Intracranial Aneurysm Detection

A MAIN PROJECT REPORT

Submitted by

ALEN SEBASTIAN (KGR22CS012)

MUHAMMED RAYAN (KGR22CS066)

SUBASH M (KGR22CS090)

TOBIN TOM (KGR22CS094)

AJAS AJMAL (LKGR22CS101)

to

The A P J Abdul Kalam Technological University

in partial fulfillment of the requirements for the award of the Degree

of

Bachelor of Technology

in

COMPUTER SCIENCE AND ENGINEERING

DEPT. OF COMPUTER SCIENCE & ENGINEERING

(NBA Accredited 2022-2025)

COLLEGE OF ENGINEERING KIDANGOOR

OCTOBER 2025

VISION AND MISSION OF COLLEGE

VISION

To be a leading engineering institution in the region, providing competent professionals, who engage in lifelong learning, driven by social values.

MISSION

To prepare engineering graduates for the development activities of the society and industry, and to prepare them for higher engineering education.

VISION AND MISSION OF THE DEPARTMENT

VISION

To become a center of excellence in Computer Science and Engineering imparting quality professional education to develop competent professionals with social values who are capable of life long learning.

MISSION

To impart quality technical education to students at undergraduate level through constant knowledge upgradation by maintaining pace with the latest sophisticated innovations , research and development and industry interaction in the field of Computer Science and Engineering with focus on lifelong learning for the well-being of the society.

Program Educational Objectives (PEO)

PEO1	Have sound knowledge and technical skills required to remain productive in the field of Computer Science and Engineering.
PEO2	Be efficient team leaders, effective communicators and successful entrepreneurs.
PEO3	Resolve technical problems with a positive outlook towards well-being of the society.
PEO4	Function in diverse environments with the ability and competence to solve challenging problems.
PEO5	Pursue lifelong learning and professional development through higher education.

Program Specific Outcomes (PSO)

PSO1 Ability to appreciate, learn and develop applications using modern programming languages, and databases.

PSO2 Ability to understand and analyze computer networks, distributed systems and computer system architectures for the designing of new systems.

PSO3 Ability to apply knowledge of domains like machine learning, cloud computing , image processing, data mining and software engineering to tackle innovative problems.

DECLARATION

We undersigned hereby declare that the project report entitled "Intracranial Aneurysm Detection" , submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under supervision of Ms.Athira S Nath. This submission represents our ideas in our own words and where ideas or words of others have been included, We have adequately and accurately cited and referenced the original sources. We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in our submission. We understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously formed the basis for the award of any degree, diploma or similar title of any other University.

Kidangoor
23-10-2025

ALEN SEBASTIAN
MUHAMMED RAYAN
SUBASH M
TOBIN TOM
AJAS AJMAL

DEPT. OF COMPUTER SCIENCE & ENGINEERING

COLLEGE OF ENGINEERING

KIDANGOOR

2025-26

CERTIFICATE

This is to certify that the report entitled **"Intracranial Aneurysm Detection"** submitted by **Alen Sebastian (KGR22CS012),Muhammed Rayan(KGR22CS066),Subash M(KGR22CS090), Tobin Tom(KGR22CS094),Ajas Ajmal(LKGR22CS101)** to the APJ Abdul Kalam Technological University in partial fulfillment of the B.Tech. degree in Computer Science and Engineering is a bonafide record of the project work carried out by this student under our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Ms. Jisha C Thankappan
Assistant Professor
Dept. of Computer Science & Engineering
College of Engineering Kidangoor
Project Coordinator

Mrs. Athira S Nath
Assistant Professor
Dept. of Computer Science & Engineering
College of Engineering Kidangoor
Project Guide

Dr. Ojus Thomas Lee
Associate Professor
Dept. of Computer Science & Engineering
College of Engineering Kidangoor
Head of the Department

ACKNOWLEDGEMENT

We take this opportunity to express our deep sense of gratitude and sincere thanks to all who helped us to complete the work successfully. Our first and foremost thanks goes to God Almighty who showered in immense blessings on our effort.

We wish to express our sincere thanks to **Dr. Indhu P Nair, Principal College of Engineering Kidangoor** for providing us with all the necessary facilities and support.

We would like to express our sincere gratitude to **Dr. Ojus Thomas Lee , Associate Professor and HOD CSE departement**, for his support and co-operation.

