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JNANA SANGAMA, BELAGAVI -590 014

A Project Report on

HoloVision – A Mixed Reality based Diagnosis for Patient Centric Healthcare

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CERTIFICATE

Certified that the Project work entitled **"HoloVision – A Mixed Reality based Diagnosis Tool for Patient Centric Healthcare"** is carried out by **Sai Ayush (1AY19EC071) and Sai Sreeram Gadde (1AY19EC072)** in the partial fulfillment for the award of the degree of Bachelor of Engineering in Electronics and Communication Engineering of Visvesvaraya Technological University, Belagavi during the year **2022-2023**. It is certified that all corrections/suggestions indicated for the assessment have been incorporated in the report deposited in the departmental library. The Project Report has been approved as it satisfies the academic requirement in respect of Project work **(18ECP83)** prescribed for the Bachelor of Engineering Degree.

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ABSTRACT

MRI has a significant need in the healthcare industry, the cross-sectional images of the body provide an insight of the problems or abnormalities. A detailed report is written by the radiologist referring to these scans. There are often errors introduced in this process, due to the inflexibility of two dimensional images. The errors are also observed during surgeries causing risk to the patient's life. Surgical errors include unwanted incisions and complicated approaches for the interested site. These errors are minimized by developing a diagnosis tool using Artificial Intelligence (AI) and emerging technologies such as Augmented Reality (AR) and Mixed Reality (MR).The tool projects the 3D model reconstructed from MRI scans using a mixed reality headset. This device enables the doctors during surgeries as well as radiologists in providing deeper information aided by higher-end visualization. This also resolves the errors occurring during surgeries and helps Radiologists to provide accurate and faster results.S

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CHAPTER 1

INTRODUCTION

Medical imaging such as MRI and CT scans has been an essential part of the diagnosis for patients. The accurate imaging of the internal cross-sectional of the body allows doctors for a better understanding of any abnormalities. These scans are usually in 2D slices, the slices can be put together to reconstruct a 3D model of the part using a technique called Volume Rendering. This 3D model is integrated with new technologies such as AI and Mixed Reality, with the aid of which the next generation of medical imaging can be achieved.

Magnetic resonance imaging (MRI) is a medical imaging technique that uses a powerful magnetic field and radio waves to produce detailed images of the inside of the body. MRI scans are often used to diagnose a variety of medical conditions, including injuries, diseases, and abnormalities. MRI scans are highly effective at producing detailed images of the body's internal structures, including the brain, organs, and musculoskeletal system. They are often used to diagnose conditions such as brain tumors, multiple sclerosis, and osteoarthritis. MRI scans are generally considered safe, although they may not be suitable for people with certain types of implants or metallic objects in their bodies.

Figure 1.1. MRI Scanning

Mixed reality is a term that refers to the combination of real and virtual worlds. It involves the use of technology to create immersive environments in which physical and digital objects coexist and interact. There are several types of mixed reality, including:

Augmented reality (AR): This involves superimposing digital content onto the real world. For example, a person might use an AR app on their smartphone to see virtual information or graphics overlaid on the camera feed of their surroundings.

Virtual reality (VR): This involves creating a fully immersive digital environment that the user can interact with. VR is typically experienced through a headset, which blocks out the real world and replaces it with a computer-generated one.

Hybrid reality: This involves combining elements of both AR and VR to create a mixed reality experience.

Mixed reality technology has a wide range of applications, including education, entertainment, and military training. It has the potential to transform how we interact with computers and the world around us.

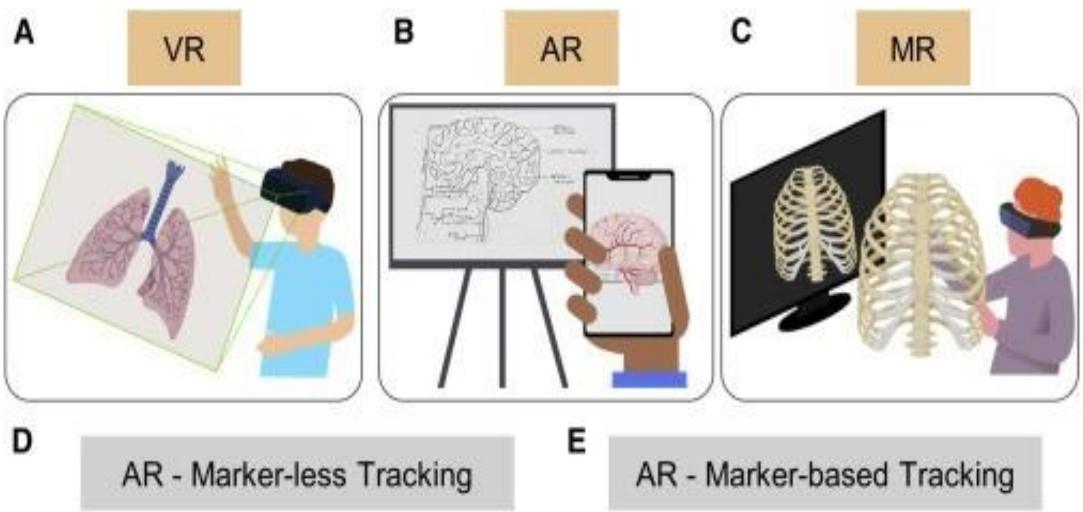

Figure 1.2. VR, AR and MR

Magnetic resonance imaging (MRI) and computed tomography (CT) scans are two different types of medical imaging tests that produce detailed images of the inside of the body. Both MRI and CT scans can be used to diagnose a wide range of medical conditions and are commonly used to help diagnose cancer, cardiovascular disease, and other conditions.

MRI uses a powerful magnetic field and radio waves to produce detailed images of the body's organs, tissues, and bones. It is particularly useful for imaging the brain and spinal cord, as well as the joints and soft tissues. MRI does not use radiation, making it a safe option for pregnant women and children.

CT scans use X-rays to produce detailed images of the body's organs, bones, and tissues. CT scans are faster and more widely available than MRI, making them a good option for emergency care. However, CT scans do use radiation, so they may not be suitable for certain patients, such as pregnant women or children.

Both MRI and CT scans are important tools in the diagnosis and treatment of many medical conditions. Your doctor will determine which test is best for you based on your specific needs and medical history.

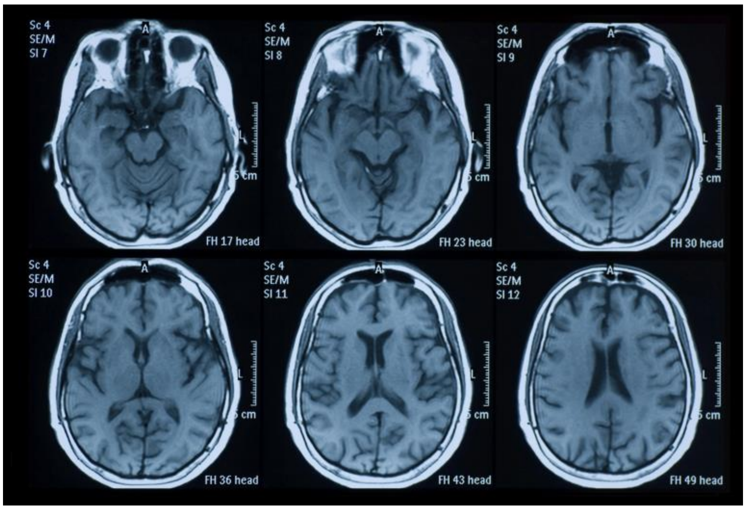

Figure 1.3. MRI scans

MRI segmentation is an essential part of our project as it allows you to identify specific regions of interest within the MRI scans and create a 3D model of those regions.

MRI segmentation is the process of dividing an MRI image into different regions, or segments, based on some defined criteria. This can be done manually by a trained observer, or it can be done automatically using image processing techniques.

There are many different approaches to MRI segmentation, including thresholding, clustering, and machine learning algorithms. The choice of approach will depend on the specific application and the desired level of accuracy.

