IARJSET ISSN (O) 2393-8021, ISSN (P) 2394-1588

International Advanced Research Journal in Science, Engineering and Technology

Impact Factor 8.066 ⁜ Peer-reviewed & Refereed journal ⁜ Vol. 12, Issue 5, May 2025

DOI: 10.17148/IARJSET.2025.125221

Lumbar Spine Disease Detection

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Abstract: Detection of lumbar diseases using deep learning is the first step toward the application of artificial intelligence technology in medical diagnostics. This project provides the INVGG-based diagnostic system for spinal health problems. Its primary aim is to develop an infrastructure that is fully self-sufficient, inexpensive, and efficiently classifies lumbar conditions such as herniated discs and spinal stenosis. The model is augmented with features such as normalization preprocessing, learning enhancement augmentation, and visual understanding explanation via Grad-CAM with minimal human monitoring. The use of deep learning allows the remote diagnosis and monitoring of spinal disorders. The system includes a web interface for immediate prediction of diseases, displaying heatmaps for diagnostics which helps radiologists and medical practitioners to provide timely, accurate, and efficient diagnoses. This system allows uploading images, displaying results alongside generated reports thus increasing operational efficiency. This spinal diagnostic system presents an adaptive solution to strengthen the spine healthcare system while improving the initiatives for clinical and research endeavors focused on lumbar diseases.

I. INTRODUCTION

The goal of the INVGG-based lumbar disease detection project is to build an autonomous and efficient intelligent system that automatically diagnoses spinal disorders from MRI images. It aims at implementing deep learning methods for real-time analysis of medical images deeply that would identify lumbar spine diseases to aid remote diagnosis and monitoring through web-enabled systems while explainable AI would optimize clinical workflows vis-a-vis the output visuals. This system provides an alternative to traditional diagnostics that require more time and are difficult to access. It provides early detection and precise identification of spine diseases which helps improve long-term healthcare manual intervention. The model is expected to be flexible and wide-ranging for various medical imaging datasets.

II. PROBLEM STATEMENT AND OBJECTIVE

Problem statement:
It has been observed that lumbar spine disorders such as Herniated discs, spinal stenosis, and degeneration are becoming more common, increasingly threatening mobility, quality of life, and long-term wellbeing. Conventional methods rely on the manual interpretation of MRI images through the lens of a radiologist. This process is slow, prone to inaccurate results, and is not scalable in resource-strapped environments. These methods lack real-time processing, dependability, and uniformity which delays prompt treatment and large population screening efforts. The problem becomes an engineering challenge of devising an intelligent, automated, scalable, and dependable lumbar disease detection system that goes beyond identifying spinal deformities to interpreting results relevant for clinical decision-making. But, with such a problem arises numerous others, offering an accurate, no--explanation-needed, economic solution requiring little to no guidance, and able to change medical settings with different images, diagnostics, and adaptability to varying needs.

Objective:
The aim of the INVGG-based lumbar disease detection system is to build an autonomous, intelligent framework that efficiently and accurately classifies lumbar spine disorders from MRI images while greatly reducing human involvement and aiding in the advancement of medical diagnostic systems. As spinal disea

III. RELATED WORK

The literature review encompasses several machine learning and deep learning techniques developed for detecting and diagnosing lumbar diseases from medical images, particularly MRI scans. The main aim of such systems is to automate the diagnostic workflow and help radiologists in attention to disc problems, herniation, degeneration, and spinal stenosis. Many researchers have used various classifiers and also some deep learning approaches like Convolutional Neural

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Networks (CNN), Support Vector Machines (SVM), and Decision Trees to classify the provided datasets of annotated spinal images. Most of the projects include some preprocessing like contrast enhancement, noise reduction, and ROI (Region of Interest) extraction. Various feature extraction methods are employed, ranging from manual skilled tasks like histogram analysis to automatic intelligent deep learning layers. Many implementations also use TensorFlow, Keras, or PyTorch for model building and training. In the interest of improving the reliability of the results, other authors include k-fold cross-validation, and various other works performed accuracy, precision, recall, and F1-score evaluations.
While the results seem encouraging, other factors such as limited or income.

IV. SYSTEM DESIGN

The system design of the Lumbar Disease Detection project incorporates surgical engineering of both software modules and computational logic which function in tandem to fully mechanize the recognition and classification of abnormalities within the lumbar spine region with medical imaging, specifically employing MRI scans. The principal framework is structured to guarantee precision, expandability, and high throughput accuracy, and is organized into modules with distinct preprocessing, model training, and prediction phases.

The system starts with the data collection step in which lumbar spine MRI images are sourced from online clinical datasets. The images undergo a preprocessing pipeline consisting of grayscale conversion, contrast enhancement, normalization, and noise reduction to standardize the input data. Contour delineation algorithms may be applied during this stage in order to extract the region of interest which normally includes the intervertebral discs or vertebrae which assist the model in focusing on pertinent anatomical parts.

Feature extraction is performed by the model of CNN (Convolutional Neural Network) which collects spatial hierarchies of features from the MRI scans. Some systems may incorporate hand-crafted features like those derived from textures, shapes, or edges into deep features to enhance more.

