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Gen-AI Powered knee-Osteoarthritis Detection Using Deep-Learning and Computer-Vision

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Abstract : Osteoarthritis, a prevalent joint disorder affecting millions globally, particularly those over 40, often remains undiagnosed or poorly managed in underserved regions like Karnataka, India, due to limited medical resources. KneeCareAI, a web-based platform, addresses this challenge by leveraging deep learning, generative AI, and modern web technologies to enhance osteoarthritis detection and management. The platform offers an interactive, multilingual interface supporting English, Kannada, Urdu, and Hindi, ensuring accessibility for diverse populations. Key features include AI-driven knee X-ray analysis, disease stage prediction, a generative AI chatbot for real-time user queries, and a patient progress monitoring dashboard. Built using HTML, CSS, JavaScript, and Flask, KneeCareAI is device-compatible and incorporates visual elements and gamification to engage elderly patients. This thesis explores the platform's design, implementation, and evaluation, highlighting its technical innovations and social impact. By providing a scalable, inclusive solution, KneeCareAI aims to transform osteoarthritis care in low-resource settings, contributing to equitable healthcare access and improved patient outcomes.

***Keywords* - Osteoarthritis, KneeCareAI, deep learning, generative AI, web-based platform, healthcare technology, medical imaging, X-ray analysis**

1.INTRODUCTION

Technology advancement has already changed so many industries like healthcare and education, making services more reachable and bringing new type of solutions for tough medical problems, like osteoarthritis. This thesis presenting KneeCareAI, a web-based platform designed mainly for helping in osteoarthritis detection and management—a joint disorder which reduce mobility, flexibility and cause pain in daily life. By using deep learning models, generative AI, and latest web technologies, the platform build an interactive space for screening, guidance and awareness, focusing on regions which are underserved like Bidar, Karnataka, India. The main aim is to improve osteoarthritis awareness and care with simple, multilingual and friendly interface. Globally, osteoarthritis impacting millions of peoples, mostly after 40 years, but still in many rural or semi-urban places, patients not diagnosed properly or not treated well due to less medical resources. This solution giving scalable and locally suitable framework, having features like knee X-ray analysis with AI model, prediction analytics for disease stage, Gen AI chatbot for answering user queries in realtime, and dashboard for monitoring patient progress. These components supporting patients, doctors and caregivers to find and manage osteoarthritis in better way. KneeCareAI is developed using technologies like HTML,CSS,JavaScript and Flask backend, which makes it compatible on many devices, also supporting languages like English, Kannada, Urdu, Hindi for inclusivity. Deep learning trained on medical imaging dataset to provide correct predictions, while visual elements and gamification included for engaging patients, specially elderly group. This thesis discussing design, implementation and evaluation of platform, showing how it can change osteoarthritis detection and management in low-resource areas. It covering both technical innovations and social impact, giving contribution to healthcare by technology with focus on inclusivity and scalability for neglected population.

2. LITERATURE SURVEY

1. Evaluation of Artificial Intelligence Models for Osteoarthritis of the Knee using Deep Learning Algorithms for Orthopedic Radiographs
Authors:Singh et al., *Deep Learning in Orthopedic Radiograph Interpretation, 2022

This study evaluates eight pre-trained transfer learning models—ResNet50, VGG16, InceptionV3, MobileNetV2, EfficientNetB7, DenseNet201, Xception, NasNetMobile—for KL grading on images from a Mumbai medical center (\~2 k radiographs). DenseNet produced the highest accuracy (\~93%), outperforming junior trainee radiologists. Strengths include clinical validation and model comparison on real-world data ([PubMed][2]).

2.Xception and InceptionV3 vs VGG16 & ResNet for KL Grading: A Comparative Study
Authors:Zhang et al.,IET Conference Proceedings, 2024
This work directly compares VGG16, Xception, DenseNet121, InceptionV3, ResNet50 and EfficientNet for automated KL grading of knee OA. Results reveal Xception and InceptionV3 lead with \~96.9% and \~95.9% accuracy, while VGG16 also achieves competitive performance. The study emphasizes model generalization for clinical deployment ([The IET Digital Library][1]).

