KOA severity assessment and support more effective, data-informed decision-making in clinical practice.</p>	<p>Multi-Modal KOA Grading Approach: Existing methods often rely on either image-based or clinical-based grading. Our system fuses both data types, offering a more comprehensive and accurate severity classification</p>

Name/ RegNo	Sub Objective	Tasks	Novelty
Gamage D.M.G.P.K. IT22188472	Smart IoT-Based Knee Health Monitoring System Using VAG Signals	<p>The task involves designing and developing a wearable device that uses Vibroarthrography (VAG) sensors to capture the subtle mechanical vibrations generated by the knee joint during various movements such as walking or bending. These vibrations carry important information about the joint's condition and can reveal abnormal sounds linked to Knee Osteoarthritis (KOA), like crepitus or grinding noises caused by cartilage degeneration or joint inflammation.</p> <p>The device is intended for continuous, real-time monitoring, allowing users to track their knee health during daily activities outside of clinical settings. The sensor data is transmitted wirelessly to a companion mobile application, which performs signal processing and analysis to detect irregularities that may indicate worsening KOA. The app not only provides timely alerts to users and healthcare providers but also tracks the progression of the disease over time by storing and visualizing historical data. This enables patients and clinicians to monitor changes in joint condition, assess the effectiveness of treatments, and make informed care decisions.</p> <p>This system aims to provide a non-invasive, convenient, and cost-effective solution for ongoing KOA monitoring, improving patient outcomes through timely feedback and reducing the need for frequent hospital visits.</p>	<p>This section uses a wearable IoT device with special sensors that listen to the vibrations of the knee joint during movement. It can continuously and automatically detect signs of knee problems like Osteoarthritis without needing hospital visits or expensive equipment. The device sends the data wirelessly to a mobile app that analyzes the information, alerts users if there are any issues, and tracks the progress of knee health over time. This real-time, portable, and easy-to-use system is especially useful for people who live far from clinics or in places with limited medical resources. It allows ongoing monitoring of knee health in everyday life, which is a big improvement over traditional methods that only check the knee during doctor visits.</p>

9. Individual component description of how it is complied with the specialization.

Member Name with Registration No	Description
Fernando W.D.A. IT22223708	<p>This component focuses on developing a deep learning-based image classification model to detect the presence of KOA using X-ray and MRI images. It directly aligns with the specialization of Machine Learning, as it involves the use of Convolutional Neural Networks (CNNs) for extracting meaningful features from medical images. The component includes advanced techniques in image preprocessing, data augmentation, and deep learning model training to accurately classify KOA conditions. It demonstrates the application to healthcare by automating disease detection from imaging data, thus enhancing diagnostic efficiency and enabling early intervention. This component also supports learning through hands-on work in medical image analysis, and contributes to Health Informatics by integrating AI into diagnostic workflows for musculoskeletal disorders.</p>
Jayasinghe J.M.N.S. IT22582942	<p>This component involves building a machine learning model that uses structured data-including clinical records, biomarker values, and demographic details-to predict the presence of KOA. It strongly aligns with the Data Science and Machine Learning specialization by applying supervised learning algorithms and Neural Networks to real-world healthcare data. Feature extraction, data preprocessing, and handling missing values are essential tasks in this component. The integration of clinical and biomarker data allows for a more personalized and accurate prediction model. This component highlights the role of AI beyond image analysis by focusing on structured health data and demonstrates how predictive analytics can support clinical decision-making. It also supports specialization in Health Data Analytics, providing students with experience in working with multi-dimensional datasets in medical research and practice</p>

<p>Perera B.B.A.R. IT22606792</p>	<p>This component aims to build a multi-modal deep learning system that classifies the severity of KOA using both radiographic/MRI images and structured clinical data. The grading is based on the widely used KLscale, which categorizes KOA from grade 0 (normal) to grade 4 (severe). This work directly aligns with the specialization of Deep Learning and Multi-Modal Fusion, as it requires combining tabular clinical data (such as age, BMI) with unstructured imaging data through a multi-input neural network. It supports Medical Decision Support Systems by providing a tool that assists clinicians in making more accurate and consistent KOA severity assessments. Furthermore, this component demonstrates skills in Software Engineering by integrating different data pipelines and model outputs into a single end-to-end system. It also contributes to the field of AI in Healthcare, delivering a personalized, data-driven severity grading model that enhances clinical decision-making and treatment planning.</p>
<p>Gamage D.M.G.P.K. IT22188472</p>	<p>This component involves the creation of an IoT-based wearable device designed to capture Vibroarthrographic (VAG) signals from the knee joint for real-time monitoring of Knee Osteoarthritis (KOA) during everyday physical activities. The device is built using low-cost sensors and microcontrollers to collect and transmit biomechanical data wirelessly. From a Data Science perspective, this component applies advanced signal processing and statistical feature extraction techniques to convert raw VAG signals into meaningful features such as RMS amplitude, spectral entropy, and peak frequency. These features are then used in lightweight machine learning models to classify the condition of the knee joint and monitor disease progression. The device communicates with a mobile application that provides real-time visual feedback, progress tracking, and alert notifications for both patients and healthcare providers. This solution not only showcases expertise in applying Data Science for health monitoring but also demonstrates innovation in IoT development by delivering a non-invasive, affordable, and scalable system-particularly beneficial in rural or low-resource settings where traditional diagnostic tools like MRI and X-ray are unavailable.</p>

10. Supervisor details.

	Title	First Name	Last Name	Signature
Supervisor	Ms.	Jenny	Krishara	<i>Jenny</i> 26/06/2025
Co-Supervisor	Ms.	Wishalya	Tissera	<i>[Signature]</i> 26/06/2025
External Supervisor	Dr.	Harsha	Perera	<i>[Signature]</i> 26/06/2025
Summary of external supervisor's (if any) experience and expertise				

Dr. S. A. Harsha Perera (MBBS)
SLMC Reg. No. 36295
Colombo North Teaching Hospital
Ragama.

Acceptable: Mark/Select as necessary

Topic Assessment Accepted	
Topic Assessment Accepted with minor changes*	
Topic Assessment to be Resubmitted with major changes*	
Topic Assessment Rejected. Topic must be changed	

* Detailed comments given below

Comments

Staff Member's Name	Signature

***Important:**

1. According to the comments given by the evaluator, make the necessary modifications and get the approval by the **Evaluator**.
2. If the project topic is rejected, identify a new topic, and request the RP Team for a new topic assessment.