SOFTWARE REQUIREMENTS SPECIFICATION

for

Spine X-Ray-Based Osteoporosis Detection Using Deep Learning Techniques

Under the supervision of

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1. Introduction

1.1 Purpose

The purpose of this document is to provide a detailed specification for the development of an automated osteoporosis diagnostic system that predicts osteoporosis from grayscale images of human spine X-rays. The system uses the VGG16 Convolutional Neural Network (CNN) for feature extraction and a Feedforward Neural Network (FNN) for classification.

1.2 Intended Audience and Reading Suggestions

The developers, data scientists, and healthcare professionals involved in building, deploying, and using the Osteoporosis Detection System, as well as medical researchers and stakeholders seeking insights into its technical framework. Readers are advised to have a basic understanding of machine learning, neural networks, and medical imaging systems to fully grasp the content.

1.3 Project Scope

This project develops an automated osteoporosis detection system using deep learning analysis of X-ray images, offering a more accessible alternative to costly DEXA and QCT scans. By leveraging advanced deep learning models (VGG16 and FNN), the system aims to achieve high diagnostic accuracy for early detection. A user-friendly interface will allow healthcare professionals to easily upload X-rays and receive diagnostic results, improving patient care and reducing healthcare costs.

1.4 References

- Bone Health Prediction using Machine Learning Approach :

  https://ieeexplore.ieee.org/document/10010985

- Comprehensive Analysis of Bone Health Predictive Modeling : Integrating Logistic

  Regression for Precise Outcome Evaluation :

  https://ieeexplore.ieee.org/document/10677598

- Machine learning-based prediction of osteoporosis in postmenopausal women with clinical examined features : A quantitative clinical study:

  https://onlinelibrary.wiley.com/doi/10.1002/hsr2.1656

- About the Datasets :

For this project, no precise datasets are available. To obtain the necessary information, data must be merged from several sources.

https://www.kaggle.com/code/satyaprakashshukl/rsna-lumbar-spine-analysis/input?select=test_images

https://www.kaggle.com/competitions/rsna-2022-cervical-spine-fracture-detection/data?select=test.csv

2. Overall Description

2.1 Project Perspective

The system leverages deep learning techniques to process and analyze medical images, offering a promising alternative to expensive and invasive diagnostic tools. The system will be implemented as a software application capable of being integrated with medical imaging software.

2.2 Project Functions

1. Preprocess spine X-ray images
2. Extract features using VGG16 CNN
3. Classify the features using FNN
4. Output the prediction result for osteoporosis detection
5. Visualize prediction results for user interpretation

2.3 User Classes and Characteristics

1. **Doctors and Healthcare Professionals:** Primary users who will use the system for diagnosis.
2. **Patients:** Indirect users, as the system aims to enhance their diagnostic care.
3. **Researchers:** Users involved in improving and adapting the model.
4. **System Administrators**: Technical staff responsible for system maintenance, updates, and troubleshooting. They need reliable performance, scalability, and ease of updates.

2.4 Operating Environment

- **Local Development Environments:** Local development environments such as PyCharm, GoogleCollabs, Visual Studio Code for Python development, Jupyter Notebook for data analysis and model testing.
- **Operating System:** Windows or Linux, MacOS.

2.5 Design And Implementation Constraints

- **Data Availability and Quality:** The performance of the deep learning model heavily relies on the availability of a large, diverse, and high-quality dataset of X-ray images with confirmed osteoporosis diagnoses. Limited data or inconsistent image quality can hinder the model's ability to generalize and achieve high accuracy.
- **Computational Resources:** Training and deploying deep learning models (e.g., VGG16, FNN) require high-performance GPUs and sufficient memory, which may limit deployment on standard hardware.
- **Scalability:** The application must handle multiple simultaneous users and large datasets efficiently, necessitating careful consideration of backend architecture and cloud resources.

2.6 User Documentation

The user documentation will provide step-by-step guidance for installing, navigating, and using the application, including workflows for uploading data, interpreting results, and managing user access. It will also cover troubleshooting.

2.7 Assumptions And Dependencies

- Availability of high-quality spine X-ray images.
- Users will provide X-ray images in the required format.
- The system assumes sufficient computational resources are available for model training and deployment.

3. External Interface Requirements

3.1 User Interface

- A user-friendly web interface for medical professionals to upload X-rays.
- Viewing diagnostic results and visualizations.

3.2 Hardware Interface

Compatibility with modern diagnostic imaging hardware for data import/export.

3.3 Software Interfaces

- Integration with TensorFlow, Keras libraries.
- Compatibility with standard image formats.

3.4 Communication Interfaces

Internet connectivity for accessing cloud-based computational resources if necessary.

4. System Features

4.1 Data Ingestion

Accept and validate spine X-ray images uploaded by users.

4.2 Data Preprocessing

- Normalize and resize images for input to the VGG16 model.
- Apply filters to enhance image quality and remove noise.

4.3 Historical Data Analysis

Analyze previously stored data to identify trends, validate model performance, and provide insights.

4.4 Prediction Result and Visualisation

- Display diagnostic results with confidence scores.
- Provide visualizations, such as heatmaps, to highlight regions of interest.

5. Non-functional Requirements

5.1 Performance Requirements

- Ensure prediction results are available within 5 seconds of input.
- Achieve a minimum prediction accuracy of 90%.

5.2 Safety Requirements

- Ensure the system does not produce misleading or harmful outputs.
- Provide warnings for uncertain predictions.

5.3 Security Requirements

Protect patient data through encryption and secure access controls.

5.4 Software Quality Attributes

The system will ensure reliability uptime and minimal interruptions, while offering a user-friendly interface for non-technical users. It will also be designed for scalability, efficiently handling increasing data volume and a growing user base.

5.5 Business Rules

- Restrict access to sensitive data based on user roles.
- Ensure that updates and maintenance do not disrupt active user sessions.
- The system must not store or share patient data without explicit user consent.