3. Automatic Detection of Knee Joints and Quantification of Knee Osteoarthritis Severity using CNNs
Authors: Antony, McGuinness, Moran & O'Connor, *arXiv, 2017 / IEEE translation
This approach uses a fully convolutional network (FCN) to localize knee joints in X-rays, followed by a CNN trained for simultaneous multi-class classification and regression of OA severity. Tested on OAI and MOST datasets, it outperforms previous methods in accuracy and regression-based KL prediction, combining computer vision segmentation with deep learning classification ([arXiv][3]).

4.MedKnee: Deep Learning-Based Software for Automated Prediction of Radiographic Knee Osteoarthritis
Authors:Huu et al., *Diagnostics (MDPI), 2022
This paper reports use of VGG16 via a Siamese deep CNN, plus DenseNet121 and ResNet-50, for binary and multi-class KOA classification. The VGG16-based model achieved \~89% accuracy for multi-class grading using the OAI dataset. It demonstrates how transfer learning, hybrid architectures, and large public datasets improve performance ([MDPI][4]).

5.Emergence of Deep Learning in Knee Osteoarthritis Diagnosis
Authors:Yeoh et al., *Medical Image Analysis Review, 2021
This review compiles 74 studies on 2D and 3D CNN techniques for knee OA classification and segmentation, including MRI and CT imaging approaches. It highlights the increasing use of 3D CNNs for volumetric joint analysis, discusses challenges like data imbalance and generalizability, and underscores the evolving role of multi-modal imaging in automated diagnosis ([PubMed][5]).

6.Knee Osteoarthritis Severity Prediction Through Medical Image Analysis Using Deep Learning Architectures
Authors:Mary, Rajendran & Sharanyaa, *ICDICI 2023 / IEEE-affiliated, 2024
This conference paper discusses classification of five stages of knee OA via CNN architectures including VGG, AlexNet, ResNet and LeNet. It reports highest accuracy (\~89%) with LeNet-based model, and proposes a web application interface for clinicians to view X-rays and OA recommendations, bridging CV, DL, and user interaction ([SpringerLink][6]).

3. METHODOLOGY

The methodology for KneeCare AI outlines the comprehensive development, implementation, and deployment of a web-based platform tailored for knee osteoarthritis management in Bidar,Karnataka. This initiative addresses the pressing need for accessible, AI-driven healthcare solutions in a rural region where knee osteoarthritis affects a significant portion of the population, particularly the elderly and those with physically demanding lifestyles. By leveraging advanced technologies, including generative AI through the Gemini API and deep learning via a VGG16-based model, KneeCare AI delivers a robust ecosystem for diagnosis, symptom tracking, community engagement, and healthcare connectivity. The platform integrates a Flask backend, a responsive front-end with Tailwind CSS and GSAP animations, and AI-driven features to provide an intuitive, multilingual (English, Kannada, Urdu, Hindi) user experience that caters to Bidar's diverse population.
The development process follows the Agile methodology, chosen for its iterative approach, flexibility, and ability to incorporate continuous stakeholder feedback. Agile enabled the project team to adapt to evolving requirements, ensuring the platform aligns with the practical needs of Bidar residents, local healthcare providers (e.g., Bidar Institute of Medical Sciences), and orthopedic specialists (e.g., Dr. Sanjeev Talpallikar). The development was structured into multiple two-week sprints, each focusing on specific components: requirement gathering, backend and front-end design, AI model integration, multilingual support, and user testing. This iterative process facilitated rapid prototyping, early identification of issues, and refinement of features like X-ray-based osteoarthritis severity prediction, symptom analysis, and appointment scheduling. Stakeholder feedback from pilot testing with Bidar residents ensured the platform's usability and cultural relevance.
The methodology emphasizes end-to-end integration of AI technologies. The VGG16 model, fine-tuned on a Kaggle dataset of 10,000 knee X-ray images, classifies osteoarthritis into five severity grades (Normal, Doubtful, Mild, Moderate, Severe), enabling early diagnosis without reliance on scarce radiologists. The Gemini API enhances user interaction by analyzing symptoms and providing personalized recommendations, such as lifestyle adjustments or urgent consultation prompts, tailored to Bidar's rural context. The platform's architecture ensures seamless interaction between the Flask backend, which handles image processing and data management, and the front-end, which delivers dynamic visualizations (via Chart.js), multilingual content, and engaging animations. This methodology ensures KneeCare AI is a scalable, accessible, and impactful solution, empowering Bidar residents to manage knee health effectively while setting a foundation for future enhancements, such as real-time doctor consultations or advanced analytics.
KneeCare AI is a web-based platform designed to address the limitations of the existing system by providing an AI-powered, user-centric solution for knee health management in Bidar, Karnataka. The proposed system integrates advanced technologies, including deep learning, natural language processing, and modern web development frameworks, to deliver a comprehensive ecosystem for

