PROJECT REVIEW - 3

Artificial Intelligence-Enabled Surveillance of Knee Osteoarthritis Through Gait Analysis

Project Category: Research

Guide:

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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 reports with key recovery metrics

DATASET OVERVIEW

- The KOA-NM dataset is designed for Knee Osteoarthritis (KOA) detection using gait analysis.
- It contains video recordings of individuals categorized based on KOA severity levels.
- A set of 6 red-colored passive reflective markers has been attached to the subject's body joints.
- The dataset is collected using a single NIKON DSLR 5300 camera placed 8m away from the walking mat.
- Videos are in .MOV format
- KOA-NM Dataset consists of gait videos classified into four categories:
  - NM (Normal Movement)
  - KOA_EL (Easy KOA)
  - KOA_MD (Moderate KOA)
  - KOA_SV (Severe KOA)

PRE PROCESSING

1. Video Format Conversion
   - Converted .MOV files to .MP4 for compatibility.
2. Frame Extraction
   - Extracted frames from videos at a uniform **FPS (Frames Per Second)**.
3. Noise Reduction & Enhancement
   - Applied Gaussian Blur and contrast enhancement for better feature extraction.
4. Pose Estimation
   - Used **Mediapipe** to extract joint movement key-points.
5. Key-Points Detection
   - Identify the maker placed in joints of subject and store.
6. Data Augmentation
   - Introduced rotation, flipping, and brightness variations to improve model generalization.

PRE PROCESSING

1. Challenges:
   - Unreadable .MOV files
   - Inconsistent FPS
   - Blurred frames
   - Missing joint key-points
2. Solutions:
   1. Converted to .MP4
   2. Standardized to fixed FPS
   3. Applied sharpening & noise reduction
   4. Improved pose estimation accuracy

FEATURE EXTRACTION

Input Data:

MOV format videos of patients walking **from left to right (side view)** across an **8-meter distance** in front of a fixed camera.

Pose Estimation with MediaPipe:

Extracts key body landmarks per frame:(x, y, z, visibility) for each joint.

Emphasis on lower-body joints (hip, knee, ankle) to assess post-knee replacement recovery.

FEATURE EXTRACTION

Preprocessing Steps:

Convert video to frames (e.g., 30 fps).Normalize and resize frames for uniformity.

Side view improves joint movement visibility during gait cycle.

Data Structuring:

Landmark data arranged as time series sequences:

Format: (frames, joints, features)

Example: 300 frames × 33 joints × 4 features

Padding/truncation applied for fixed sequence length.

Model Architecture

Architecture

1. Feature Extraction (CNNs) – Extracts spatial features from each frame.
2. LSTM Layer – Captures temporal dependencies in gait patterns.
3. Fully Connected Layer – Classifies severity levels of KOA.

LSTM for KOA Detection

- **Handles sequential gait data** effectively.
- **Remembers long-term dependencies** in walking patterns.
- **Outperforms traditional CNNs** in analysing movement over time.
- **Improves KOA severity classification** by learning time-series variations in gait

