

**COLOUR CODED DEEP INFORMATION REGARDING
MEDICAL VOLUME RENDERING**

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Technology Degree in Biomedical Engineering

By

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SCHOOL OF BIO AND CHEMICAL ENGINEERING

DEPARTMENT OF BIOMEDICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY (DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE

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MAY – 2022



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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **AKSHYA.V (Reg. No.38240004)**, who carried out the project entitled "**COLOUR CODED DEEP INFORMATION IN MEDICAL VOLUME RENDERING**" under our supervision from **September 2021 to March 2022**.

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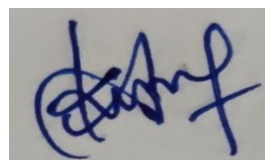
External Examiner

DECLARATION

I, **AKSHYA V (38240004)**, thereby declare that the Project Report entitled **COLOUR CODED DEEP INFORMATION REGARDING MEDICAL VOLUME RENDERING** done by me under the guidance of Dr. Sudhakar T (Internal) at Sathyabama Institute of Science and Technology is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Biomedical Engineering.

DATE: 23/04/2022

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SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

I am pleased to acknowledge my sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

I would like to express my sincere and deep sense of gratitude to my Project Guide **Dr. Sudhakar T, M.Sc., Ph.D., Head of the Department, Department of Biomedical Engineering** for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of our project work.

We wish to express our thanks to all **Teaching and Non-teaching** staff members of the **Department of Biomedical Engineering** who were helpful in many ways for the completion of the project.

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ABSTRACT

The benefits of medical imaging are enormous. Medical images provide considerable amounts of anatomical information and this facilitates medical practitioners in performing effective disease diagnosis and deciding upon the best course of medical treatment. A transition from traditional monochromatic MRI images to a coloured 2D representation of the anatomical structure could further aid medical professionals in extracting valuable medical information. The proposed framework in our research starts with performing colour transfer by finding deep semantic correspondence between two medical images: a coloured reference image, and an MRI image. We extend this idea of reference-based colorization technique to perform coloured volume rendering from a stack of grayscale medical images. Furthermore, we also propose to use an effective reference image recommendation system to aid for selection of good reference images. With our approach, we successfully perform coloured medical volume visualization and essentially eliminate the painstaking process of user interaction with a transfer function to obtain colour parameters for volume rendering with induced haptics.

LIST OF ABBREVIATIONS

ABBREVIATIONS	EXPANSIONS
PC	PERSONAL COMPUTER
CT	COMPUTED TOMOGRAPHY
API	APPLICATION PROGRAMMING INTERFACE
GUI	GRAPHICS USER INTERFACE
MIP	MAXIMUM INTENSITY PROJECTION
GPU	GRAPHICAL PROCESSING UNIT
IVD	INTERVERTEBRAL DISC
ALL	ANTERIOR LONGITUDINAL LIGAMENT
PLL	POSTERIOR LONGITUDINAL LIGAMENT
MRI	MAGNETIC RESONANCE IMAGING
CNN	CONVOLUTIONAL NEURAL NETWORK
NMR	NUCLEAR MAGNETIC RESONANCE
GLCM	GRAY LEVEL CO-OCCURRENCE MATRIX
DICOM	DIGITAL IMAGING AND COMMUNICATIONS IN MEDICINE
MATLAB	MATRIX LABORATORY

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CHAPTER 1

INTRODUCTION

The contribution of this study is primarily in volume rendering. Using volume rendering acceleration in computer graphics has become very important due to fast evolution of the graphics processing devices in the recent years. The vast amount of production and development of computer graphics devices in the industry enabled the consumers to own high performance graphics computation power without a high expenditure on workstations. The main focus of our study is on the capabilities of software accelerated volume rendering techniques.

1.1 MOTIVATION:

The main motivation for this study “Colour Coded Deep Information Regarding Medical Volume Rendering” is to propose useful solutions and techniques by gaining insights for the visualization section from the project: “*Three Dimensional Brain Image Processing*” which is directed by Assist. Prof. Dr. Erkan Mumcuoğlu in the *Informatics Institute* department of *Middle East Technical University*. The primary focus of this project is to register medical imaging volumetric datasets of patient’s brain which were acquired with different modalities (Nuclear Medicine, Radiology, etc.) and visualize them in three dimensional spaces for the medical staff use.

