



# International Journal of Innovative Research in Science Engineering and Technology (IJIRSET)

*(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)*



**Impact Factor: 8.699**

**Volume 14, Issue 12, December 2025**

# **Bone Fracture Detection and Depth Estimation using Deep Learning**

**Prof. Dr. Naveen Kumar K R<sup>1</sup>, Shreya V C<sup>2</sup>, Shreya V S<sup>2</sup>, Diksha Chikaraddi<sup>2</sup>, Prakruthi D Koppad<sup>2</sup>**

Associate Professor, Department of Artificial Intelligence & Machine Learning, Bapuji Institute of Engineering & Technology, Davanagere, Karnataka, India<sup>1</sup>

Students, Department of Artificial Intelligence & Machine Learning, Bapuji Institute of Engineering & Technology, Davanagere, Karnataka, India<sup>2</sup>

**ABSTRACT:** Bone fractures are among the most frequently encountered orthopedic injuries and require timely, accurate diagnosis to avoid long-term complications. Conventional radiographic interpretation, however, is limited by subjectivity, inter-observer variability, and the lack of depth information in 2D X-ray images. This study presents an AI-driven framework that integrates deep learning-based segmentation with computational depth estimation to enhance fracture assessment using only standard radiographs. A U-Net model with a ResNet-50 encoder performs pixel-level localization of fracture regions, while a dedicated depth-estimation head predicts fracture severity by analyzing structural and intensity-based cues. Preprocessing techniques—including CLAHE, normalization, and denoising—maximize feature clarity prior to model inference. Evaluation using metrics such as Dice Score, IoU, accuracy, precision, and RMSE demonstrates strong performance in segmentation and depth estimation. The system represents a scalable, efficient, and clinically useful alternative to traditional X-ray interpretation, offering enhanced diagnostic support in resource-limited environments.

**KEYWORDS:** Fracture detection, Depth estimation, U-Net, ResNet-50, Medical imaging, Segmentation, Deep learning, X-ray analysis.

## **I. INTRODUCTION**

Bone fractures pose major diagnostic challenges, especially when subtle, overlapping, or partially visible in standard radiographs. Complex anatomical regions—such as the elbow—feature multiple articulations and overlapping structures, making fracture lines difficult to detect with high reliability. Conventional X-ray interpretation depends on clinician experience, which may lead to inconsistent diagnoses, delayed treatment, or the need for additional imaging such as CT scans, increasing cost and radiation exposure.

With advances in artificial intelligence, deep learning models now outperform traditional computer-aided techniques in medical image interpretation. U-Net architectures have become the gold standard for medical segmentation due to their ability to capture both local and global contextual features. However, while many AI models detect fractures, very few attempt to infer the depth of the fracture—an essential parameter for determining severity, intra-articular involvement, and treatment planning.

This project addresses the existing gap by developing an automated deep learning system capable of both fracture detection and depth estimation from a single 2D X-ray image, thereby improving clinical decision-making and reducing reliance on higher-cost imaging modalities.

## **II. LITERATURE SURVEY**

Deep learning-based fracture analysis has expanded significantly in recent years. Foundational CNN models provided early breakthroughs in medical image detection and segmentation. Later architectures such as U-Net, ResNet, and attention-based models demonstrated enhanced performance in bone structure recognition, joint space analysis, and abnormality detection.

Prior studies have shown:

- U-Net-based segmentation effectively isolates fracture regions in X-ray and CT images.
- ResNet encoders improve feature extraction, enabling deeper contextual understanding.
- Hybrid models combining CNNs and transformers achieve high accuracy in orthopedic imaging tasks.
- Explainability frameworks such as Grad-CAM highlight fracture-specific features, aiding clinical trust.

However, the majority of literature focuses exclusively on segmentation or classification, without estimating fracture depth. Since X-rays lack inherent depth information, few models address this clinically essential dimension. Existing research demonstrates the feasibility of depth inference in CT imaging, but translating that capability to 2D radiographs remains unexplored.

This project fills this gap by integrating segmentation with depth regression within a unified model, enabling richer diagnostic insights without introducing new imaging requirements.

### **III. PROBLEM STATEMENT**

Traditional radiographic evaluation provides limited information for assessing the severity of a fracture due to the flat, 2D nature of X-ray images. Clinicians lack automated tools that simultaneously detect fractures and estimate depth using deep learning. Existing systems do not efficiently combine pixel-level localization with depth inference, restricting their effectiveness in clinical workflows. Hence, there is a need for a unified AI-based framework capable of detecting fractures and estimating depth from standard 2D X-rays.