Model Training

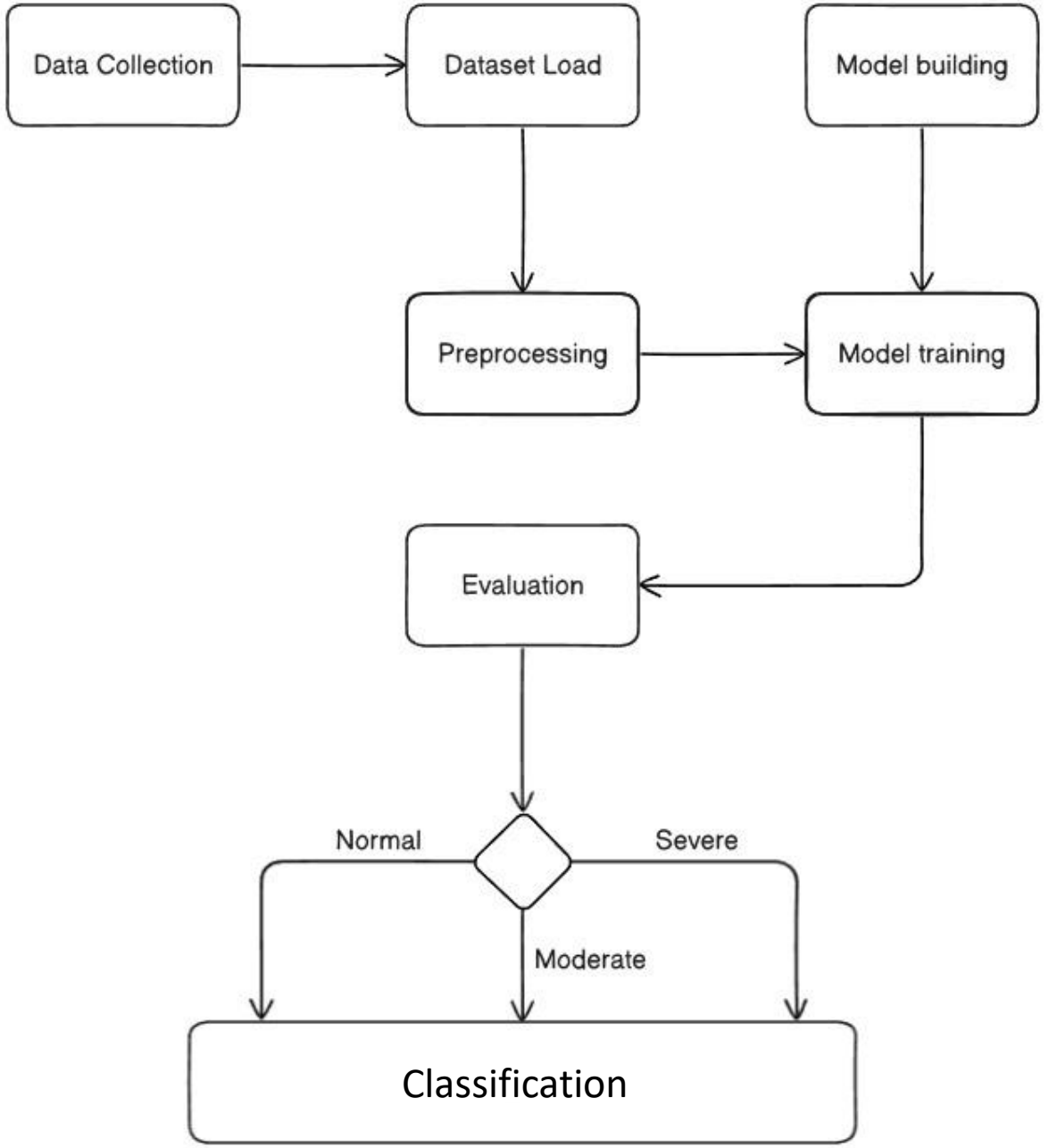
Model Training & Validation

- **Dataset:** KOA-NM (Train, Validation, Test splits).
- **Loss Function:** Categorical Cross-Entropy.
- **Optimizer:** Adam for efficient learning.
- **Performance Metrics:** Accuracy, Precision, Recall, F1-score.