The main advantage of *Nuclear Medical Imaging* studies is to present not only the morphologic information about the organ systems of the patients, but also give information about their functions. The medical images acquired by *Radiology Technology* present a higher level of detail for the anatomical structures of the patient’s organ systems. However, they present less information about the functions. The main disadvantage of Nuclear Medical Imaging is that the resolution of the acquired datasets is very low.

Technology, and the small structures may not be localized correctly. In some situations, there is a requirement for building a correlation between the results acquired by both of the techniques for better diagnostics, and guide the surgeon before an operation by localizing the functional information with the anatomical structure. This process is called *co-registration*, which requires sophisticated hardware and software systems. Even though the results are registered, visualizing the datasets in a three-dimensional environment using computer graphics has a great importance on enabling doctors to understand the structures more clearly.

There are many researches about this phenomenon, and in many developed countries such techniques are being used. In *SIMS Hospital Vadapalani*, very sophisticated devices are used for acquiring medical imaging datasets on different modalities, however this co-registration and visualization with computer graphics processes cannot be established. *Analyze* [37] is one of the most popular software systems for establishing this technique; However, it requires a huge amount of expenditure.

The aim of the project “Color Coded Deep Information in Medical Imaging Processing” is to develop a system that is able to co-register and visualize multimodality medical image datasets according to the requirements, and distribute this system to the hospitals that are interested, with no fee. The motivation for our studies is to propose a solution for the visualization section of this project.

1.2 ORGANIZATION OF THE THESIS:

This Thesis has 6 Chapters:

Chapter 1: Gives the motivation and some introductory information about visualization. It also mentions different methods of computer visualizations.

Chapter 2: Gives detailed information about the Literature Survey undertaken.

Chapter 3: Summarizes the aim of the thesis and the different kinds of scope that this thesis might tend to offer in the near future.

Chapter 4: Presents detailed information about materials and methods of the implementation developed for this thesis.

Chapter 5: Gives the testing results and discussed of the implementation and presents some qualitative comparison with software *Analyze*.

Chapter 6: Concludes the thesis by discussing the results of the tests, and gives a pathway for the future studies.

1.3 THREE-DIMENSIONAL VISUALIZATION:

“Forming an image is *mapping* some property of an object onto *image space*. This space is used to visualize the object, and its properties and may be used to characterize quantitatively its structure or function. Imaging science may be defined as the study of these mappings and the development of ways to better understand them, to improve them, and to use them productively”.

3D visualization refers to the process of transforming and displaying the three-dimensional objects in a way that their nature is able to be seen. 2D display devices that visualize shaded graphics of the rendered objects or 3D display devices that enable stereoscopic or holographic type of displays are used for visualizing the outputs of 3D visualization methods. The term *visualization* not only concerns methods for displaying but also includes methods for manipulating and analyzing the displayed information, “this term implies inclusion of cognitive and interpretive elements”. The term *3D imaging* is generally defined as acquiring digital samples of objects in a three-dimensional environment. This term also includes processing, analyzing and visualizing of the sampled datasets.

1.4 METHODS OF THREE-DIMENSIONAL VISUALIZATION:

There are various kinds of techniques used for visualizing 3D datasets. The generally used methods especially in biomedical research and clinical applications shall be defined briefly in this section.

1.5 2D DISPLAY:

2D image generation and display methods aim to generate optimal 2D images from 3D volumetric datasets by allowing the user to set the orientation of the 2D image plane for visualizing unrestricted view of important features in the sampled 3D information.

Multiplanar Reformatting is the process of constructing 2D images from the volumetric dataset by reslicing the set of data in any arbitrary spatial direction which visualize the images that lie along the non-acquired orthogonal orientations of the volume. Figure 1.1 [38] shows an example for this method of display.

