PROJECT REVIEW - 1

Artificial Intelligence-Enabled Surveillance of Knee Osteoarthritis Through Gait Analysis

Project Category: Research

Guide:

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Problem Statement

AI-Powered Post-Operative Monitoring for Joint Replacement Using GAIT

Joint replacement surgeries, such as total knee arthroplasty (TKA) and total hip arthroplasty (THA), require extensive post-operative rehabilitation to ensure optimal recovery and long-term mobility. Current monitoring approaches rely on periodic in-clinic assessments, which may lead to delayed detection of complications such as abnormal gait patterns, reduced joint mobility, and improper weight distribution. This gap in continuous monitoring increases the risk of post-operative issues, affects patient recovery, and prolongs rehabilitation time.

This project aims to develop a GAIT based system for automated post-operative assessment of joint replacement patients. By leveraging computer vision, deep learning, and biomechanical modelling, the proposed system will analyse patients' movements through video input to detect abnormalities in joint function, gait mechanics, and rehabilitation progress. The system will generate automated reports with clinically relevant metrics, providing quantitative insights for healthcare providers to optimize patient recovery.

Objective

Develop an AI-Based Gait Analysis Model

Implement computer vision and deep learning algorithms to extract movement features from video data.

Detect Post-Surgical Abnormalities and Deviations

Identify gait deviations, improper joint mobility, weight distribution issues, and other complications.

Automate the Post-Operative Assessment Process

Generate detailed reports with key recovery metrics (e.g., stride length, knee flexion, hip rotation).

Literature Review

S. No	Author/Title	Methodology	Identification of gaps and limitations.
1	Yuguo Feng, Yu Liu , Yuan Fang, Jin Chang, Fei Deng, Jin Liu, Yan Xiong (Advances in the Application of Wearable Sensors for Gait Analysis Post-Total Knee Arthroplasty)	• Analyzed the use of wearable sensors, including accelerometers, gyroscopes, and magnetometers, for gait evaluation post-TKA. • Assessed patient-reported outcome measures (PROMs) alongside sensor-derived gait variables. • Evaluated recovery times ranging from 1 week to 5 years postoperatively.	• Noted a lack of standardized metrics and protocols for gait analysis using wearable sensors. • Emphasized the need for more longitudinal cohort studies to confirm the benefits of wearable technology in clinical practice.
2	Pragadesh Natarajan, R. Dineth Fonseka, Monish Movin Maharaj, Lianne Koinis & Ralph Jasper Mobbs (Continuous Data Capture of Gait and Mobility Metrics Using Wearable Devices Post-Orthopedic Surgery)	• Conducted a scoping review exploring the use of wearable devices for objective data capture in monitoring postoperative mobility. • Included studies utilizing various wearable technologies, such as accelerometers and gyroscopes, to collect continuous gait and mobility data. • Assessed the feasibility and effectiveness of remote monitoring in providing real-time feedback to patients and clinicians..	• Identified a lack of standardized metrics and protocols for data collection and analysis using wearable devices. • Noted variability in device types, placement, and data interpretation methods, presenting challenges in standardizing assessments. • Emphasized the need for validation studies to ensure data accuracy and reliability in diverse patient populations.

Literature Review

S. No	Author/Title	Methodology	Identification of gaps and limitations.
3	John Dundon, MD, Patrick M Aubin, William Hunter (Objective Gait Analysis Following Total Knee Arthroplasty with a Smart Implant)	• Presented a case study of a patient with a TKA implant fitted with an embedded inertial measurement unit (IMU). • Collected extensive gait data, including parameters such as step count, walking speed, and knee range of motion. • Utilized the data to inform early interventions, such as manipulation under anaesthesia, to address postoperative complications.	• The reliance on implantable devices may limit applicability due to cost and invasiveness. • Further research with larger sample sizes is necessary to validate the effectiveness of smart implants in gait monitoring.

Literature Review

S. No	Author/Title	Methodology	Identification of gaps and limitations.
4	Jun Fukui, Yasumoto Matsui, Takafumi Mizuno, Tsuyoshi Watanabe, Marie Takemura, Shinya Ishizuka, Shiro Imagama & Hidenori Arai (Comparison of gait analysis before and after unilateral total knee arthroplasty for knee osteoarthritis)	• Utilized wearable sensors to capture gait parameters preoperatively and at multiple postoperative intervals. • Assessed changes in gait patterns, including stride length, cadence, and joint kinematics, to evaluate recovery progress.	• Focused exclusively on unilateral TKA, limiting applicability to bilateral cases. • The follow-up period may be insufficient to assess long-term gait adaptations and functional outcomes. • Did not account for potential confounding factors such as variations in rehabilitation protocols or patient adherence.
5	Shayan Bahadori, Robert G. Middleton and Thomas W. Wainwright (Using Gait Analysis to Evaluate Hip Replacement Outcomes—Its Current Use, and Proposed Future Importance)	• Provided a comprehensive review of gait analysis techniques applied to total hip replacement (THR) outcomes. • Discussed various methods, including optical motion capture systems and wearable sensors, for assessing postoperative gait function. • Highlighted the advantages and challenges associated with different gait analysis technologies.	• emphasized the need for standardized protocols in gait analysis to ensure consistency and comparability across studies. • Acknowledged challenges such as variability in patient populations, measurement techniques, and data interpretation. • Called for more longitudinal studies to assess long-term outcomes and the impact of different surgical approaches on gait.

Limitations Identified from Literature Survey

- High computational complexity in existing KOA detection models makes real-time deployment challenging.
- Lack of robust temporal feature extraction techniques reduces the accuracy of gait analysis.
- Existing models struggle with generalization across diverse gait datasets, limiting adaptability.
- Dependency on large datasets increases the risk of overfitting, reducing the model’s reliability in real-world scenarios.

Research Objectives

- Enhance KOA detection accuracy using transfer learning with CNN-based feature extraction combined with LSTM for gait sequence analysis.
- Reduce computational demands with optimized deep learning architectures while maintaining high detection accuracy.
- Improve generalization by leveraging pre-trained models and incorporating biomechanical movement analysis.
- Develop an AI-driven gait assessment tool for early KOA detection, aiding healthcare professionals in timely diagnosis.

Justification of Project (SDG Alignment)

The project aligns with **Sustainable Development Goal 3: Good Health and Well-being**

- Enables early diagnosis and intervention for **Knee Osteoarthritis**, reducing long-term disability.
- Supports **remote and AI-assisted gait analysis**, making healthcare accessible, especially in rural areas.
- Enhances **precision in KOA severity detection**, aiding doctors in personalized treatment planning.
- Contributes to **rehabilitation monitoring**, helping patients track recovery post-surgery or therapy.