One common approach to MRI segmentation is to use machine learning algorithms, such as neural networks, to automatically identify regions of interest within the image. NNUNet, which you mentioned earlier, is a popular neural network architecture for medical image segmentation that has shown promising results in various studies.

After the segmentation process, you can use the resulting segmented images to create a 3D model of the region of interest. ITK, which you mentioned earlier, is a popular toolkit for medical image processing that can be used for this purpose. ITK allows you to perform various operations on the segmented images, such as smoothing, edge detection, and thresholding, to create a 3D model that accurately represents the region of interest.

Overall, MRI segmentation is an important step in your project as it allows you to isolate specific regions of interest within the MRI scans and create a detailed 3D model of those regions, which can be used for visualization and analysis.

MRI segmentation can be used for a variety of purposes, including measuring the size and shape of organs, identifying abnormalities or abnormalities, and assessing the effectiveness of treatments. It is an important tool in medical imaging and can help doctors make more accurate.

Figure 1.4. MRI Segmentation

3D modeling is becoming increasingly popular in the healthcare industry, as it allows for the creation of detailed, accurate representations of the human body, medical devices, and other objects. This can be useful for a variety of purposes, such as surgical planning, patient education, and training medical professionals.

For example, 3D modeling can be used to create virtual simulations of surgical procedures, allowing doctors to plan and practice their approaches before performing them in real life. It can also be used to create interactive visual aids for patient education, helping patients understand their conditions and treatments. In addition, 3D modeling can be used to design and test new medical devices, such as prosthetics, implants, and surgical instruments. It allows engineers and designers to create prototypes and test their functionality before building physical prototypes. Overall, 3D modeling has the potential to greatly improve the healthcare industry by providing more accurate, detailed, and interactive visualizations for a variety of purposes.

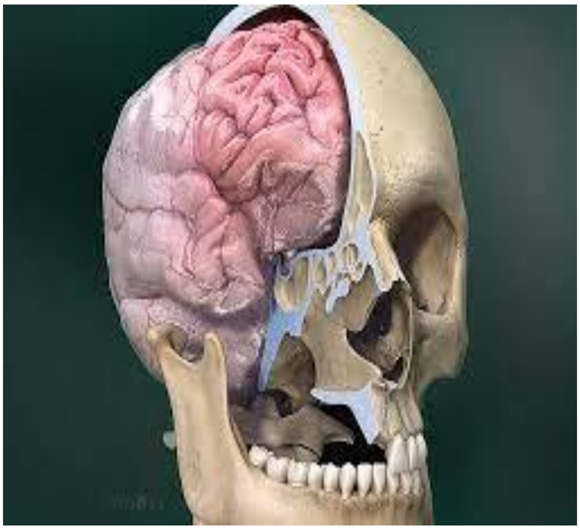

Figure 1.5. 3D model of head

Volume rendering is another powerful tool for visualizing complex 3D structures, especially from medical imaging data like MRI scans. Volume rendering allows you to create 3D images from a stack of 2D images, which can reveal details that are difficult to see in individual slices.

To implement volume rendering in your project, you will need to use a library or toolkit that supports this functionality, such as VTK (the Visualization Toolkit) or Unity's built-in volume rendering tools. These tools typically allow you to define transfer functions that map voxel values to color and opacity, and to adjust rendering parameters like lighting and shading.

Some of the challenges you might encounter when implementing volume rendering include optimizing performance for large datasets, dealing with artifacts like noise and aliasing, and selecting appropriate transfer functions to highlight relevant features of the data. To overcome these challenges, it can be helpful to experiment with different rendering techniques, adjust parameters carefully, and consult with experts in the field as needed.

Overall, incorporating volume rendering into your project can help you create even more detailed and realistic 3D visualizations of your MRI data, and can provide valuable insights for medical research and diagnosis.

ITK (Insight Toolkit) and VTK (Visualization Toolkit) are two powerful libraries for medical image processing and visualization, respectively. They are often used together in medical imaging projects, such as your MRI segmentation and 3D modeling project.

Figure 1.6. ITK Logo

VTK, on the other hand, is a powerful open-source library for 3D visualization and graphics that provides a wide range of tools for creating 3D models, rendering, and interacting with them. VTK can be used to create visualizations of medical images, such as your 3D model created from MRI segmentation. It provides a powerful toolkit for rendering 3D models and supports a wide range of file formats.

Figure 1.7. VTK Logo

Unity is a powerful cross-platform game engine that can be used for a wide range of applications, including creating interactive and immersive 3D visualizations. In your project, you can use Unity to create an augmented reality (AR) space that allows users to interact with the 3D models you have created from MRI segmentation.

To use Unity in your project, you can export the 3D models you have created using ITK and VTK to a format supported by Unity, such as OBJ or FBX. You can then import these models into Unity and use them as game objects in your AR space.

Unity provides a wide range of tools and features for creating interactive 3D experiences, including physics, lighting, animation, and scripting. You can use these tools to create an AR space that allows users to interact with the 3D models you have created in various ways, such as rotating, scaling, and moving the models in real-time.

In Unity, a 3D model can be manipulated and animated using a variety of tools and features. It can be positioned, rotated, scaled, and have its appearance modified using materials and textures. It can also be given behaviors and interactions using programming languages such as C# or Unity's own scripting system.

In addition, Unity supports various input devices, such as VR/AR headsets, controllers, and touch screens, which can be used to interact with the 3D models in your AR space. You can also use Unity to add audio, visual effects, and other elements to enhance the user experience.

Overall, Unity is a powerful tool that can help you create an immersive and interactive AR space that allows users to explore and interact with the 3D models you have created from MRI segmentation

CHAPTER 2

LITERATURE SURVEY

I Gupta, S. Dangi and S. Sharma et.al, [1] proposed reasearch work on AR and VR. Augmented reality and virtual reality are becoming increasingly prominent in academia and industry. A technology that superimposes additional information on top of the real world is known as augmented reality. Since augmented reality is inextricably linked to the natural world, it is regarded as a partially immersive component of reality. However, unlike virtual reality, augmented reality does not provide a completely immersive experience. Virtual reality has long been depicted as a medium defined by a bevy of technological devices, such as laptops, head-mounted displays, microphones, and motion-sensing gloves. The goal of this research is to conduct a comprehensive assessment of the literature on augmented reality and virtual reality-based Human Machine Interfaces in healthcare. The concept of a smart healthcare environment is gaining traction in industry and product development, resulting in the development of new and more intelligent solutions, technologies, and architectures. Cloud computing, the Internet of Things (IoT), data analytics, artificial intelligence, machine learning, augmented reality, and virtual reality are all being used by manufacturers and developers in their manufacturing and overall operations. The research will also examine the advantages of augmented reality in the medical field, as well as the problems these technologies face and where they are heading in the future.

This paper talks about the benefits and challenges faced for augmented reality in healthcare. The future trends of the AR are also discussed. AR is game-changing for the medical industry. This technology provides an ideal incision and strategic planning in pre-surgery.

