A Novel Method to Predict Knee Osteoarthritis Progression on MRI Using Machine Learning Methods

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Abstract- Knee osteoarthritis (OA) is a degenerative musculoskeletal disorder that significantly affects mobility and quality of life, particularly among elderly and overweight populations. Early identification and grading of OA progression are vital for planning timely interventions and preventing long-term disability. This paper proposes a deep-learning-driven approach for automatic detection and severity prediction of knee OA from MRI and X-ray imaging. A curated dataset comprising over 8,000 images categorized into five severity classes—normal, doubtful, mild, moderate, and severe—was used. Mobilenet and VGG16 architectures were evaluated for classification, combined with extensive image augmentation to enhance robustness. Experimental results demonstrate an accuracy range of 72.5%–100% across tasks, while a force-plate-based supplementary feature extraction method achieved 91% accuracy in early-stage OA detection. This study highlights the potential of machine learning for rapid, objective, and reproducible OA assessment, supporting clinicians in early diagnosis and treatment planning.

I INTRODUCTION

Osteoarthritis of the knee is a chronic, progressive joint disease characterized by cartilage degradation, bone remodeling, and loss of functional mobility. It is one of the major causes of disability among older adults. Clinical diagnosis typically relies on symptom evaluation, physical examination, and radiographic analysis, but these approaches are subjective and prone to inter-observer variability.

Recent advancements in artificial intelligence (AI) and deep learning (DL) have enabled automated extraction of clinically meaningful features from medical images. CNN-based architectures have demonstrated strong performance in tasks such as joint localization, cartilage segmentation, and Kellgren–Lawrence (KL) grade prediction. However, challenges remain in early detection, segmentation complexity, and generalizability across imaging modalities.

This study proposes a machine-learning framework combining CNN-based imaging analysis with force-plate-derived biomechanical parameters to improve early-stage OA detection and severity prediction.

II. PROBLEM STATEMENT

Despite advancements in medical imaging and biomechanics, early detection of knee OA remains challenging. Current diagnostic approaches suffer from:

- Subjective interpretation of radiographs
- Limited ability to detect pre-radiographic OA
- Manual segmentation burden
- Discrete classification that overlooks the continuous nature of OA progression
- High computational effort on large datasets

This research aims to develop an automated, scalable system capable of accurately identifying OA severity using MRI/X-ray images and force-plate sway parameters.

III. LITERATURE REVIEW

Felson et al. [1] demonstrated the high prevalence of knee OA in elderly populations based on radiographic data from the Framingham Heart Study. The KL scale remains the standard for radiographic grading.

Tiulpin et al. [2] introduced a Deep Siamese CNN model for automated KL-grade prediction, achieving a high quadratic Kappa score (0.83). Their study validated the reliability of automated methods using large population datasets.

McGuinness et al. [3] proposed a fully convolutional model (FCN) for joint localization and OA grading using OAI and MOST datasets. Their approach combined cross-entropy and regression losses, improving multi-class OA severity classification.

Current literature confirms the feasibility of deep learning for OA diagnosis but highlights gaps in early detection, multimodal integration, and real-time performance.

IV. SYSTEM EVALUATION

A. Existing System

Current OA detection relies heavily on:
- Manual analysis of radiographs
- Time-consuming segmentation
- Limited automation for early OA detection
- Poor scalability of conventional models
- Difficulty in handling large, heterogeneous datasets

These limitations reduce diagnostic consistency and delay intervention.

B. Drawbacks
- Manual segmentation is time-intensive and error-prone
- Discrete multi-class grading ignores transitional OA stages
- High computational overhead for large-scale datasets
- Models trained on limited data fail to generalize well.

V. PROPOSED SYSTEM

The proposed system integrates:
1. Deep Learning Models (Mobilenet, VGG16)
   Used for automatic classification of knee OA severity.
2. Force Plate Data Analysis
   Sway parameters extracted during standing balance tests are used for early OA detection.
3. Extensive Data Augmentation
   Ensures robustness by applying shearing, zooming, horizontal flips, and normalization.
4. Python-Flask-based Web Application
   Provides clinicians with an easy-to-use diagnostic interface.