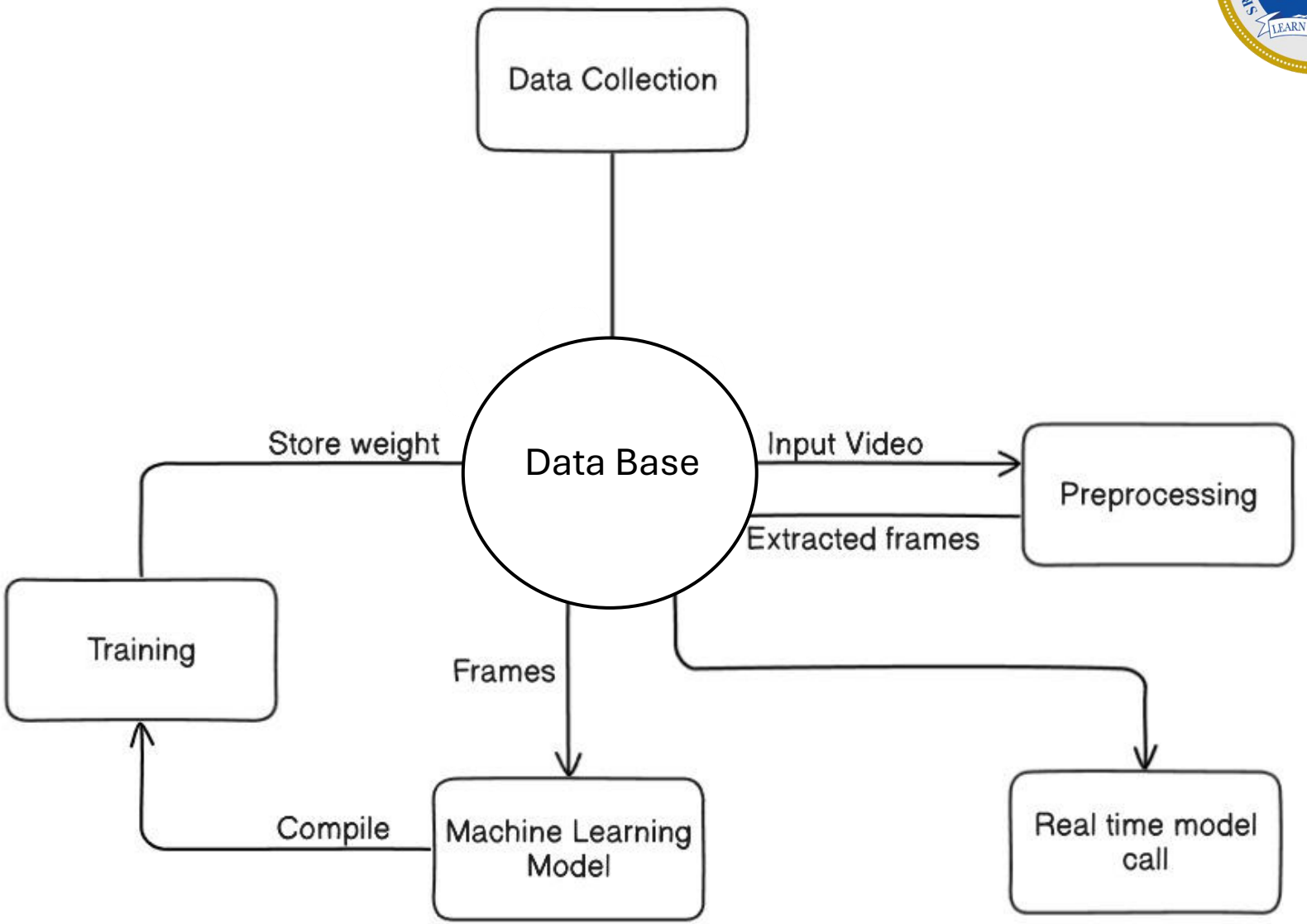
Expected Outcomes

- Early detection of KOA severity levels.
- Automated gait analysis for doctors.
- Improved patient diagnosis & treatment planning.