S. Lim et al., [2] proposed reasearch work on Surgical Navigation System for Epidural Needle Intervention. An augmented reality (AR)-assisted surgical navigation system was developed for epidural needle intervention. The system includes three components: a virtual reality-based surgical planning software, a patient and tool tracking system, and an AR-based surgical navigation system. A three-dimensional (3D) path plan for the epidural needle was established on the preoperative computed tomography (CT) image. The plan is then registered to the intraoperative space by 3D models of the target vertebrae using skin markers and real-time tracking information. In the procedure, the plan and tracking information are transmitted to the head-mounted display (HMD) through a wireless network such that the device directly visualizes the plan onto the back surface of the patient. The physician determines the entry point and inserts the needle into the target based on the direct visual guidance of the system. An experiment was conducted to validate the system using two torso phantoms that mimic human respiration. The experimental results demonstrated that the time and the number of X-rays required for needle insertion were significantly decreased by the proposed method (43.6±20.55sec, 2.9±1.3times) compared to those of the conventional fluoroscopy-guided approach (124.5 ± 46.7s, 9.3±2.4times), whereas the average targeting errors were similar in both cases. The proposed system may potentially decrease ionizing radiation exposure not only to the patient but also to the medical team

R. S. Cruz, L. Lebrat, P. Bourgeat, C. Fookes, J. Fripp and O. Salvado, [3] proposed reasearch work on 3D Deep Learning Approach for Cortical Surface Reconstruction. The study of neurodegenerative diseases relies on the reconstruction and analysis of the brain cortex from magnetic resonance imaging (MRI). Traditional frameworks for this task like FreeSurfer demand lengthy runtimes, while its accelerated variant FastSurfer still relies on a voxel-wise segmentation which is limited by its resolution to capture narrow continuous objects as cortical surfaces. Having these limitations in mind, we propose DeepCSR, a 3D deep learning framework for cortical surface reconstruction from MRI. Towards this end, we train a neural network model with hypercolumn features to predict implicit surface representations for points in a brain template space. After training, the cortical surface at a desired level of detail is obtained by evaluating surface representations at specific coordinates, and subsequently applying a topology correction algorithm and an isosurface extraction method. Thanks to the continuous nature of this approach and the efficacy of its hypercolumn features scheme, DeepCSR efficiently reconstructs cortical surfaces at high resolution capturing fine details in the cortical folding. Moreover, DeepCSR is as accurate, more precise, and faster than the widely used FreeSurfer toolbox and its deep learning powered variant FastSurfer on reconstructing cortical surfaces from MRI which should facilitate large-scale medical studies and new healthcare applications.

Kristina Prokopetc and Romain Dupont, [4] proposed reasearch work on 3D Reconstruction for Mixed Reality in Healthcare: Classical Multi-View Stereo vs Deep Learning. Faithfully reproducing surroundings in 3D is a key-component in Mixed Reality for medical training in neonatology, where a user sees a hospital room in a Virtual Reality helmet while retaining tangible interaction with a baby mannequin and various medical tools. Deep learning solutions have high claims against classical methods but their performance in real-life application remains unclear. To fill this blank, we present a comparative study of depth map based Multi-View Stereo methods for dense 3D reconstruction. We compare classical state-of-the-art methods to their learned counterparts and assess their robustness to weakly-textured and reflective surfaces as well as accuracy on thin structures both globally and locally. We also analyze the effect of depth filtering along with computational effort. Our experiments reveal various factors which contribute to the performance gap between the methods that we discuss in detail. This study is the first to evaluate traditional dense geometry reconstruction methods against brand-new deep learning models. It helps to better understand what suits best the challenges of hospital environments. Furthermore, it builds a solid analytic ground to underscore the strengths and weaknesses of the learned methods.

Nodirov Jakhongir, Akmalbek Abdusalomov, Taeg Keun Whangbo, [5] proposed reasearch work on 3D Volume Reconstruction from MRI Slices based on VTK

. In today's fast-advancing world, Deep learning brought the huge potential to the healthcare system and it still undergoes different amazing new techniques. New automatic brain tumor segmentation models have been realized. As a result, it is being much more affordable and faster to save lives. However, most of the tumor detection works are still being conducted with 2D single slices of brain image, although, there are new 3D CNN models with more benefits. Those 3D models enable to scan of brain images in 3d volume. 2D models accept only single slices as input and they innately fail to use context from neighboring slices. Missed voxel data from contiguous slices might affect the detection of tumors and decrease the accuracy of the model. 3D models address this issue by utilizing 3D convolutional kernels to make predictions from volumetric inputs. The capacity to use interslice features can increase the further performance of the model. Therefore, in practice, 3D volumes enable to obtain much more efficient and clear diagnoses. İn this paper we purpose our new 3D MRI reconstruction algorithm based on VTK toolkit.

N. Wilkie, G. McSorley, C. Creighton, D. Sanderson, T. Muirhead and N. Bressan, [6] proposed reasearch work on Mixed Reality for Veterinary Medicine: Case Study of a Canine Femoral Nerve Block. The femoral nerve blockage is a procedure that aims to provide anesthesia to the hip, anterior thigh, and stifle. This procedure presents several challenges when performed in veterinary patients with diverse anatomy and physiology. Successful use of this technique will improve a dog's recovery time after surgery in comparison to the commonly used epidural block. A mixed reality application to guide practitioners in the femoral nerve block procedure was developed in Unity and Visual Studio. A 3D model for use within the application was created from pictures of a cadaver leg using photogrammetry software. The Microsoft HoloLens headset provides the mixed reality hardware platform. This paper presents the workflow used in developing the mixed reality application and custom 3D model, as well as initial results with respect to the utility of the application in guiding an anesthesiologist in the procedure of the femoral nerve block.

M. Aledhari and R. Razzak, [7] proposed research work on An Adaptive Segmentation Technique to Detect Brain Tumors Using 2D Unet. The UNet is one of the most well-known convolutional neural network (CNN) architectures used for biomedical image segmentation. Unfortunately, the 2D variant is typically discouraged for volumetric brain tumor segmentation due to slices being correlated with one another. Thus, 3D-Unets have become prevalent in the annual Multimodal Brain tumor Segmentation Challenge (BRaTS) hosted by the Perelman School of Medicine of University of Pennsylvania (UPenn). However, with unique data preprocessing and generator techniques, 2DUnets may achieve competitive accuracy and performance with 3D-Unets. Furthermore, the addition of residual blocks (R) and squeeze-and-excitation (SE) blocks in the upsampling portion of 2D-Unets could further speed up performance and minimize computational costs without sacrificing f1 or Jaccard's similarity score. This reveals that 2D-UNets for 3D biomedical image segmentation are still valuable. This paper involves the detailed comparison between 2D-Unets and 2D-SE-RUNets for the purposes of segmenting a whole high-grade glioma (HGG) using the metrics of Jaccard's similarity, recall, specificity, and precision. Results indicate that the 2D-SE-RUNet model is superior to the traditional 2D UNet due to efficieny, which can benefit those looking to save computational costs and time.

Zequn Wu, Tianhao Zhao, Chuong Nguyen, [8] proposed reasearch work on 3D Reconstruction and Object Detection for HoloLens. Current smart glasses such as HoloLens excel at positioning within the physical environment, however object and task recognition are still relatively primitive. We aim to expand the available benefits of MR/AR systems by using semantic object recognition and 3D reconstruction. Particularly in this preliminary study, we successfully use a HoloLens to build 3D maps, recognise and count objects in a working environment. This is achieved by offloading these computationally expensive tasks to a remote GPU server. To further achieve realtime feedback and parallelise tasks, object detection is performed on 2D images and mapped to 3D reconstructed space. Fusion of multiple views of 2D detection is additionally performed to refine 3D object bounding boxes and separate nearby objects.

Khaoula Belhaj Soulami, Elias Ghribi, Yassin Labyed, Mohamed Nabil Saidi, Ahmed Tamtaoui, and Naima Kaabouch, [9] proposed research work on Mixed-Reality Aided System for Glioblastoma Resection Surgery using Microsoft HoloLens. Glioblastoma is the most common and primary type of brain cancer. A surgical intervention is the first treatment as it improves the prognosis of the patient. Unfortunately, this type of tumor is aggressive, and difficult to remove completely, which makes the resection surgery more challenging. Magnetic resonance imaging (MRI) is the most used screening technique for brain cancer diagnosis and surgery planning as it provides detailed information about the tumor's location and size. In this paper, we propose a system for the reconstruction of three-dimensional brain models containing a glioblastoma tumors using the Microsoft headset HoloLens. The developed mixed-reality system projects and overlaps the 3D brain model from the MRI images onto the patient's head during the surgery. This system has the potential to simplify the surgery, reduce the surgery high-risk, increase the resection precision, and help remove the tumor tissue as much as possible.