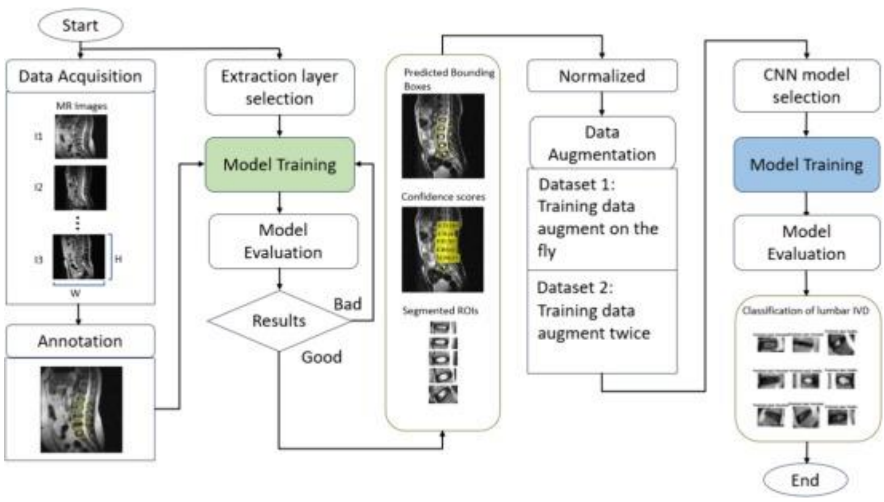

Figure 1: System Architecture

V. METHODOLOGY

The proposed system for lumbar disease detection combines machine learning, medical imaging, and data processing to achieve high accuracy in identifying the abnormalities in the lumbar spine. The methodology contains the following key components:

Data Acquisition and Preprocessing
MRIs of the lumbar spine are acquired from publicly available datasets or clinical databases. These images go through several preprocessing steps like conversion to grayscale, reduction to set dimensions, noise elimination, and contrast improve to make them clearer. Region of Interest (ROI) selection is performed on intervertebral discs and vertebrae which are critical for the diagnosis.

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Feature Extraction and Model Architecture

The images are processed and passed through Feature Extraction Layers which utilize CNNs to capture spatial features. Some layers recognize features as disc patterns, deformation of discs and irregularity in spacing. Additional algorithms may also be incorporated whereby optional manual features such as texture or edge detection are utilized with the aim of enhancing performance. Depending on the complexity and size of the dataset, the model architecture is flexible and can include VGG16, ResNet, other custom CNNs.

Classification System

The classification layer receives the features that have been extracted and processes them in order to find and identify the following lumbar ailments: disc herniation, spinal stenosis

VI. IMPLEMENTATION

The design of the Lumbar Disease Detection System combines software and algorithms in chronic stepwise fashion, merging and intertwining medical image processing with intelligent classification. The system commences with the gathering and preprocessing of lumbar spine MRI images which are obtained from freely available medical imaging datasets or from hospital archives. These images form the basic input needed for training and evaluation, capturing the system's purpose.

Firstly, the raw MRI scans undergo a series of preprocessing operations intended to improve the quality of the dataset. Included are image resizing, grayscale conversion, dataset normalization, noise reduction, and histogram equalization. These steps are intended to improve feature delineation within images along with enhance the model's learning efficacy. Moreover, ROI (Region of Interest) contouring is performed to isolate vertebral discs or specific regions within the lumbar spine to enhance focus during analysis.

The system's backbone is built on deep learning frameworks such as TensorFlow or PyTorch and follows a CNN-based architecture. The neural network is trained on images to recognize specific patterns associated with spinal abnormalities such as herniated discs, spinal stenosis, and degenerative disc disease. Layers of the CNN model will be responsible for the automatic spatial feature extraction of the MRI images.

VII. FUTURE ENHANCEMENTS

The efficiency and clinical usefulness of the lumbar disease detection system can be improved by adding one or more defined features. More accurate analyses can be performed after implementing advanced computer vision techniques such as vertebrae and disc segmentation. The system can also be enhanced to multi-disease and multi-severity classification which aids the physicians in detecting and evaluating stages of many diseases like herniated discs and spinal stenosis.

The addition of automated report creation features derived from natural language processing (NLP) will lower the manual effort required to produce readable summaries of diagnostics. Data retrieval and clinic workflow can be enhanced through integration with Electronic Health Records (EHR) systems. Making the system compatible with 3D MRI scans, multi-view processing, and mobile or web-based platforms will enhance remote diagnostic flexibility. Self-directed model updates with new patient data will ensure continuous refinement and real-world adaptability. The system will become more intelligent, scalable, and suited for routine clinical practice.

VIII. CONCLUSION

The implementation of modern technology in the medical field is epitomized by the astonishing features of The Lumbar Disease Detection System. Using machine learning and medical imaging, the system identifies and classifies lumbar spine disorders automatically while providing a manual decrease, thereby enhancing the efficiency of the diagnostic process.

The system offers prompt and accurate results while in providing auxiliary support to healthcare professionals for devising early interventions alongside treatment pathways. Although the system currently faces limitations in multi-disease detection, degree of severity grading, and clinical real-time application, it is still promising and provides guidance for future work further in development. This system, equipped with AI, automation, integrated data, and advanced intelligent medical diagnostic frameworks, can evolve to become a robust, adaptable solution for intelligent diagnostics in medicine.

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