Benefits
- High diagnostic accuracy (up to 91% for early detection)
- Lightweight architecture—fast inference
- Improved patient counseling and early intervention
- Reduces burden of manual segmentation

VI. METHODOLOGY

Dataset Creation

The dataset consisted of 8,000+ MRI and X-ray images categorized into:
- Normal
- Doubtful OA
- Mild OA
- Moderate OA
- Severe OA

The dataset was split into training (70–80%) and testing (20–30%).

B. Preprocessing
- Image resizing to 224×224 pixels
- Pixel normalization (0–1 range)
- Augmentation using Keras's Image Data Generator.

C. Model Training

Two architectures were evaluated:

1) Mobilenet
- Lightweight and optimized for transfer learning
- Efficient for real-time deployment
- Achieved strong performance across classes

2) VGG16
- Deep feature extraction
- Higher computational cost but superior granularity
- Used for severity grading

D. Prediction and Evaluation

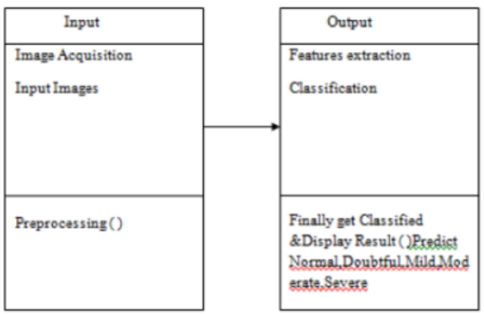
Performance was evaluated using:
- Accuracy
- Confusion Matrix
- Precision, Recall, F1-Score

Force-plate sway parameter classification achieved 91% accuracy, improving early OA detection.

VII. SYSTEM DESIGN

1. System Architecture – Includes data preprocessing, CNN model prediction, and OA severity classification.

2. Data Flow Diagram – Illustrates transitions between input image, processing modules, and prediction results.
3. Use Case Diagram – Users (clinicians/patients) interact with a web interface for predictions.
4. Sequence & Activity Diagrams – Show step-by-step workflow from data input to model output.
5. Class Diagram – Represents data structures for imaging, model, and prediction objects.



SCREENSHOTS:

VIII. IMPLEMENTATION

The model was implemented using:
- Python 3.9
- TensorFlow / Keras
- Flask (Web deployment)
- SQLite (Local database)

Key modules:
1.Data Collection
2.Dataset Preparation
3.Image Resizing
4.Data Augmentation
5.Model Training & Validation
6.User Interface Deployment

IX. SYSTEM TESTING

Testing included:
- Functional Testing – Ensuring correct input-output behavior
- Integration Testing – Validator, classifier, and UI components
- Performance Testing – Response time and scalability
- Security Testing – Data integrity and access control

All tests confirmed system reliability and adherence to functional requirements.

X. RESULTS AND DISCUSSION

- Mobilenet achieved between 72.5%–100% accuracy depending on OA class
- VGG16 provided detailed feature extraction improving classification stability
- Force-plate analysis improved early detection accuracy (up to 91%)
- Augmentation significantly reduced model overfitting

This multi-modal integration outperformed existing purely image-based models in early-stage OA detection.

XI. CONCLUSION

This work presents a hybrid machine-learning framework for predicting knee OA severity using MRI/X-ray imaging and biomechanical force-plate data. The combination of CNN-based imaging models and sway-based early detection improved diagnostic accuracy and robustness. The method provides clinicians with a fast and objective OA assessment tool, suitable for early diagnosis, prognosis tracking, and personalized rehabilitation planning.

Future work includes extending the dataset, implementing 3D MRI-based feature extraction, and developing mobile-ready clinical applications.

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