M. FARZANA, M. J. HOSSAIN ANY, M. T. REZA and M. Z. PARVEZ [10] Automated semantic segmentation of brain tumors from 3D MRI images plays a significant role in medical image processing, monitoring and diagnosis. Early detection of these brain tumors is highly requisite for the treatment, diagnosis and surgical pre-planning of the anomalies. The physicians normally follow the manual way of delineation for diagnosis of tumors which is time consuming and requires too much knowledge of anatomy. To resolve these limitations, convolutional neural network (CNN) based U-Net autoencoder model is proposed which performs automated segmentation of brain tumors from 3D MRI brain images by extracting the key features of the tumor. Additionally, Image normalization, image augmentation, image binarization etc. are applied for data pre-processing. Later on, the model is applied to the new 3D MRI brain images to test the accuracy of it. Applying the proposed method, the accuracy is obtained upto 96.06% considering the 18 subjects. Finally, this approach is a well-structured model for segmenting the tumor region from MRI brain images as compare to the other existing models which may assist the physicians for better diagnosis and therefore, opening the door for more precise therapy and better treatment to the patient

Isensee, F., Jaeger, P. F., Kohl, S. A., Petersen, J., & Maier-Hein, K. H. (2021)[11]. Biomedical imaging is a driver of scientific discovery and a core component of medical care and is being stimulated by the field of deep learning. While semantic segmentation algorithms enable image analysis and quantification in many applications, the design of respective specialized solutions is non-trivial and highly dependent on dataset properties and hardware conditions. We developed nnU-Net, a deep learning-based segmentation method that automatically configures itself, including preprocessing, network architecture, training and post-processing for any new task. The key design choices in this process are modeled as a set of fixed parameters, interdependent rules and empirical decisions. Without manual intervention, nnU-Net surpasses most existing approaches, including highly specialized solutions on 23 public datasets used in international biomedical segmentation competitions. We make nnU-Net publicly available as an out-of-the-box tool, rendering state-of-the-art segmentation accessible to a broad audience by requiring neither expert knowledge nor computing resources beyond standard network training.

A. Tamer et al., [12] Over the past decade, auto-segmentation for tumors has drawn a lot of attention due to its significant impact on cancer treatment. Auto-segmentation architectures have a significant role in alleviating the enormous workload on the medical staff. This has motivated us to explore the latest solutions in auto-segmentation to use it in auto-segmentation. It works on automatically contouring tumors to make radiology treatment more attainable since manual contouring is repetitive and subjective to human error. Auto-segmentation usually strives to achieve high accuracy to reduce the time the radiologists take to contour the tumor. Saving time is critical as instead of contouring all the tumors, the radiologist can spend the time editing on the segmented tumor thus more patients can be diagnosed in less amount of time. There have been a lot of auto-segmentation architectures created for general purposes like the Segnet which is sometimes used in medical segmentation, but such architectures fail to achieve high accuracy especially in the details of the tumor. The U-Net is an auto-segmentation architecture specifically created for auto-segmentation on medical images like MRI and CT. The U-Net architecture can achieve high accuracy of segmentation with fewer amounts of data. We improved U-Net performance by using residual blocks on each layer of the architecture itself usually referred to as Res-U-Net. Our final proposed fine-tuned Res-U-Net model has achieved 97.10% on the used data which was the best of our 3 proposed fine-tuned models. The used data was Low-grade gliomas (LGGS) brain tumor dataset.

DISCUSSION

Dr. Pradeep A V, a Radiologist at People Tree Hospital (Yeshwantpur) with work experience of 8 years, graduated from All India Institutes of Medical Sciences (AIIMS), New Delhi

Key points:

1. The software converts the 2D scan into a 3D model with just a click using the software.
2. The development of scanning machines has drastically improved making the acquisition time of machines very less.
3. The recent machines have very high accuracy, when a 3D model is built, small veins also can be built.
4. Challenges with current scans and their 3D modeling is that surgeons still make judgment about where to perform incision.
5. Surgeons keep the scans in the OT for performing surgeries and refer them.
6. Mixed reality based technology is not in use in India yet, and would be very useful for surgeons.

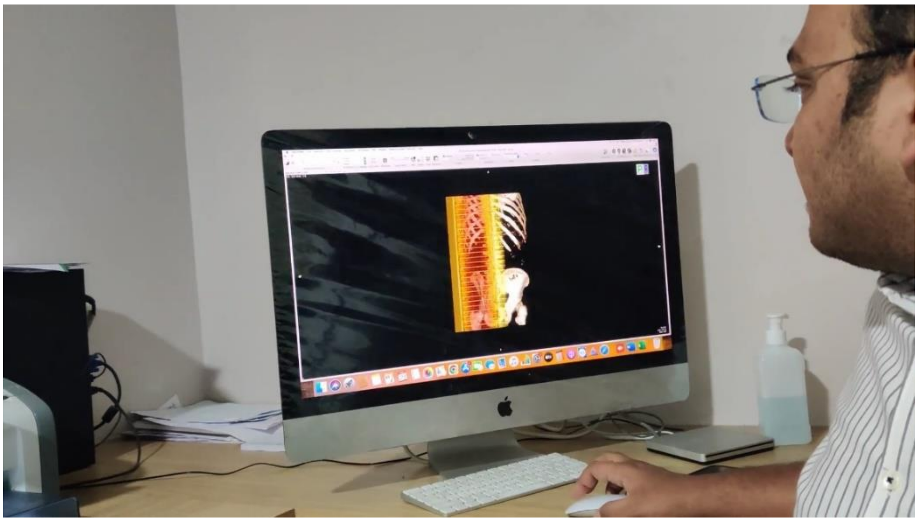

Figure 2.1. Exisiting System

CHAPTER 3

PROBLEM STATEMENT

- The degree or dimensions of the abnormalities due to tumors or injuries in the body part are difficult to visualize in 2D space while diagnosis, thus introducing diagnostic errors.

- About 66% of the surgeries and 6.6% of the surgeries lead to permanent injuries and death respectively due to surgical errors which can be avoided using advanced technologies.

OBJECTIVE

1. Identify suitable method and algorithm for MRI Image Processing.

2. Software implementation of identified algorithm and its functional verification.

3. Integrating the design into the exsisting system to aid healthcare professionals with faster, easier, and more accurate diagnosis and treatment using 3D reconstruction of MRI scans.

Figure 3.1. Mixed Reality

CHAPTER 4
METHODOLOGY

Phase 1: Segmentation

The segmentation is done using two trained Unet models using the nnUnet framework. The two separate nnUnet models have unique architectures optimized for their specific task.

The first model was trained on the Calgary-Campinas-359 (CC-359) dataset, The Calgary-Campinas-359 (CC-359) dataset is a commonly used dataset in medical imaging research, particularly for brain imaging. It consists of 359 T1-weighted magnetic resonance imaging (MRI) scans of the brain, each with a resolution of 256x256x256 voxels. The dataset includes both normal brain images as well as images with tumors and other abnormalities, making it a valuable resource for researchers studying brain diseases and disorders. The primary purpose of this model was to perform brain masking and skull stripping, which involves removing all non-brain tissue from the MRI scan to isolate the brain region. For training the model, 200 datasets were used that accurately segmented the brain from each slice of the MRI scan. We employed a 2D Unet architecture to train this model, which is a popular and widely used architecture for image segmentation tasks. The model was trained for a total of 336 epochs.

The output segmentation file is then used with the input MRI scan to generate a cropped MRI scan of the brain. This MRI scan shows the Skull-stripped MRI scan showing only the brain tissues.