We wish to express our sincere thanks to **Dr . Ojus Thomas Lee and Ms. Jisha C Thankappan , Project Coordinators** for providing valuable suggestions and guidance which have been helpful in the various phases of the completion of the project.

We wish to express our sincere gratitude towards **Mrs. Athira S Nath,Project Guide** for giving advices to work with the project and complete it sucessfully.

We thank all the teaching and non teaching staff members of our Department for their support.

Finally we thank our parents, all our friends, near and dear ones who directly and indirectly contributed to the success of this work.

Alen Sebastian
Muhammed Rayan
Subash M
Tobin Tom
Ajas Ajmal

Abstract

Intracranial aneurysms are abnormal dilations of cerebral arteries that can rupture and cause life-threatening hemorrhage, making early detection essential for patient survival. This project presents an automated intracranial aneurysm detection and localization system using deep learning to assist radiologists in accurate diagnosis. The model is developed using the RSNA Intracranial Aneurysm Detection Dataset, which includes multi-site MRI, MRA, and CTA scans with expert annotations covering 13 predefined brain regions. Advanced convolutional and 3D neural network architectures are applied for detecting and segmenting aneurysms, supported by preprocessing techniques such as intensity normalization, skull stripping, and data augmentation. Model performance is assessed through metrics like accuracy, sensitivity, specificity, Dice coefficient, and AUC to ensure high reliability and generalization across imaging modalities. The proposed AI-based system aims to enhance the speed, precision, and consistency of aneurysm detection, thereby improving clinical decision-making and patient outcomes..

Contents

List of Figures

Chapter 1

Introduction

Intracranial aneurysms are relatively common vascular abnormalities in the brain, yet they are often missed during diagnosis due to their small size, anatomical variability, and the complexity of imaging data. Accurate detection is crucial, as ruptured aneurysms can lead to severe hemorrhage and high mortality. In clinical practice, manual review of CTA (Computed Tomography Angiography) and MRA (Magnetic Resonance Angiography) scans is labor-intensive, time-consuming, and susceptible to human error, especially when analyzing large volumes of data. To address these challenges, this project focuses on developing an AI-based pipeline capable of automatically detecting and localizing intracranial aneurysms from large-scale brain imaging datasets. The system is trained and validated using the RSNA Intracranial Aneurysm Detection Dataset, a diverse, multi-institutional collection of annotated MRI, MRA, and CTA series that include localization coordinates for each aneurysm. The methodology involves preprocessing DICOM images for intensity normalization and alignment, followed by training deep learning architectures such as 2D and 3D Convolutional Neural Networks (CNNs) and segmentation networks for precise detection and localization.

Chapter 2

Problem Statement

Develop an AI-based system to automatically detect and localize aneurysms in brain scans, helping radiologists improve accuracy, speed, and patient outcomes. Rapid and accurate automated detection of aneurysms on routine brain imaging studies could help prevent devastating outcomes for patients

Chapter 3

Literature Review

AI-based medical imaging systems have recently gained significant attention for improving diagnostic accuracy and efficiency. With the increasing complexity of brain imaging data, automated detection of intracranial aneurysms has become an important research focus. These systems aim to assist radiologists by rapidly identifying and localizing aneurysms, reducing diagnostic errors, and improving patient outcomes.

3.1 Toward human intervention-free clinical diagnosis of intracranial aneurysm via deep neural network

Develop an AI system to automatically detect and segment brain aneurysms from CT scans without manual preprocessing, helping radiologists diagnose faster and more accurately.it has Two-stage approach: First, analyze the whole brain scan to find high-risk areas where aneurysms are likely. Second, zoom into small patches at full resolution to precisely segment aneurysms. Uses 3D patching strategy to handle large medical images.Algorithms used here are 3D U-Net (image segmentation), 3D CNN (to extract features from brain scans), Custom loss function (to handle small targets and uncertain boundaries)

3.2 A Survey of Intracranial Aneurysm Detection and Segmentation

Classify approaches based on input data (3D geometric, volumetric, 2D images) Identify trends, challenges, and future directions in CAD systems for intracranial aneurysm analysis.Here the methods proposed are Selection criteria: semi-automated or automated methods for IA detection, isolation, or segmentation Exclusion: aortic aneurysms, retinal microaneurysms, manual annotation methods.Algorithms such as 3D U-Net, ResNet, DeepMedic, nnU-Net, Faster R-CNN, MeshCNN, PointNet, PointNet++, Transformers are used.