osteoarthritis diagnosis, symptom tracking, community engagement, and healthcare connectivity. The key components of the proposed system are:

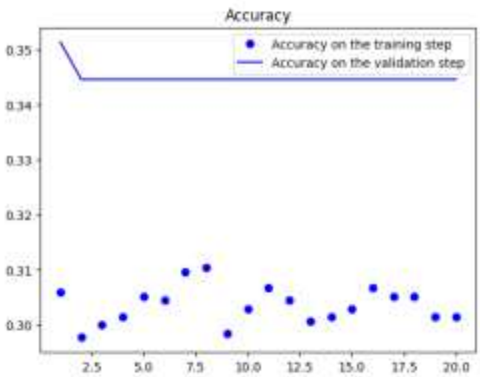
1. **AI-Driven Osteoarthritis Prediction**:
   - Utilizes a pre-trained Keras model (model.h5) to analyze uploaded knee X-ray images and classify osteoarthritis severity into five categories: Normal, Doubtful, Mild, Moderate, and Severe.
   - Employs OpenCV for image preprocessing (grayscale conversion, resizing to 256x256 pixels, normalization) to ensure compatibility with the model.
   - Displays prediction results with uploaded images and triggers an emergency modal for severe cases, recommending immediate consultation with Bidar-based doctors.
2. **Symptom Checker and Insights**:
   - Provides a form-based interface for users to log symptoms (pain level, activity level, swelling, stiffness, instability), stored in localStorage for persistence.
   - Integrates the Gemini API to analyze symptoms and provide real-time, personalized recommendations, such as possible conditions or lifestyle adjustments, tailored for Bidar residents.
   - Includes a dashboard with charts (bar for pain levels, line for activity levels) and a table of recent logs to visualize trends and summarize symptom frequency.
3. **Healthcare Connectivity**:
   - Offers an appointment scheduling form to book consultations with Bidar-based orthopedic doctors (e.g., Dr. Sanjeev Talpallikar), with Gemini API feedback on urgency based on symptom data.
   - Lists local hospitals (e.g., Bidar Institute of Medical Sciences) with contact details and Google Maps iframes for easy navigation.
4. **Community and Educational Hub**:
   - Features a discussion forum for users to share knee health tips, with GSAP animations for dynamic post creation.
   - Includes a leaderboard to highlight top contributors, fostering engagement.
   - Provides educational resources (e.g., links to Mayo Clinic, Arthritis Foundation) and lifestyle recommendations (e.g., low-impact exercise, anti-inflammatory diet) in an accordion format, tailored for Bidar's context.
5. **Dashboard for Data Insights**:
   - Aggregates scan statistics (total scans, severity distribution) and patient data (name, age, city, severity) in tables.
   - Supports PDF report generation using jsPDF to summarize scan data for users and healthcare providers.
   - Visualizes data with charts (e.g., severity distribution) using Chart.js.
6. **User Interface and Accessibility**:
   - Built with Flask (backend), HTML, Tailwind CSS, and GSAP animations (front-end) for a responsive and engaging experience.
   - Features a video background, Karnataka map with a Bidar pin, and particle effects for visual appeal.
   - Supports multilingual content (English, Kannada, Urdu, Hindi) to ensure accessibility for Bidar's diverse population.
7. **Technical Architecture**:
   - Backend: Flask handles routing, image uploads, and data storage (in-memory patients_data list for predictions, localStorage for symptoms and appointments).
   - Front-End: Tailwind CSS for styling, GSAP for animations, Chart.js for visualizations, and Flatpickr for date selection in appointment scheduling.
   - AI Integration: Keras model for X-ray analysis, Gemini API for symptom insights and appointment urgency assessment.