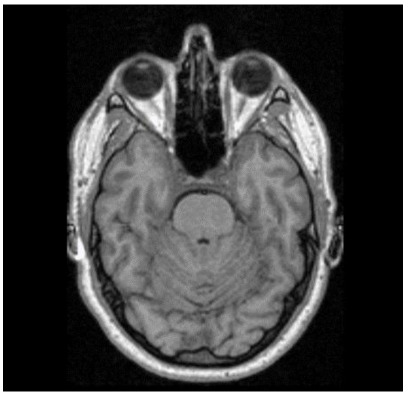

Figure 4.1 : brain MRI

The second model was trained on the BraTS 2020 dataset, The BraTS dataset includes MRI scans of different modalities, such as T1-weighted, T2-weighted, and FLAIR images, as well as ground truth labels for the tumors. The ground truth labels are provided by expert radiologists who manually segment the tumor regions on the images. The dataset is organized into training, validation, and testing sets, with each set containing images and corresponding ground truth labels. The dataset also includes preprocessed images that have been skull-stripped and bias-corrected, as well as raw images that can be used for more advanced preprocessing techniques. There are three masks present, as the tumor is intrinsically heterogenous i.e glioma. The segmentations were mainly enhancing tumor, non-enhancing tumor and edema. This model's primary task was to accurately segment the tumor from the surrounding brain tissue of the cropped MRI scan generated. To accomplish this, we utilized a 3D full-resolution architecture, which has demonstrated superior performance on 3D medical imaging segmentation tasks. The model was trained for 200 epochs.

Figure 4.2 : Brainmask Segmentation

After training was complete, we applied the trained models to a previously unseen test dataset, which comprised MRI scans from patients with brain tumors. The output of the brain mask nnUnet model is a binary mask, while the output of tumor segmenting nnUnet model had 3 masks present.

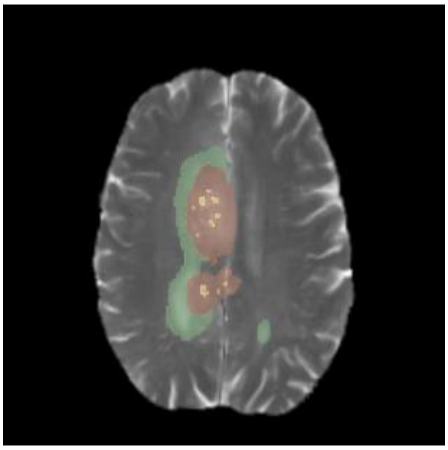

Figure 4.3 : Tumor segmentation

The tumor segmentation file and the brain mask segmentation file are merged into a single file by overlapping the tumor on the brain mask. Since the dimensions of both the files are the same of that of the input MRI scan, the overlapping procedure does not lead to errors. It is implemented by a custom Python script using the NumPy and Nibabel libraries. The script takes the file paths of the brain mask segmentation and tumor segmentation files as input and outputs a new brain mask segmentation file with the tumor overlaid.

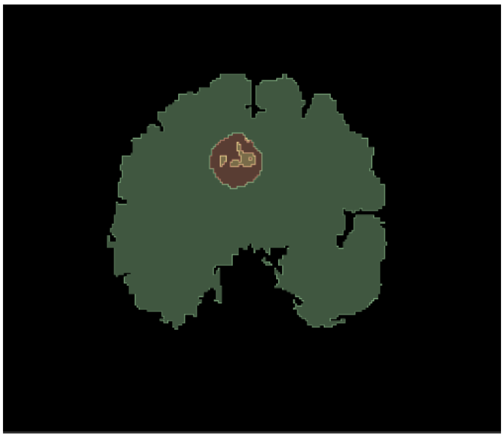

Figure 4.4 : Merged segmentations

First, the script loads the brain mask segmentation file and its data using the nib.load() and get_fdata() functions, respectively. It then loads the tumor segmentation file and its data in the same way. The overlapping voxels between the two segmentations are identified using the np.where() function. Next, the script updates the brain mask segmentation data at the overlapping voxels by adding a discreet value to the corresponding voxels in the tumor segmentation data. This ensures that the tumor voxels are distinguishable from the brain mask voxels in the overlaid segmentation.

Finally, the script saves the updated brain mask segmentation data as a new NIfTI file using the nib.Nifti1Image() and nib.save() functions. The output file name can be specified by the user.

Phase 2: 3D Reconstruction

The final segmentation file is loaded using the ITK library and then converted to a VTK image. The VTK image is written to the disk in the MetaImage format using the vtkMetaImageWriter function.

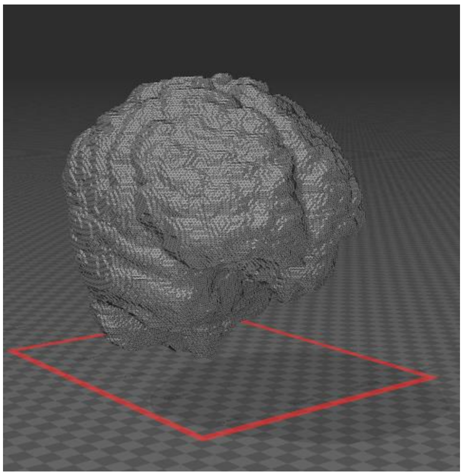

Figure 4.5 : 3D Reconstruction

Then, the marching cubes algorithm is applied to extract a surface mesh from the volume using the vtkMarchingCubes function. This algorithm creates an isosurface, i.e., a 3D surface representing a specific value of the input image. In this case, the isovalue is set to 1, which corresponds to the tumor region in the brain mask segmentation. The resulting surface mesh is stored in vtk_polydata. Finally, the reconstructed surface mesh is written to the disk in the OBJ format using the vtkOBJWriter function.

Phase 3: Augmented Reality and Device Integration

The augmented reality (AR) functionality is integrated into the project using an AR development kit such as Vuforia or ARKit. Once the 3D model of the segmented brain tumor is created, it is imported into a 3D modeling software such as Unity. The 3D model is then rendered as an AR object that can be viewed through a smartphone or tablet camera. The app is designed with interactive features, such as touch-based controls, to allow the user to manipulate and explore the 3D model. Additional features, such as real-time data visualization or audio instructions, can also be integrated to provide a more immersive experience. The app is tested on different devices and adjusted as necessary to ensure compatibility and performance.