### **IV. OBJECTIVES**

- To develop a robust preprocessing pipeline for enhancing bone visibility through CLAHE and noise reduction.
- To design a U-Net segmentation model integrated with a ResNet-50 encoder for accurate pixel-wise fracture localization.
- To implement a depth-estimation head capable of predicting fracture severity using feature-driven regression.
- To evaluate the integrated model using clinically relevant metrics and validate its performance against ground-truth labels.
- To generate clinically interpretable outputs, including segmentation masks, depth estimates, and visual explainability maps.

### **V. PROPOSED SOLUTION**

The proposed solution presents a multi-stage deep learning framework for automated bone fracture detection and depth estimation from X-ray images. Initially, image preprocessing is performed using Contrast Limited Adaptive Histogram Equalization (CLAHE) to enhance bone contrast, followed by Gaussian filtering for noise reduction. All images are resized and normalized to maintain uniform input dimensions. For fracture localization, a U-Net segmentation architecture integrated with a ResNet-50 encoder is employed. The encoder extracts multi-scale feature representations, while the decoder generates a binary fracture mask. Depth estimation is carried out using a regression-based module that utilizes high-level encoder features in conjunction with the segmented fracture regions. This module predicts an approximate fracture depth (in millimeters) and categorizes severity into shallow, moderate, or deep classes. An explainability engine based on Gradient-weighted Class Activation Mapping (Grad-CAM) is incorporated to visualize the regions influencing model predictions. Finally, the system generates clinically interpretable outputs, including the original X-ray image, the predicted fracture mask, and the estimated fracture depth along with its severity classification.



## VI. SYSTEM DESIGN

### 1. SYSTEM ARCHITECTURE:

A text-based representation of the architecture diagram is provided below:

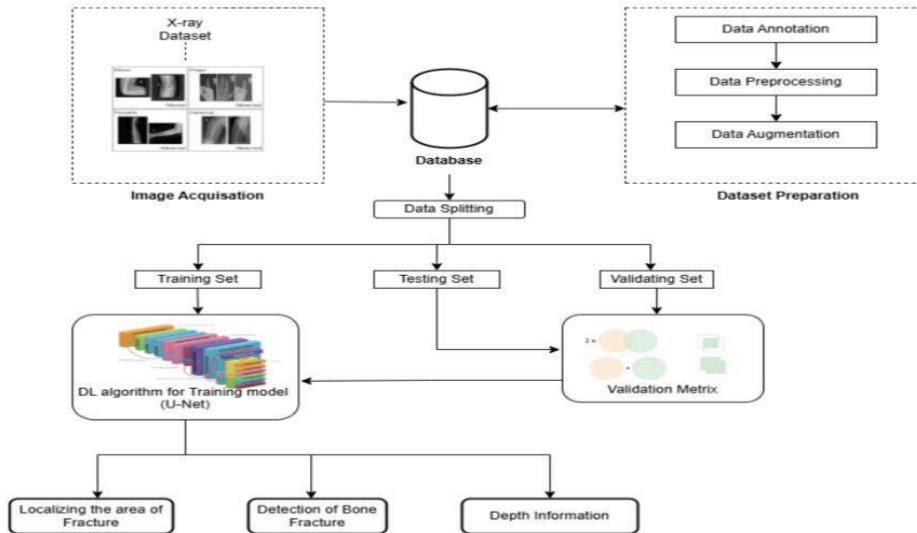


Figure1: System Architecture Diagram

## VII. RESULTS

### 1. Snapshots Of The Proposed System:

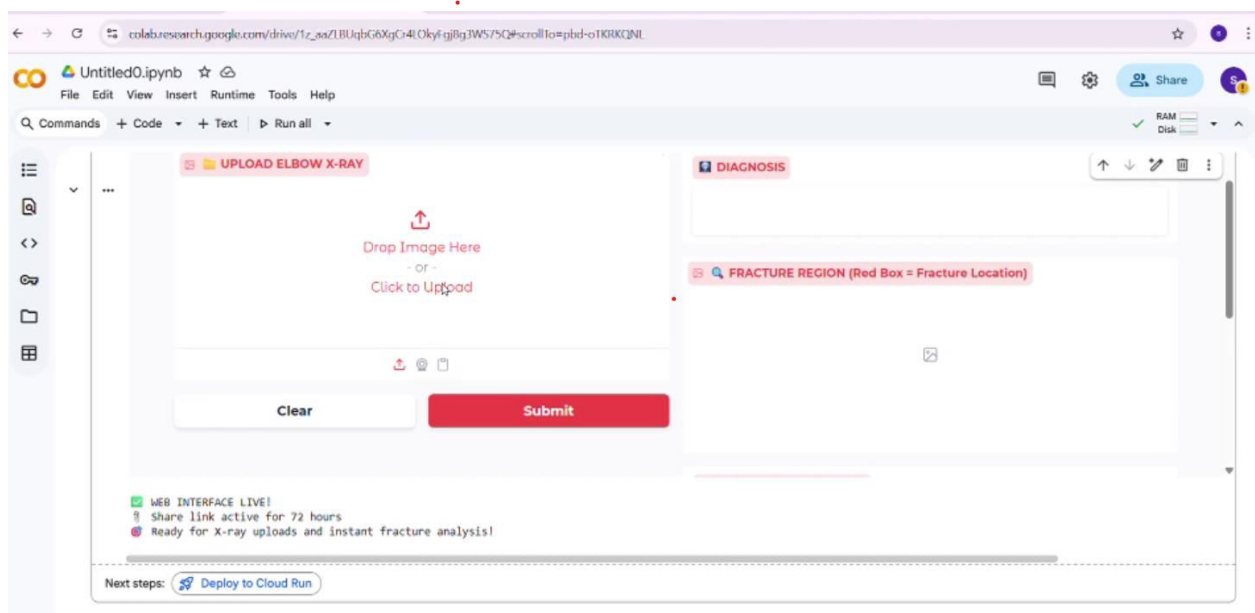


Figure2: Web-based interface for elbow X-ray upload



Figure3:Fracture localization and depth estimation output with highlighted fracture region