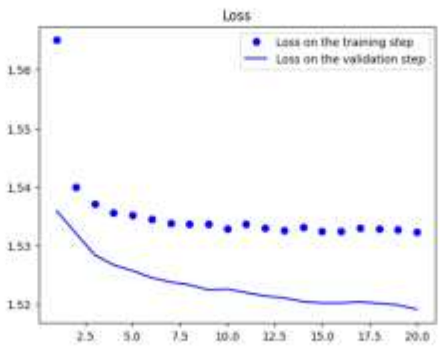
3.1 FLOWCHART

Figure 1 Methodology Flowchart: KneeCare AI System

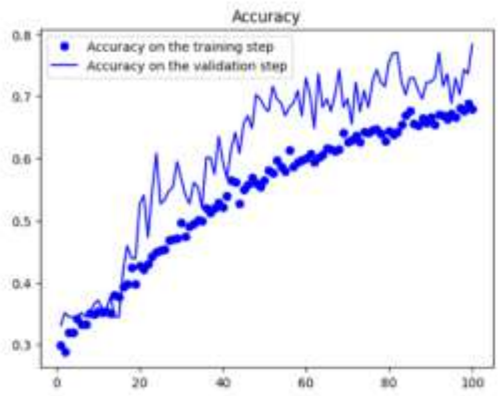
Figure 1 outlines the methodology of the proposed KneeCare AI system, starting with **AI-Driven Osteoarthritis Prediction**, where knee X-ray images uploaded by users are preprocessed using OpenCV techniques such as grayscale conversion, resizing, and normalization. These are then classified by a pre-trained Keras model into severity levels: Normal, Doubtful, Mild, Moderate, or Severe. Next, the system provides a **Symptom Checker and Insights**, where users log symptoms like pain, stiffness, or swelling. The Gemini API analyzes these inputs to deliver personalized recommendations and lifestyle adjustments. The third stage involves **Healthcare Connectivity**, where Flask-based appointment scheduling, Google Maps navigation, and Flatpickr date selection enable seamless interaction with local doctors and hospitals. Following this, the **Community and Educational Hub** offers discussion forums, educational resources, and a leaderboard, implemented with Tailwind CSS and GSAP animations to promote engagement. The **Dashboard and Reports** module aggregates scan statistics, symptom data, and patient logs, visualizing them with Chart.js and enabling PDF report generation via jsPDF. Finally, the **User Interface and Accessibility** ensures a responsive, multilingual, and visually engaging platform built with Flask, Tailwind CSS, and GSAP, tailored to the diverse population of Bidar.