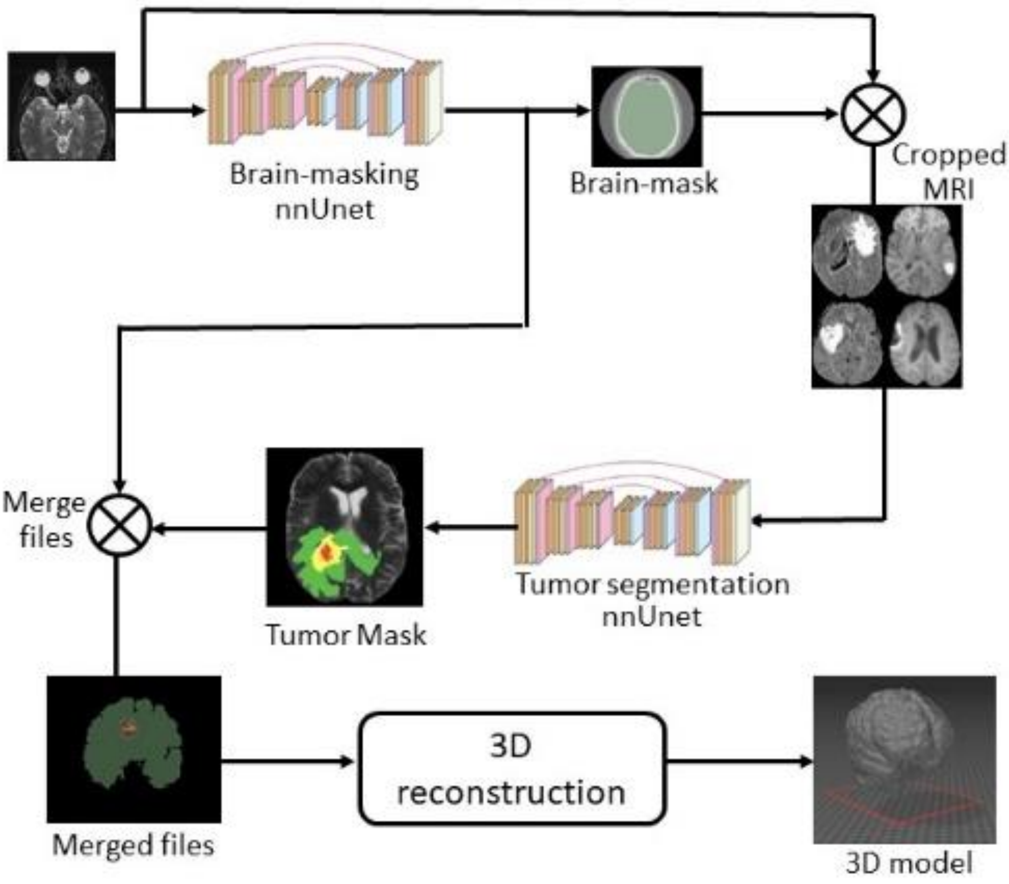

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Figure 4.1 Flowchart

CHAPTER 5

REQUIREMENTS

• Unity

Unity is a popular game engine that can be used to develop mixed reality experiences, including augmented reality (AR) and virtual reality (VR) applications. Unity offers a range of tools and features that make it easy for developers to create interactive and immersive mixed reality content.To create mixed reality experiences using Unity, developers can use the engine's scripting language (C#) to create interactions and behaviors for virtual objects. They can also use Unity's visual scripting tool, called "Playmaker," to create more complex interactions without needing to write code.

Overall, Unity is a powerful tool for creating mixed reality experiences, and it is widely used by developers in a variety of industries, including gaming, entertainment, education, and healthcare.

Figure 5.1. Unity Logo

● Vuforia

Vuforia is an augmented reality software development kit (SDK) for mobile devices that enables the creation of augmented reality applications. It uses computer vision technology to recognize and track planar images and 3D objects in real time. This image registration capability enables developers to position and orient virtual objects, such as 3D models and other media, in relation to real world objects when they are viewed through the camera of a mobile device. The virtual object then tracks the position and orientation of the image in real-time so that the viewer's perspective on the object corresponds with the perspective on the target. It thus appears that the virtual object is a part of the real-world scene.

Vuforia is a software platform that can be used to create mixed reality (MR) experiences, specifically augmented reality (AR) applications. Vuforia allows developers to create AR applications that can detect and track specific images or objects in the real world, and then superimpose virtual content onto the camera feed in a way that appears to blend seamlessly with the physical environment.To create MR experiences using Vuforia, developers can use the platform's image recognition and object tracking features to define the real-world elements that will trigger the display of virtual content.

Figure 5.2. Vuforia Logo

● 3D Slicer

3D Slicer is a free, open-source software platform for medical image analysis and visualization. It is developed and maintained by the Slicer Community, a group of researchers, developers, and clinicians who collaborate to advance the field of medical image analysis.

3D Slicer is a powerful tool for analyzing and visualizing 3D medical images, such as CT (computed tomography) and MRI (magnetic resonance imaging) scans. It includes a range of features and tools for processing and analyzing image data, including image registration, segmentation, and visualization. It also includes a large number of pre-built modules for specific tasks, such as brain image analysis, cardiovascular image analysis, and cancer image analysis. Slicer is used in a variety of medical applications, including autism, multiple sclerosis, systemic lupus erythematosus, prostate cancer, lung cancer, schizophrenia, orthopedic biomechanics, COPD, cardiovascular disease and neurosurgery. Slicer is used in a variety of medical applications, including autism, multiple sclerosis, systemic lupus erythematosus, prostate cancer, lung cancer, schizophrenia, orthopedic biomechanics, COPD, cardiovascular disease and neurosurgery. Slicer is used in a variety of medical applications, including autism, multiple sclerosis, systemic lupus erythematosus, prostate cancer, lungcancer, schizophrenia, orthopedic biomechanics, COPD, cardiovascular disease and neurosurgery.

3D Slicer provides image registration, processing of DTI (diffusion tractography), an interface to external devices for image guidance support, and GPU-enabled volume rendering, among other capabilities. 3D Slicer has a modular organization that allows the addition of new functionality and provides a number of generic features not available in competing tools.

One of the main features of 3D Slicer is its support for a wide range of medical image formats, including DICOM, NRRD, and MHA. You can use 3D Slicer to load and view the MRI scans you are using in your project, as well as perform segmentation and other image processing tasks.

In your project, you can use 3D Slicer for various tasks related to MRI segmentation, such as:

- Preprocessing: 3D Slicer provides various tools for preprocessing MRI data, such as correcting image artifacts and normalizing the intensity values.
- Segmentation: 3D Slicer provides a range of segmentation algorithms, such as thresholding and region growing, which can be used to segment specific regions of interest within the MRI scans.
- Visualization: 3D Slicer provides powerful tools for visualizing the segmented data, such as rendering 3D models, creating cross-sectional views, and generating volume renderings.
- Analysis: 3D Slicer provides various tools for analyzing the segmented data, such as calculating volumes, measuring distances, and performing statistical analyses.

One of the key advantages of using 3D Slicer in your project is its ability to integrate with ITK and VTK. This allows you to perform advanced image processing and 3D modeling tasks using the algorithms provided by ITK and VTK within the 3D Slicer environment. Additionally, 3D Slicer provides a powerful set of tools for viewing and manipulating 3D models, which can be useful for visualizing and analyzing the results of your segmentation and modeling processes.
In summary, 3D Slicer can be a valuable tool in your project for medical image processing,

segmentation, and 3D modeling, especially when used in conjunction with ITK and VTK. In addition, 3D Slicer provides a module for 3D modeling and printing, which can be used to create 3D models from the segmented MRI scans. You can use this module to create high-quality 3D models that accurately represent the regions of interest within the MRI scans.

Figure 5.3. 3Dslicer

- ## Mixed Reality Headset

In general, a mixed reality headset is a device that allows users to experience a combination of real and virtual worlds. These headsets typically use a combination of sensors, cameras, and displays to create an immersive environment in which physical and digital objects can coexist and interact.

There are several types of mixed reality headsets on the market, including augmented reality (AR) headsets, which superimpose digital content onto the real world, and virtual reality (VR) headsets, which create a fully immersive digital environment. Some headsets offer a hybrid of both AR and VR, allowing users to experience a mix of real and virtual elements in a single environment.

Figure 5.4. Mixed Reality Headset

- **Mobile Phone (Application)**

An augmented reality (AR) application is a type of software that superimposes digital content onto the real world in real time, using a device such as a smartphone or tablet. This allows users to view and interact with virtual objects and information as if they were physically present in their environment.

AR applications can be used for a variety of purposes, including entertainment, education, and productivity. For example, an AR game might allow users to catch virtual creatures in the real world, while an AR education app might provide interactive lessons and quizzes. An AR productivity app might allow users to view and interact with virtual documents and tools in a real-world workspace.

To create an AR application, developers typically use specialized software and tools, such as Unity or Vuforia. These allow them to create and design the virtual content, as well as set up the AR technology and interactions.Overall, AR applications provide a new and immersive way to view and interact with digital content, and have the potential to revolutionize a wide range of industries and applications.

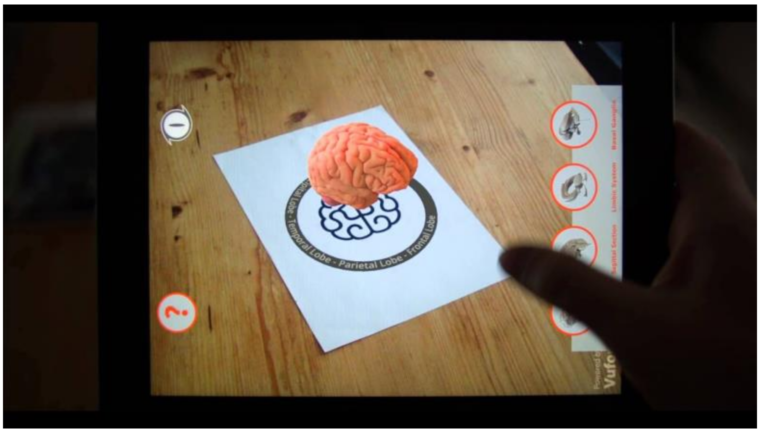

Figure 5.6. AR Application

- ## Jupyter Notebook

Jupyter Notebook is an open-source web application that allows you to create and share documents that contain live code, equations, visualizations, and narrative text. It is commonly used for data analysis, scientific computing, machine learning, and other fields of research.