3.3 A Deep-Learning Model for Intracranial Aneurysm Detection on CT Angiography Images in China

To develop and validate an AI model for detecting intracranial aneurysms on CTA scans.Methods used here are Two-stage deep-learning system—global detection and local fine segmentation across multiple hospitals.Algorithms such as Cascaded deep-learning neural networks (nnU-Net–based) with 3D CTA image training and data augmentation.

3.4 IntrA: 3D Intracranial Aneurysm Dataset for Deep Learning

To create an open-access, annotated 3D intracranial aneurysm dataset (IntrA) that supports the development, training, and benchmarking of deep learning models for diagnosis and segmentation of aneurysms using realistic 3D vessel structures.Algorithm used here are PointNet, PointNet++, SO-Net, PointCNN, SpiderCNN, DGCNN, MeshCNN, and related geometric deep learning models.

Chapter 4

System Analysis

This chapter covers current approaches and limitations in intracranial aneurysm detection, a detailed analysis of the proposed AI-based detection and localization system, and the functional and non-functional requirements of the proposed system.

4.1 Existing System

- **No Automation:** No automated detection or localization mechanism is available..
- **High Expertise Dependency:** The process relies heavily on the radiologist's knowledge, skill, and experience.
- **2D Visualization:** Visualization is limited to 2D image slices without automatic highlighting of aneurysm regions.
- **Prone to Diagnostic Errors:** Small, irregular, or obscured aneurysms may be overlooked.
- **Inconsistent Accuracy:** Diagnostic results may vary between different radiologists.
- **Limited Analytical Tools:** Current systems lack automated segmentation, measurement, or 3D visualization capabilities.
- **Data Handling Challenges:** Difficulties arise in processing and analyzing large, multi-modal imaging data from different sources.

4.2 Proposed System

4.2.1 Overview

The proposed system introduces an automated intracranial aneurysm detection and localization framework using an ensemble deep learning model. Unlike traditional manual methods, the system automatically accepts and preprocesses DICOM brain scans obtained from MRI, MRA, or CTA modalities. The preprocessing stage involves intensity normalization, skull stripping, and noise reduction to prepare the data for model training and inference. The detection module then identifies the presence of aneurysms within the processed brain images, analyzing volumetric features and vascular structures. Once detected, the system precisely localizes and maps each aneurysm to one of the 13 predefined anatomical brain regions defined in the RSNA Intracranial Aneurysm Detection dataset. By combining multiple models in an ensemble (e.g., 3D CNNs, U-Net, and ResNet architectures), the system improves robustness, reduces false positives, and enhances localization accuracy. This AI-based approach assists radiologists by providing automated detection, 3D visualization, and clear localization output, enabling faster diagnosis, higher accuracy, and better patient management.

4.2.2 Advantages

- **Automated Detection:** Eliminates the need for manual inspection by radiologists, reducing workload and human error.
- **High Accuracy:** The ensemble deep learning model improves detection precision and reduces false positives.
- **Faster Diagnosis:** Rapid analysis of large brain imaging datasets enables quicker clinical decision-making.
- **Reliable Localization:** Accurately maps detected aneurysms to specific anatomical brain regions for targeted evaluation.
- **Enhanced Visualization:** Provides 3D mapping and highlighting of aneurysm regions, improving interpretability.
- **Consistency in Results:** Ensures uniform diagnostic performance across multiple imaging modalities and sites.
- **Scalability:** Capable of efficiently processing large volumes of MRI, MRA, and CTA scans.
- **Clinical Support Tool:** Assists radiologists by acting as a decision-support system, enhancing diagnostic confidence.

- **Improved Patient Outcomes:** Enables early detection and intervention, potentially preventing aneurysm rupture and related complications.