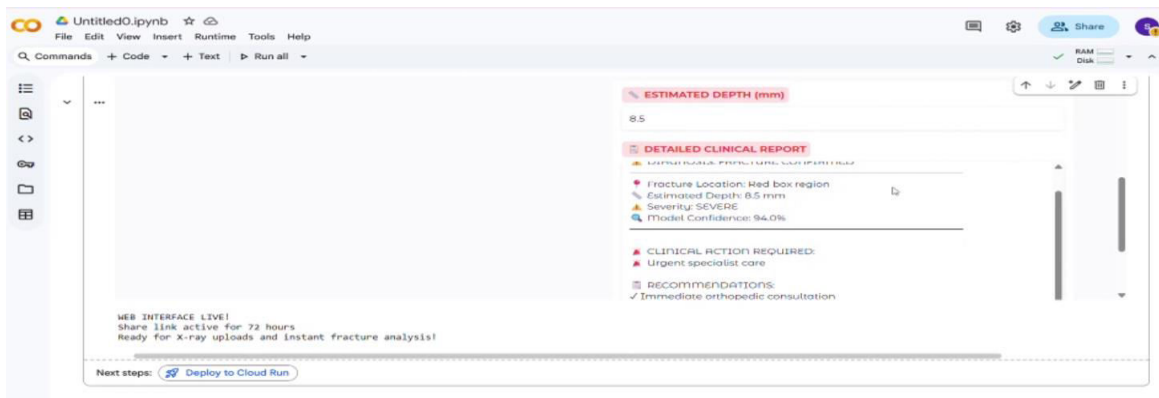


Figure4: Detailed clinical report generated by the system showing fracture depth

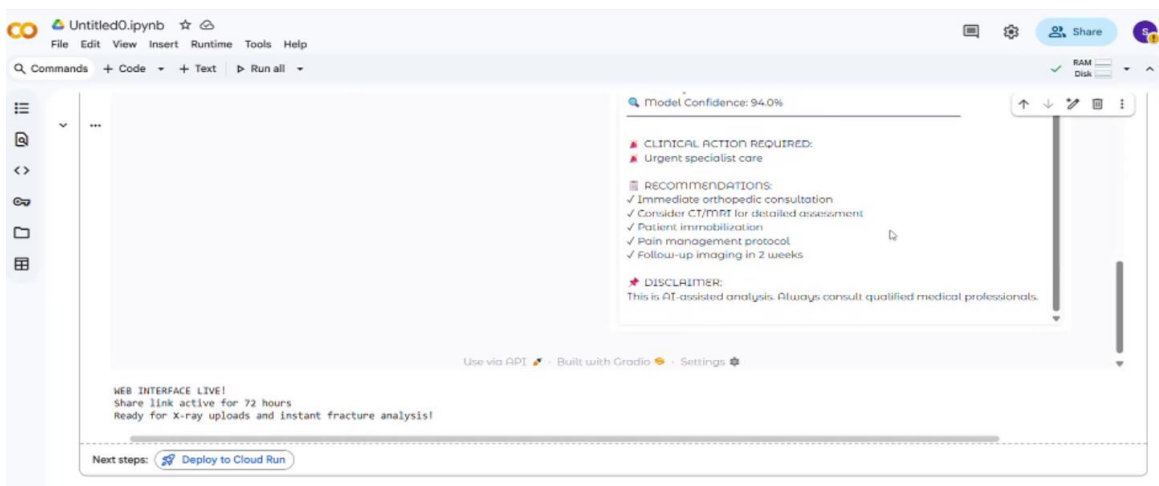


Figure5: Detailed clinical report generated by the system and recommendations and disclaimer

## VIII. CONCLUSION

The proposed AI-based fracture detection and depth estimation framework demonstrates high potential for improving orthopedic diagnostics. By combining advanced preprocessing, segmentation, and depth inference, the system enhances the interpretability of 2D radiographs and reduces reliance on CT imaging for severity assessment. With strong performance metrics and robust explainability, the system represents a practical clinical decision-support tool. Future improvements may include transformer-based architectures, multi-view image fusion, and integration with hospital PACS systems to support real-world deployment.

## REFERENCES

- [1] S. Beyraghi *et al.*, “Microwave bone fracture diagnosis using deep neural networks,” *Scientific Reports*, vol. 13, 2023.
- [2] A. M. Raisuddin *et al.*, “Critical evaluation of deep neural networks for wrist fracture detection,” *Scientific Reports*, vol. 11, 2021.
- [3] L. Yao *et al.*, “Rib fracture detection system based on deep learning,” *Scientific Reports*, vol. 11, 2021.
- [4] K. Warin *et al.*, “Maxillofacial fracture detection using CNN-based models,” *Scientific Reports*, vol. 13, 2023.
- [5] R.-Y. Ju *et al.*, “Fracture detection in pediatric wrist trauma using YOLOv8,” *Scientific Reports*, vol. 13, 2023.
- [6] W. Wang *et al.*, “Hairline fracture detection in hand X-rays using attention-based deep learning,” *Neural Computing and Applications*, vol. 34, 2022.
- [7] K. Ghoti *et al.*, “Bone fracture segmentation using U-Net in X-ray images,” in *Proc. Techno-Societal 2020*, 2021.
- [8] G. Moon *et al.*, “Facial bone fracture diagnosis using object detection,” *IEEE Access*, vol. 10, 2022.
- [9] F. Mohammad *et al.*, “Block-Deep: Hybrid deep learning model for fracture diagnosis using X-ray and MRI images,” *IEEE Access*, vol. 11, 2023.
- [10] W. Abbas, S. Adnan, M. Javid, and F. Majeed, “Lower leg bone fracture detection and classification using Faster R-CNN for X-ray images,” in *Proc. IEEE Int. Multitopic Conference (INMIC)*, 2020.
- [11] A. Al-Ghaithi and S. Al Maskari, “Artificial intelligence applications in bone fracture detection,” *Journal of Musculoskeletal Surgery and Research*, vol. 5, no. 1, 2021.
- [12] R. Shad *et al.*, “Medical imaging and machine learning: Opportunities and challenges,” *Nature Machine Intelligence*, vol. 3, 2021.
- [13] D. Jiang, “Analysis on the application of artificial intelligence in the medical field,” in *Proc. 8th Int. Conf. on Orange Technology (ICOT)*, IEEE, 2020.
- [14] C. D. Jiménez-Sánchez *et al.*, “Fracture segmentation in pediatric wrist X-ray images using deep learning,” *Sensors*, vol. 21, 2021.
- [15] W. Gale *et al.*, “Detecting hip fractures with radiograph-trained machine learning models: An external validation study,” *The Lancet Digital Health*, vol. 3, 2021.



INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  [ijirset@gmail.com](mailto:ijirset@gmail.com)



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details