Jupyter Notebook supports several programming languages, including Python, R, Julia, and many others. The notebooks can be run on your local machine or on a remote server, making it easy to collaborate with others or work on projects from anywhere.

Figure 5.7. Jupyter Logo

Jupyter Notebook is a web-based interactive computational environment that allows you to create and share documents containing live code, equations, visualizations, and narrative text.

One of the primary benefits of using Jupyter Notebook is that it allows you to write and execute code in an interactive and iterative way. You can use Jupyter Notebook to load and preprocess the MRI data, perform segmentation using nnU-Net, and train machine learning models using

ITK and VTK. You can also use Jupyter Notebook to visualize and analyze the results of your experiments, including accuracy metrics, loss curves, and segmentation visualizations.

Another benefit of Jupyter Notebook is that it allows you to document and share your work with others in a reproducible and transparent way. You can use Jupyter Notebook to write explanations and comments alongside your code, and share your notebook with colleagues or collaborators for review and feedback.

In addition, Jupyter Notebook supports various programming languages, including Python, R, and Julia, which makes it a versatile tool that can be used in a wide range of projects and applications. Overall, Jupyter Notebook can be a powerful tool that can help you streamline and automate various aspects of your project, including data preprocessing, model training, and result visualization. It can also facilitate collaboration and communication among project members and help ensure the reproducibility and transparency of your work.

- **Python (Programming Language)**

Python is a popular programming language that is widely used in the field of scientific computing, including medical imaging and analysis. In your project, Python can be used for various tasks, including data preprocessing, machine learning, and visualization.

One of the primary benefits of using Python in your project is that it provides a rich ecosystem of libraries and frameworks for scientific computing. For example, you can use libraries such as NumPy, Pandas, and SciPy to perform data preprocessing and analysis, and libraries such as TensorFlow, PyTorch, and Scikit-learn to train machine learning models for MRI segmentation.

Figure 5.8. Python

Python can also be used for visualization and data presentation. Libraries such as Matplotlib and Seaborn allow you to create various types of plots and graphs to visualize the MRI data and the results of your experiments. Additionally, Python can be used to create interactive visualizations and dashboards using libraries such as Plotly and Bokeh.

Another benefit of using Python in your project is that it is a widely used and supported programming language with a large and active community. This means that you can find a wealth of resources, tutorials, and forums online to help you with any challenges or questions you may have during the course of your project.

Overall, Python can be a powerful tool for your project, providing you with the necessary libraries and frameworks to perform various tasks related to medical image processing, analysis, and visualization.

- ## Linux (Operating System)

Linux is an open-source operating system that is widely used in scientific computing, including medical imaging and analysis. In your project, Linux can be used for various purposes, including software installation, data management, and automation.

One of the primary benefits of using Linux in your project is that it provides a stable and secure environment for your work. Linux is known for its stability and reliability, which is important when working with large datasets and complex software tools. Additionally, Linux is known for its security features, which can help protect your data and ensure that your work remains confidential. Linux can also be used to manage and organize your data. You can use the command line interface (CLI) in Linux to move, copy, and rename files and directories, as well as to perform other data management tasks. Additionally, you can use tools such as rsync and scp to transfer data between different systems and locations.

Another benefit of using Linux in your project is that it provides a rich ecosystem of software tools and packages that are essential for scientific computing. For example, Linux provides a package management system that makes it easy to install and update software packages such as Python, ITK, VTK, and other libraries that you may need for your project.

Finally, Linux can be used for automation and scripting, which can help you save time and increase productivity. You can use shell scripts to automate repetitive tasks, such as data preprocessing and model training, and use cron jobs to schedule tasks to run automatically at specific times.

Figure 5.9. Ubuntu Linux

- ## VTK (Visualization Tool Kit)

VTK (Visualization Toolkit) is a powerful open-source software system for 3D computer graphics, image processing, and visualization. It is widely used in scientific computing, including medical imaging and analysis. In your project, VTK can be used for various purposes, including data visualization, volume rendering, and segmentation.

One of the primary benefits of using VTK in your project is that it provides a rich set of tools and algorithms for visualizing and processing 3D data. VTK includes a wide range of visualization and analysis tools, such as surface and volume rendering, contouring, and iso-surfacing, as well as tools for data processing, such as image smoothing, noise reduction, and segmentation.

VTK also supports a wide range of file formats, including DICOM, NIFTI, and other medical imaging formats, which makes it a valuable tool for medical image processing and analysis. In addition, VTK is designed to be extensible, which means that you can customize and extend its functionality to suit your specific needs. You can use VTK in combination with other libraries and tools, such as ITK and Python, to create custom workflows and pipelines for your project.

Finally, VTK has a large and active community of developers and users, which means that you can find a wealth of resources, tutorials, and forums online to help you with any challenges or questions you may have during the course of your project. Overall, VTK can be a powerful tool for your project, providing you with a rich set of tools and algorithms for visualizing and processing 3D data, as well as a large and active community of developers and users to support you in your work.

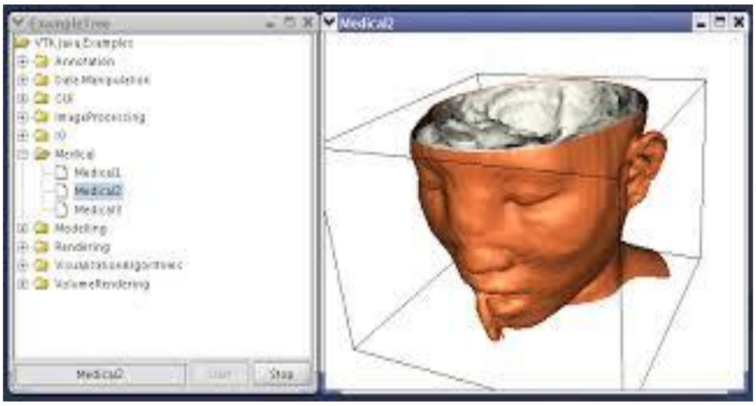

Figure 5.10. VTK

- **ITK (Insight Segmentation and Registration Toolkit)**

ITK (Insight Segmentation and Registration Toolkit) is an open-source software system for image processing and analysis. It is widely used in scientific computing, including medical imaging and analysis. In your project, ITK can be used for various purposes, including image segmentation, registration, and analysis.

One of the primary benefits of using ITK in your project is that it provides a rich set of tools and algorithms for image processing and analysis. ITK includes a wide range of image processing and analysis tools, such as registration, segmentation, filtering, and feature extraction, as well as tools for statistical analysis. ITK also supports a wide range of file formats, including DICOM, NIFTI, and other medical imaging formats, which makes it a valuable tool for medical image processing and analysis.

In addition, ITK is designed to be extensible, which means that you can customize and extend its functionality to suit your specific needs. You can use ITK in combination with other libraries and tools, such as VTK and Python, to create custom workflows and pipelines for your project.

Finally, ITK has a large and active community of developers and users, which means that you can find a wealth of resources, tutorials, and forums online to help you with any challenges or questions you may have during the course of your project.

Overall, ITK can be a powerful tool for your project, providing you with a rich set of tools and algorithms for image processing and analysis.

Figure 5.11. ITK Logo

- **Boston x86 Server**

Boston Limited is a company that provides computing solutions for various industries, including scientific research, artificial intelligence, and machine learning. The Boston x86 server is a high-performance server that is designed for demanding workloads, such as data analytics, machine learning, and scientific computing. The Boston x86 server is based on the latest Intel Xeon processors and is optimized for performance and scalability. It can support multiple GPUs for parallel processing, and can also support large amounts of memory and storage for data-intensive applications.