4.2.3 System Architecture

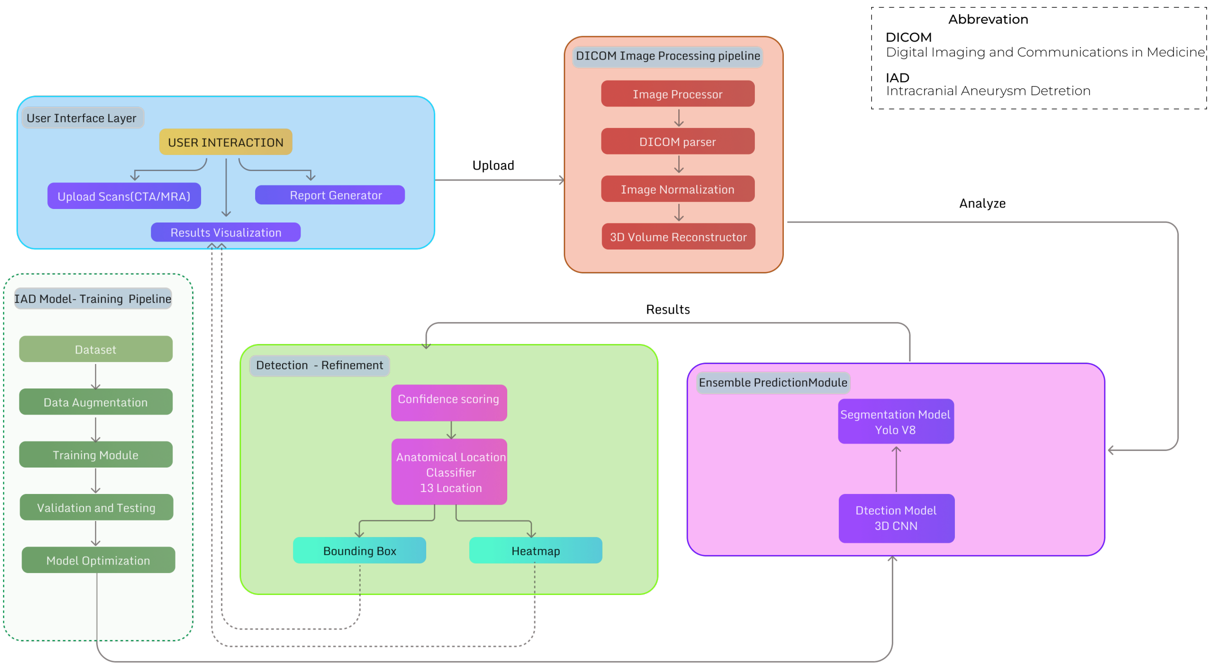

Figure 4.1: *System Architecture*

4.3 Design Diagrams

4.3.1 Use Case Diagram

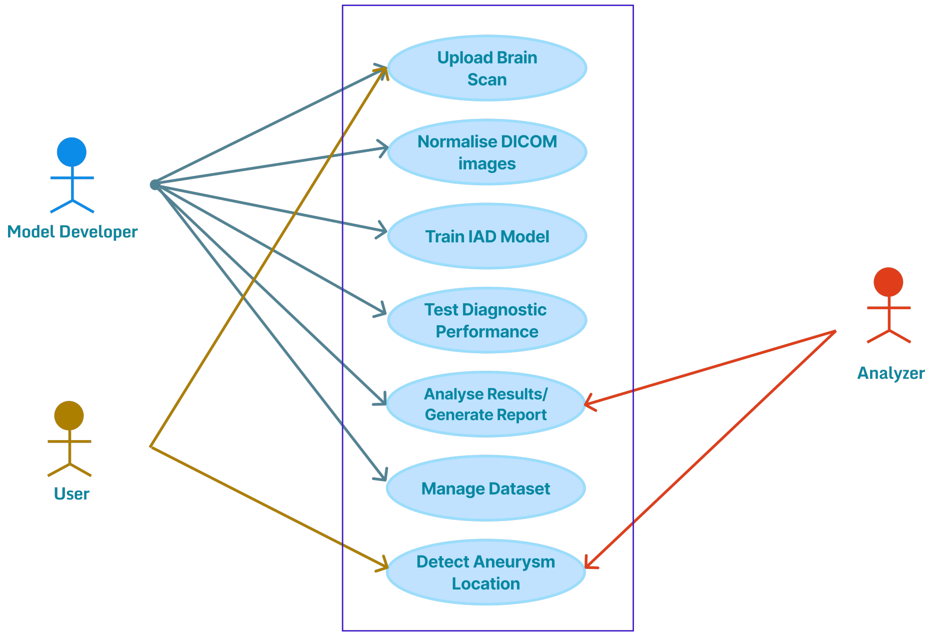

Figure 4.2: *Use Case Diagram*

4.3.2 Sequence Diagram

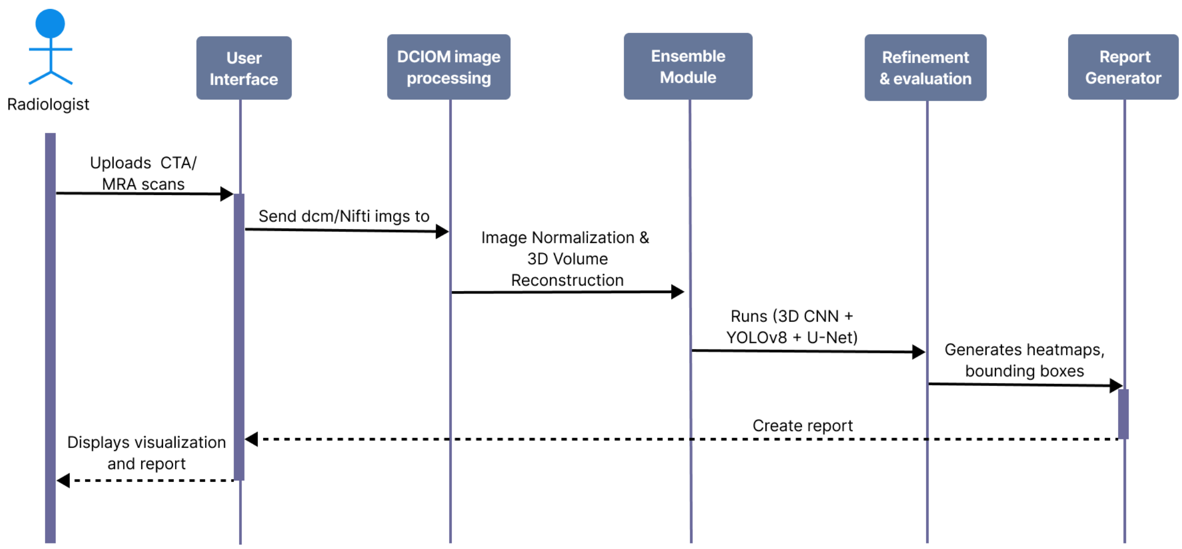

Figure 4.3: *Sequence Diagram*

4.3.3 Data Flow Diagram

Figure 4.4: *Level 0 Data Flow Diagram*

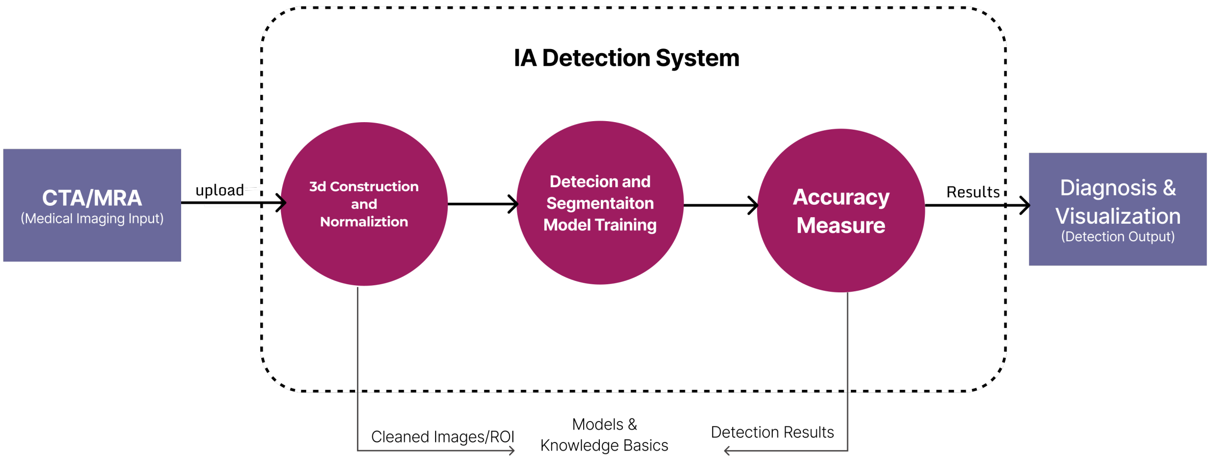

Figure 4.5: *Level 1 Data Flow Diagram*

4.3.4 Activity Diagram

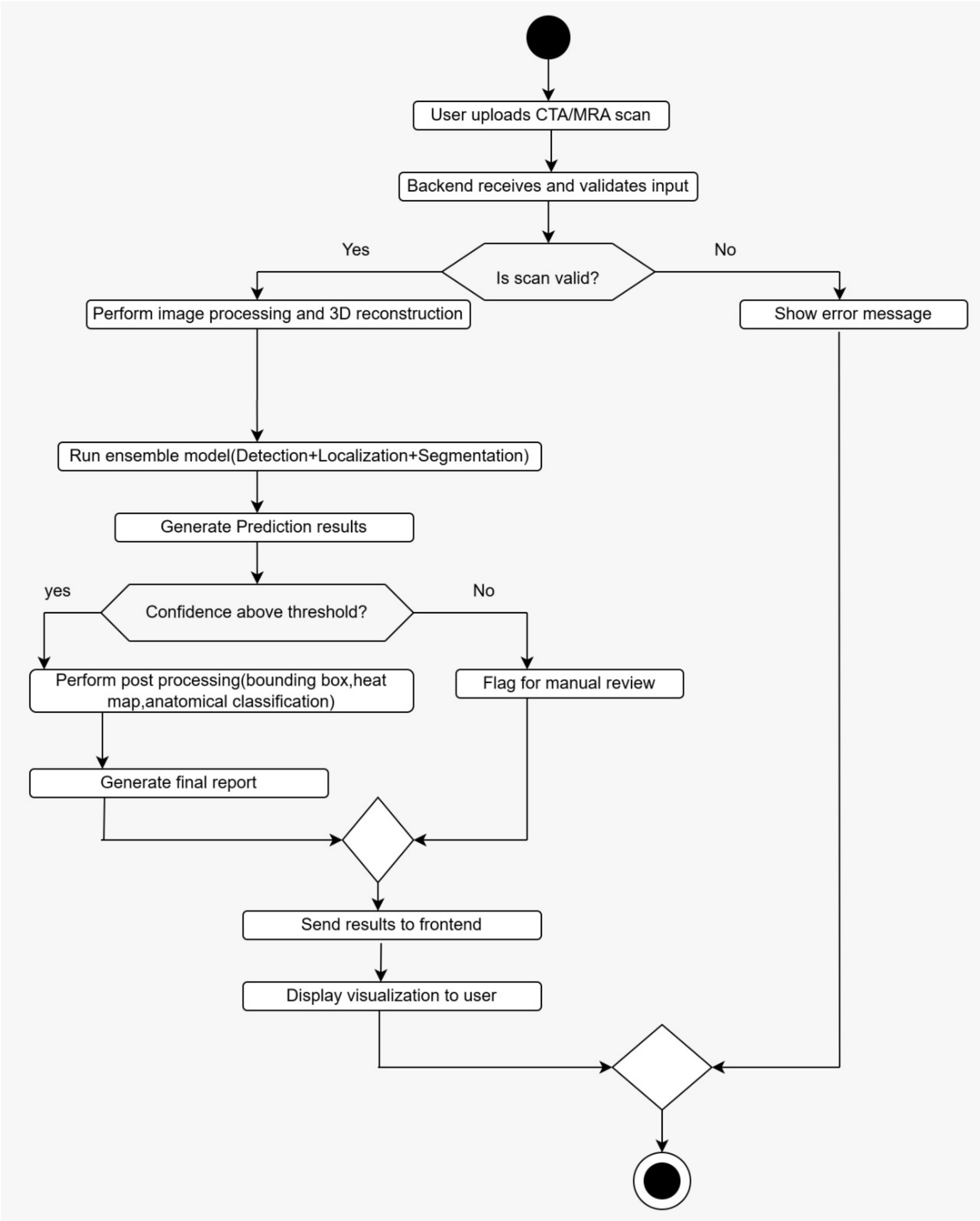

Figure 4.6: *Activity Diagram*

4.3.5 Hardware and Software Requirements

SOFTWARE REQUIREMENTS

```
OPERATING SYSTEM               - Windows 10 / 11 (64-bit) or Ubuntu 20.04 / 22.04 LTS
PROGRAMMING LANGUAGE           - Python 3.10
DEEP LEARNING FRAMEWORKS       - TensorFlow 2.10
DATA HANDLING LIBRARIES        - NumPy 1.24, Pandas 2.0
MACHINE LEARNING / EVALUATION  - Scikit-learn 1.3 or higher
VISUALIZATION TOOLS            - Matplotlib 3.7, Seaborn 0.12
MEDICAL IMAGING TOOLKIT        - pydicom 2.4
DEVELOPMENT ENVIRONMENT        - Jupyter Notebook
GPU ACCELERATION TOOLKIT       - CUDA Toolkit 11.8, cuDNN 8.9 (for NVIDIA GPUs)
DATASET SOURCE                 - RSNA Intracranial Aneurysm Detection (Kaggle)
```

HARDWARE REQUIREMENTS

```
PROCESSOR              - Intel Core i5 / AMD Ryzen 7 or higher