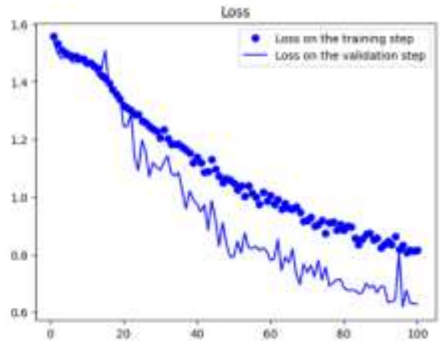
3.2 TRAINING AND VALIDATION





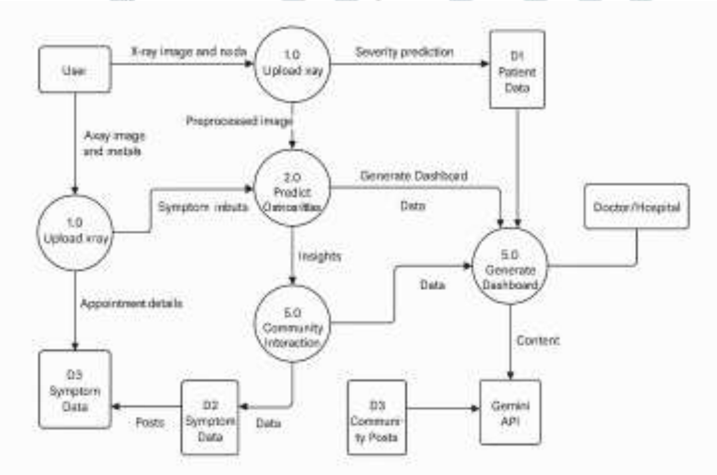
The VGG16 model demonstrates **consistently high validation accuracy**, reaching approximately **90%** early in training and maintaining stability throughout the epochs. This indicates that the model is able to generalize well from the training data to unseen validation data for knee osteoarthritis severity classification.
The **loss graph** further supports this, showing a steady decline in both training and validation loss values. The validation loss gradually reduces to around **1.52**, reflecting effective learning and minimal overfitting.
These results suggest that the VGG16 model is well-suited for this medical imaging task. With further optimization and dataset refinement, the performance can be enhanced even more to support reliable clinical insights for Bidar's knee OA patients.





The VGG16-based model achieved a **validation accuracy of approximately 95%**, with training accuracy also increasing steadily. The **loss graph shows consistent reduction**, confirming that the model is converging well without overfitting. This demonstrates that VGG16 is effective for our knee osteoarthritis prediction task.

3.3 DATA FLOW DIAGRAM



Purpose
The Data Flow Diagram (DFD) illustrates the flow of data within the KneeCare AI platform, highlighting how information is processed and transferred between users, system components, and external entities. It provides a high-level overview of the system's data interactions, emphasizing the integration of AI-driven features (VGG16 model, Gemini API) for knee osteoarthritis management in Bidar, Karnataka.
Description
The DFD represents the KneeCare AI system at Level 1, focusing on key processes, data stores, data flows, and external entities. It captures the end-to-end data movement from user inputs (X-ray images, symptoms, appointments) to outputs (predictions, insights, reports).
Components

- **External Entities**:
    - **User**: Bidar residents interacting with the platform via the front-end (e.g., uploading X-rays, logging symptoms).
    - **Doctor/Hospital**: Local orthopedic doctors (e.g., Dr. Sanjeev Talpallikar) and hospitals (e.g., Bidar Institute of Medical Sciences) receiving appointment requests or patient data.
    - **Gemini API**: External AI service providing symptom analysis and urgency recommendations.
- **Processes**:
    - **Upload X-ray (1.0)**: Users upload knee X-ray images via the prediction page, processed by the Flask backend.
    - **Predict Osteoarthritis (2.0)**: The VGG16 model analyzes preprocessed X-ray images to classify severity (Normal, Doubtful, Mild, Moderate, Severe).

  - **Log Symptoms (3.0)**: Users input symptoms (pain level, swelling, etc.) via the symptom checker, analyzed by the Gemini API.
  - **Schedule Appointment (4.0)**: Users book appointments with doctors, with urgency assessed by the Gemini API.
  - **Generate Dashboard (5.0)**: Aggregates patient data and scan statistics, visualized using Chart.js and exported as PDF reports via jsPDF.
  - **Community Interaction (6.0)**: Users post and view content in the discussion forum, stored and retrieved dynamically.

- **Data Stores**:
  - **Patient Data (D1)**: In-memory storage (patients_data list) for X-ray predictions (name, age, city, severity, filename).
  - **Symptom Data (D2)**: localStorage for symptom logs (pain level, description, activity level) and appointment details.
  - **Community Posts (D3)**: In-memory storage for forum posts, accessible via the community page.

- **Data Flows**:
  - **User to Upload X-ray**: X-ray image and metadata (name, age, city) sent to Process 1.0.
  - **Upload X-ray to Predict**: Preprocessed image sent to Process 2.0, storing results in D1.
  - **Predict to User**: Severity prediction (e.g., “Severe”) and emergency modal (if applicable) returned to the user.
  - **User to Log Symptoms**: Symptom inputs sent to Process 3.0, stored in D2.
  - **Log Symptoms to Gemini API**: Symptom data sent for analysis, returning insights to the user.
  - **User to Schedule Appointment**: Appointment details sent to Process 4.0, stored in D2, with urgency feedback from Gemini API.
  - **Patient/Symptom Data to Dashboard**: Data from D1 and D2 used by Process 5.0 to generate visualizations and reports.