Architecture Diagram



Data Flow Diagram



Functional Test Cases

Test Case	Description	Initial Result	Modifications & Fixes	Final Result
TC1: Dataset Preprocessing	Verify if the KOA-NM dataset is correctly loaded, structured, and split into train, validation, and test sets.	Failed (Some .MOV files were unreadable)	Converted .MOV files to .mp4, handled missing/corrupt files	Passed
TC2: Frame Extraction	Check if video files are correctly converted into frames for analysis.	Failed (Skipped frames, inconsistent FPS)	Adjusted frame extraction logic to maintain uniform FPS	Passed
TC3: Feature Extraction from Frames	Verify if extracted frames contain relevant joint movement information.	Failed (Blurred frames, missing keypoints)	Enhanced preprocessing with noise reduction and keypoint refinement	Passed
TC4: Pose Estimation	Check if OpenPose/Mediapipe can extract gait features from video input.	Passed	N/A	Passed
TC5: Model Training	Ensure the CNN-LSTM model successfully trains on the KOA dataset and achieves a minimum of 85% accuracy.	Failed (Accuracy was 78%)	Tuned hyperparameters, increased training epochs, and added data augmentation	Failed (OverFitting)
TC6: KOA Classification	Verify if the trained model correctly classifies gait into KOA severity levels.	N/A	N/A	N/A
TC7: Real-Time Prediction	Check if the model can process and classify a new gait video within 30 seconds.	N/A	N/A	N/A
TC8: Report Generation	Validate if the system generates an automated PDF report with severity level, gait heatmaps, and treatment suggestions.	N/A	N/A	N/A

IMPACT AND FUTURE WORK:

1) This analysis can serve as a diagnostic tool for healthcare professionals to monitor recovery progress in knee arthroplasty patients.

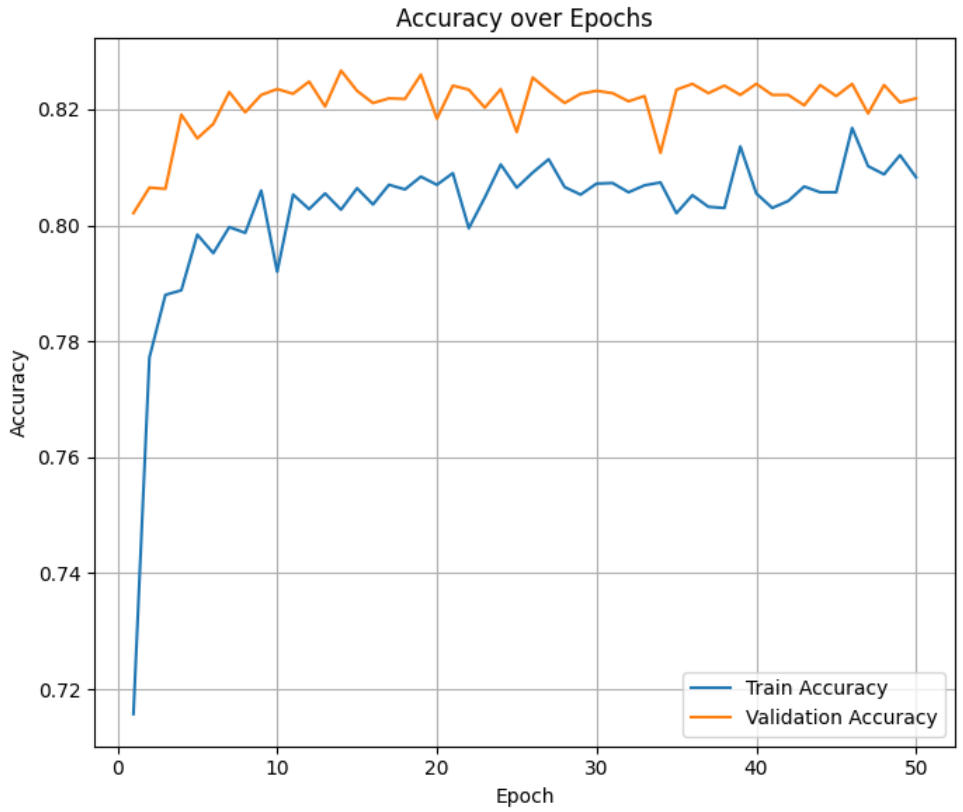
2) Future improvements could include adding more diverse datasets, refining the model, or integrating real-time monitoring for clinical applications.