RAM                    - 16 GB
GPU                    - NVIDIA RTX 3060 or higher
STORAGE                - 512 GB SSD
INTERNET CONNECTIVITY  - High-speed connection (for dataset download & cloud sync)
```

Chapter 5

System Implementation

The project has been developed using Python and deep learning frameworks for the back-end processing and analysis. The system is implemented using TensorFlow and PyTorch frameworks, which enable efficient training and deployment of complex neural network architectures for medical image analysis. The web interface is built using Flask/Django for seamless integration with hospital information systems, ensuring real-time processing and results delivery.

5.1 Modules

Project has been mainly divided into five modules.

Module 1: User Interface Layer

The User Interface Layer serves as the front-end gateway to the IAD system, providing clinicians and radiologists with an intuitive platform for uploading medical images, initiating analysis, and reviewing results.

Key Components:

- **Upload Scans (CTA/MRA):** Allow users to upload medical imaging files in CTA or MRA formats with their DICOM metadata.
- **User Interaction:** Provide users with a central hub for managing cases, configuring analysis parameters, and navigating system functionalities.
- **Report Generator:** Generate automated diagnostic reports that transform detection results into clinically relevant documents for patient medical records.
- **Results Visualization:** Allow users to visualize detection outcomes through 2D/3D views, color-coded overlays, and interactive manipulation tools.

Module 2: DICOM Image Processing Pipeline

The DICOM Image Processing Pipeline transforms raw medical imaging data into standardized, high-quality 3D volumetric representations suitable for deep learning analysis.

Key Components:

- **Image Processor:** Perform initial quality checks, format validation, and artifact detection on uploaded medical images.
- **DICOM Parser:** Extract metadata and image data from DICOM format including patient demographics, acquisition parameters, and spatial information.
- **Image Normalization:** Standardize image intensity values and spatial dimensions to ensure consistent input for deep learning models.
- **3D Volume Reconstructor:** Convert 2D image slices into 3D volumetric representation for comprehensive vascular structure analysis.

Module 3: IAD Model - Training Pipeline

The IAD Model Training Pipeline encompasses the complete machine learning workflow for developing robust aneurysm detection models.

Key Components:

- **Dataset:** Provide a collection of annotated brain scan images from multiple institutions including both positive (with aneurysms) and negative cases.
- **Data Augmentation:** Expand training data through transformations such as rotation, scaling, flipping, and intensity variations to improve model generalization.
- **Training Module:** Implement neural network learning process using deep learning architectures (3D U-Net, ResNet) with optimized hyperparameters.
- **Validation and Testing:** Evaluate model performance on unseen data using metrics like sensitivity, specificity, and Dice coefficient.
- **Model Optimization:** Fine-tune model for accuracy and efficiency through techniques like transfer learning, ensemble methods, and hyperparameter optimization.

Module 4: Detection - Refinement Module

The Detection-Refinement Module processes the initial detection results to improve accuracy and reduce false positives through advanced classification and localization techniques.

Key Components:

- **Confidence Scoring:** Assign probability scores to detected regions indicating the likelihood of being a true aneurysm (range: 0.0 to 1.0).
- **Anatomical Location Classifier:** Identify the specific location of detected aneurysms among 13 possible anatomical sites (e.g., anterior communicating artery, internal carotid artery, middle cerebral artery).
- **Bounding Box:** Define precise spatial coordinates and dimensions of detected aneurysms for accurate localization in 3D space.