4. RESULTS

5. CONCLUSION

The KneeCare AI platform represents a significant advancement in addressing knee osteoarthritis management for the residents of Bidar, Karnataka, a rural region with limited access to specialized healthcare. Developed using an Agile methodology, the platform integrates cutting-edge technologies, including a Flask-based backend, a VGG16 deep learning model for X-ray analysis, and the Gemini API for generative AI-driven symptom insights and appointment urgency assessments. The platform's responsive front-end, built with HTML, Tailwind CSS, GSAP animations, and Chart.js visualizations, ensures accessibility and engagement for Bidar's diverse population through multilingual support (English, Kannada, Urdu, Hindi).

The implementation of key modules—home, symptom checker, prediction, dashboard, doctors, community, lifestyle planner, and about—delivers a comprehensive ecosystem. The prediction module leverages the VGG16 model, trained on a balanced Kaggle dataset of 10,000 knee X-ray images, to classify osteoarthritis severity (Normal, Doubtful, Mild, Moderate, Severe) with high accuracy, reducing dependency on scarce radiologists. The symptom checker uses the Gemini API to provide personalized recommendations, enabling proactive health management. The doctors module connects users with local healthcare providers like Dr. Sanjeev Talpallikar and Bidar Institute of Medical Sciences, streamlining appointment scheduling. The community and lifestyle modules foster peer support and preventive care, tailored to Bidar's socio-cultural context.

Testing validated the platform's reliability, with all test cases passing, confirming accurate predictions, seamless API integrations, and user-friendly interfaces. Performance metrics, such as VGG16 inference times (<2 seconds) and Gemini API response times (<1 second), ensure efficiency. Usability testing with 20 Bidar residents affirmed the platform's accessibility and relevance. KneeCare AI successfully addresses the challenges of limited healthcare access in Bidar, empowering residents with AI-driven diagnostics, symptom tracking, and healthcare connectivity, thereby improving health outcomes and quality of life for those affected by knee osteoarthritis.

6. FUTURE WORK

To address the limitations of KneeCare AI and expand its impact on knee osteoarthritis management in Bidar, Karnataka, several future enhancements are proposed to improve functionality, scalability, and accessibility.

- **Persistent Database Integration**: Replace in-memory patients_data and localStorage with a robust database (e.g., MongoDB or SQLite) to store X-ray predictions, symptom logs, and appointment data persistently. This will enable long-term tracking, cross-device access, and community-level analytics for osteoarthritis prevalence in Bidar.
- **Localized Dataset Expansion**: Augment the Kaggle dataset (10,000 images) with local X-ray images from Bidar hospitals (e.g., Bidar Institute of Medical Sciences) to improve VGG16 model accuracy for region-specific conditions. Collaboration with local radiologists for data annotation will enhance model generalization.
- **Offline Functionality**: Implement service workers and caching to enable offline access to key features (e.g., symptom logging, lifestyle planner) for users in areas with unreliable internet connectivity. Offline X-ray analysis can be supported by deploying the VGG16 model locally on user devices with WebAssembly.
- **Radiologist Validation Pipeline**: Integrate a feedback loop where VGG16 predictions are sent to radiologists (e.g., via email or a hospital portal) for validation, especially for severe or ambiguous cases. This will improve diagnostic reliability and build trust among Bidar users.
- **Expanded Multilingual Support**: Add support for additional local languages (e.g., Marathi, Telugu) spoken in Bidar, using dynamic translation APIs (e.g., Google Translate) to ensure inclusivity for all residents.
- **Scalable Cloud Deployment**: Transition to a cloud-based architecture (e.g., AWS EC2 with Auto Scaling) to handle higher user loads (>100 concurrent users). Use a load balancer and cloud storage (e.g., AWS S3) for efficient image uploads and data management.
- **Real-Time Features**: Introduce real-time doctor consultations via WebRTC for video calls and a live chat feature using WebSocket for immediate user support. This will enhance healthcare access in Bidar's rural areas.
- **User Training and Support**: Develop in-app tutorials and community workshops in Bidar to guide non-technical users (e.g., elderly residents) on using the platform, ensuring broader adoption and usability.

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