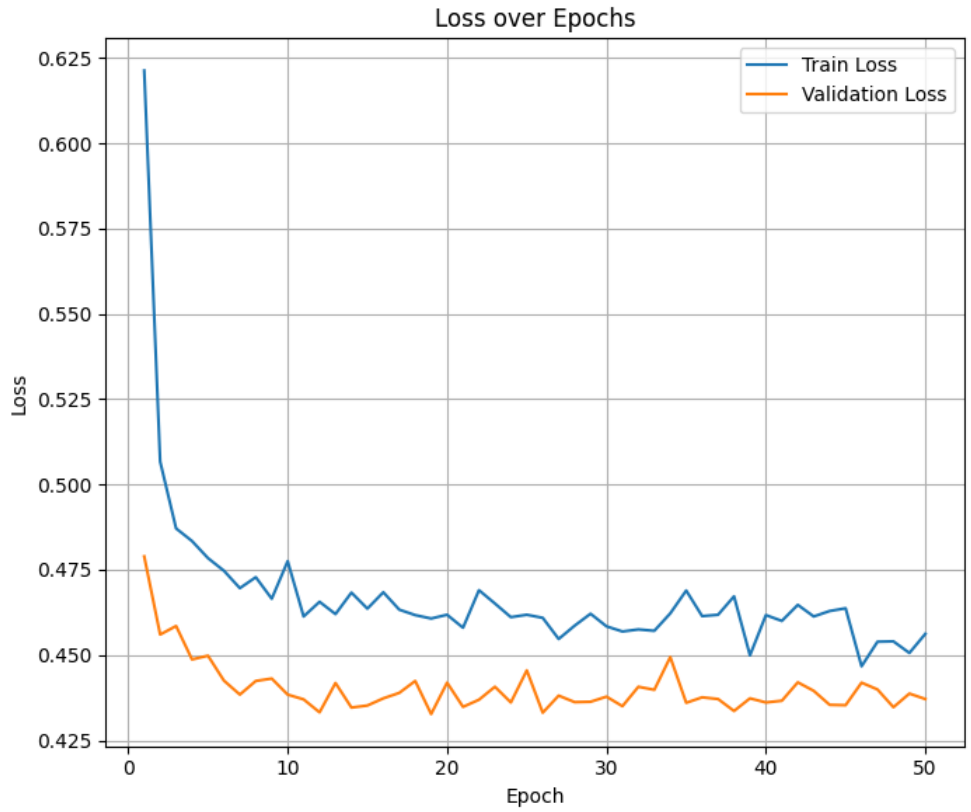
Final Thought:
The integration of AI and machine learning into healthcare can provide valuable insights into patient recovery and help in optimizing rehabilitation strategies.

RESULT

Class	Precision	Recall	F1-Score	Support
NM (Normal)	0.74	0.43	0.54	3389
KOA	0.84	0.95	0.89	4244
Accuracy			0.82	5633
Macro Avg	0.79	0.69	0.72	5633
Weighted Avg	0.81	0.82	0.80	5633

GRAPHS


Accuracy over Epochs
Accuracy
Epoch
Train Accuracy
Validation Accuracy
0.72
0.74
0.76
0.78
0.80
0.82
0
10
20
30
40
50


Loss over Epochs
Loss
Epoch
Train Loss
Validation Loss
0.425
0.450
0.475
0.500
0.525
0.550
0.575
0.600
0.625
0
10
20
30
40
50

CONCLUSION

Objective Recap:

The project aimed to analyze knee arthroplasty recovery using video-based gait analysis through an LSTM model, focusing on different recovery stages: Normal, Early, Mid, and Severe.

Key Findings:

- The model successfully classified gait patterns into the four predefined stages.
- Significant progress was observed in the model's ability to detect nuances in gait changes over time.
- The use of LSTM helped in capturing the temporal dependencies in movement, leading to more accurate predictions.