- **Heatmap:** Provide visual representation of detection confidence areas using color gradients to highlight regions of interest for radiologist review.

Module 5: Ensemble Module

The Ensemble Module combines multiple deep learning models to achieve superior detection and segmentation performance through complementary strengths of different architectures.

Key Components:

- **Detection Model (3D CNN):** Utilize 3D Convolutional Neural Network for initial aneurysm detection from volumetric medical images with high sensitivity.

- **Segmentation Model (YOLO V8):** Apply YOLO V8 architecture for precise boundary delineation of detected aneurysms with pixel-level accuracy.

- **Integration:** Combine predictions from both models through weighted voting or averaging strategies to enhance overall accuracy and reduce false positives.

Chapter 6

Conclusion

Deep learning can effectively detect and localize intracranial aneurysms, assisting radiologists in achieving faster and more accurate diagnoses. Proper preprocessing and data handling play a crucial role in ensuring reliable and consistent results across different hospitals and imaging modalities. Despite significant progress, current models still face challenges in detecting small aneurysms and minimizing false positives, highlighting the need for further optimization through advanced architectures and data augmentation. Incorporating ensemble and 3D convolutional neural networks can enhance model robustness and spatial understanding of complex brain structures. Continuous training using large-scale, multi-institutional datasets can improve generalization and reduce bias across diverse patient populations. With continued validation and clinical testing, this AI-based approach holds great potential to support doctors in real-world clinical workflows, improve diagnostic confidence, and enhance patient safety. Future research can focus on explainable AI for better interpretability, real-time integration into radiology systems, and automated report generation to further streamline the diagnostic process.

Bibliography

[1]Yang, J., Xie, M., Hu, C., Alwalid, O., Xu, Y., Liu, J., et al. (2021). Deep Learning for Detecting Cerebral Aneurysms with CT Angiography. Radiology, 298(1), 155–163. Radiological Society of North America (RSNA).

[2]Yang, X., Xia, D., Kin, T., Igarashi, T. (2020). IntrA: 3D Intracranial Aneurysm Dataset for Deep Learning. arXiv preprint arXiv:2003.02920.

[3] Zhao, Z., Qian, H., Tian, C., Guo, Y., Li, W., et al. (2020). Deep Learning Based Detection and Localization of Intracranial Aneurysms in Computed Tomography Angiography. arXiv preprint arXiv:2005.11098.

[4] Terasaki, Y., Yokota, H., Tashiro, K., Maejima, T., Takeuchi, T., Kurosawa, R., et al. (2022). Multidimensional Deep Learning Reduces False Positives in the Automated Detection of Cerebral Aneurysms on TOF-MRA: A Multi-Center Study. Frontiers in Neurology, 12, 742126.

[5] Bizjak, Ž., Špiclin, Ž. (2023). A Systematic Review of Deep-Learning Methods for Intracranial Aneurysm Detection in CT Angiography. Biomedicines, 11(11), 2921. MDPI.Hu, B., Shi, Z., Lu, L., Miao, Z., Wang, H., Zhou, Z., et al. (2024). A Deep-Learning Model for Intracranial Aneurysm Detection on CT Angiography Images in China: A Stepwise, Multicentre, EarlyStage Clinical Validation Study. The Lancet Digital Health, 6, e261–e271.

[6]Indrakanti, A. K., Wasserthal, J., Segeroth, M., Yang, S., Nicoli, A. P., Schulze-Zachau, V., et al. (2025). Multi-centric AI Model for Unruptured Intracranial Aneurysm Detection and Volumetric Segmentation in 3D TOF-MRI. Journal of Imaging Informatics in Medicine. Springer.

[7]RSNA Intracranial Aneurysm Detection Dataset. (2020). Kaggle Competition Platform. Available at: https://www.kaggle.com/ competitions/rsna-intracranial-aneurysm-detection.

[8]Deep learning–based intracranial aneurysm detection in CTA images." Scientific Reports (Nature), 2023. Available at: https:// www.nature.com/articles/s41598-023-38586-9.

[9]"Deep learning approaches for intracranial aneurysm detection: A comprehensive review." arXiv preprint arXiv:2312.17670v4, 2024. Available at: https://arxiv.org/html/2312.17670v4

[10] Deep learning-based cerebral aneurysm detection with CT angiography." PubMed Central (PMC8968557), 2022. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC8968557/.