One of the primary benefits of using the Boston x86 server in your project is that it provides a high-performance computing platform that can handle large amounts of data and complex calculations. This can be particularly important for projects that involve medical image processing, which can require significant computing resources. In addition, the Boston x86 server is designed for easy management and maintenance, with features such as remote management and monitoring, which can help to reduce the workload and complexity of managing large computing clusters.

Figure 5.12. Boston x86 Server

CHAPTER 6

RESULTS & DISCUSSION

The Holovision project aims to leverage deep learning and augmented reality technology to improve the diagnosis, visualization and understanding of brain tumors. The project involves acquiring a dataset of brain tumors in NIFTI format from the internet, segmenting the tumors using a deep learning architecture called nnU-Net, and reconstructing the segmented tumors in 3D using ITK and VTK. The 3D reconstructed tumors are then deployed onto a Unity application with Vuforia for viewing in augmented reality.
Two Unity applications were developed for displaying the brain tumor model:

1. Marker-Based (Maker) Application: The marker-based application, also known as the Maker application, utilizes a pre-defined marker to anchor the virtual model of the brain tumor in the real world. This marker can be a printed image or an object with a distinct pattern that is recognized by the application. Once the marker is detected by the

application, the 3D model of the brain tumor is overlaid onto the marker, allowing users to view the tumor in augmented reality. This application is useful in situations where the user wants to view the tumor in a specific location, such as on a table or desk.

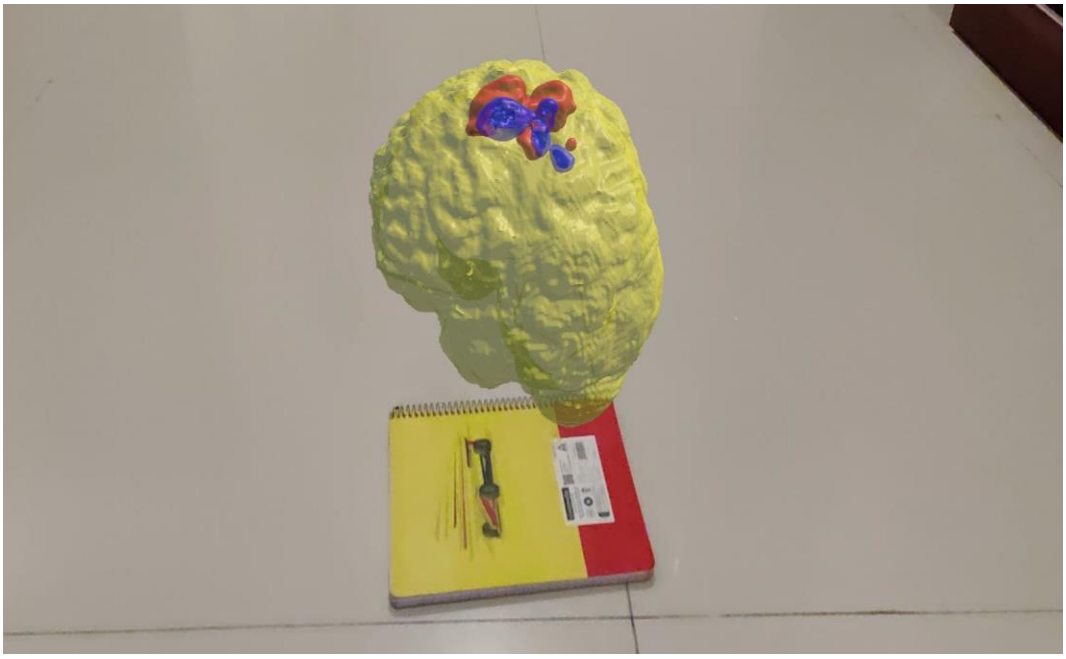

Figure 6.1 : Marker-Based AR -1

Figure 6.2 : Marker-Based AR -2

2. Markerless Application: The markerless application, on the other hand, does not require a pre-defined marker to anchor the virtual model of the brain tumor. Instead, the application uses computer vision techniques to detect features in the real world

environment, such as edges or corners of objects, to anchor the virtual model. This allows users to view the tumor in augmented reality without needing to place a marker in the real world. This application is useful in situations where the user wants to view the tumor in a more natural setting, such as in a patient's room or in a surgical theater.

Figure 6.3 : Marker-less AR - 1

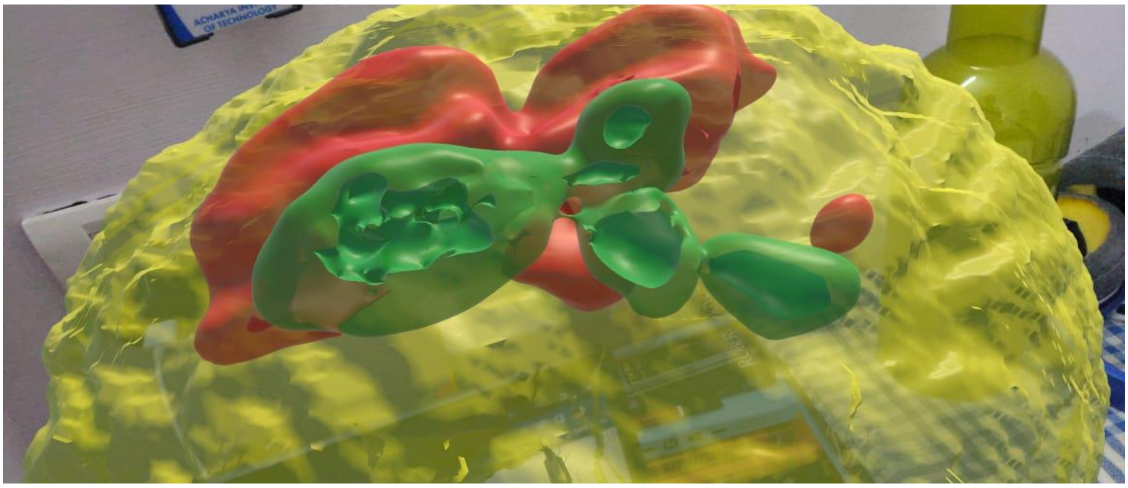

Figure 6.4 : Markerless AR -2

Both applications allow users to interact with the 3D model of the brain tumor in augmented reality. Users can view it from different angles and perspectives. The applications also provide additional information about the tumor, such as its location, size, and type, which can aid in diagnosis, treatment planning, and patient education.

The development of both marker-based and markerless applications provides flexibility in the way users can view and interact with the brain tumor model. This can improve the usefulness and accessibility of the application in different medical settings.

The goal of the project is to provide medical professionals with a more accurate and intuitive way of diagnosing, visualizing and understanding brain tumors, which can aid in diagnosis, treatment planning, and patient education. The project aims to improve upon existing visualization techniques by providing a more interactive and immersive experience through augmented reality technology. The ultimate goal is to contribute to the advancement of medical technology and improve patient outcomes.

CHAPTER 7

FUTURE SCOPE

The potential future scope of the project :

- Improve accuracy: One potential future scope for your project could be to improve the accuracy of the brain tumor segmentation. This could involve experimenting with different deep learning models or improving the training data set to increase accuracy.
- Expand to other medical applications: Once the brain tumor segmentation and visualization have been successfully implemented, you could explore other medical applications for this technology. For example, you could explore segmenting other types of tumors or visualizing other medical conditions in augmented reality.
- Real-time segmentation and visualization: Another potential future scope could be to develop real-time segmentation and visualization of the brain tumor. This would require optimizing the deep learning model and visualization techniques to work in real-time, which could have applications in surgery or other medical procedures.
- Collaborate with medical professionals: You could also consider collaborating with medical professionals to incorporate their feedback and expertise into your project. This

could help to identify areas for improvement and potential new applications for the technology.

- Integration with electronic medical records (EMR): Another future scope for your project could be to integrate the brain tumor segmentation and visualization into electronic medical records (EMR) systems. This could improve patient care and provide medical professionals with easy access to the visualizations and data.

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