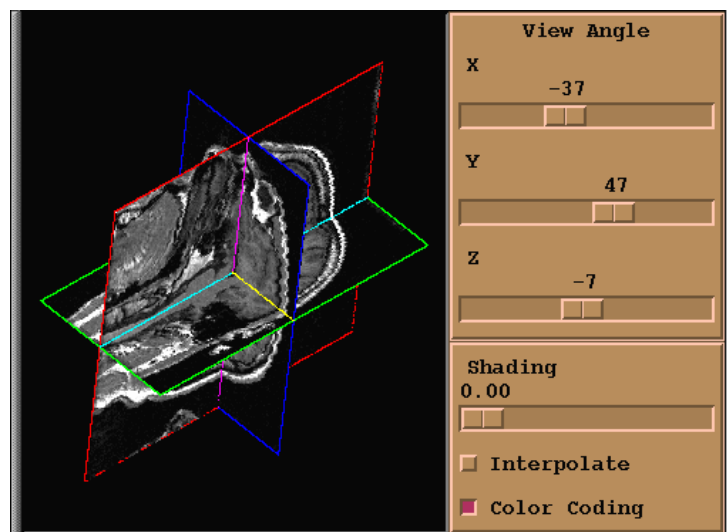


Fig 1.5.1: Multiplanar slicing

Oblique Sectioning is the method of visualizing a desired plane in the 3D volumetric dataset that is not parallel to any orthogonal orientation in which the volume has been acquired. An example display for oblique sectioning is given in Figure 1.5.2.

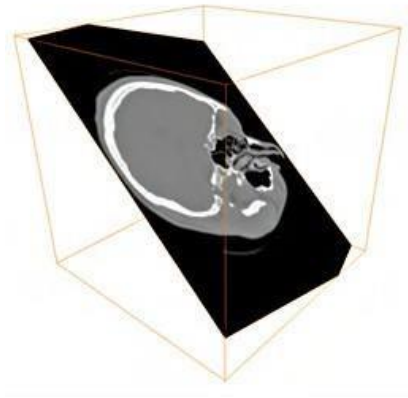


Fig 1.5.2: Oblique Sectioning

Curved Sectioning is the method of displaying structures that have curvilinear morphology which oblique and multiplanar methods cannot display. An example for curved sectioning is given in Figure 1.5.3.

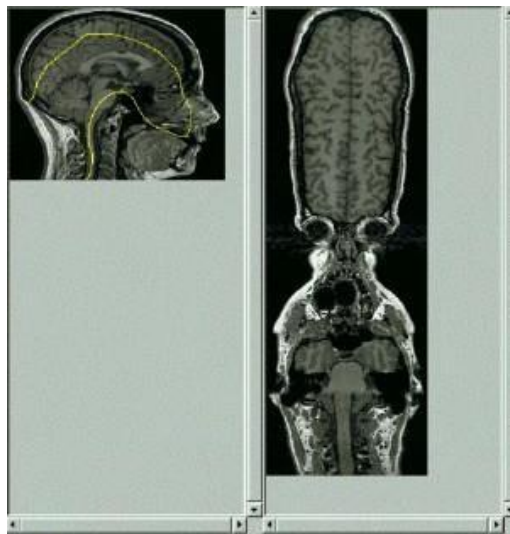


Fig 1.5.3: Curved Sectioning

CHAPTER 2

LITERATURE SURVEY

B. Mados, et. al (2021), It deals with the problematics of the dense volume datasets representation, wherein voxels are formed as multi-bit scalar values, and are briefly oriented to the use of hierarchical data structures, not only as the medium for encoding and storing of volume datasets, but also for maintaining their lossless compression. The main contribution is in the design of the hierarchical data structure, that permits the carving of subtrees, which are homogenously filled not only by binary symbols, but by any other mathematical representation of voxel value from defined set of values. Designed data structure provides the possibility of acquiring fixed-length and also variable-length according to the (Huffman) encoding of voxel values in leaf node level of the data structure and also in the non-leaf nodes.

Chaoqing Xu, et. al (2021), Through the analysis and comparison across different feature categories and their enhanced technologies, identified two patterns: First, property enhancement volume rendering techniques (external feature and internal feature) put emphasis on visual mapping, while perception enhancement volume rendering techniques (structure feature and ideographic feature) focus more on interactive visualization design. Second, different types of feature enhancement are not purely independent but interact with each other.

Dominik Engel, et. al (2021) A novel deep learning-based technique for volumetric ambient occlusion in the context of direct volume rendering. The proposed Deep Volumetric Ambient Occlusion (DVAO) approach can duly predict the per-voxel ambient occlusion that persist in volumetric data sets, while considering global information provided via the transfer function. The proposed neural network only needs to be executed upon change of this global information, and thus supports real-time volume interaction. Accordingly, the DVAOs ability to predict volumetric ambient occlusion, appears such that it can be applied directly and interactively to volume rendering process.

Fajar, Santoso, et. al (2018) The research focusses on rendering the DICOM images to volumetric images by using the ray marching method. Then automatically each part of the brain is colorized by computing the transfer functions based on the value of grayscale display, which is compared to the tissue density. The proposed method focuses on the value which each colorized part of the brain as well as the use of ray marching algorithm to the module produce colorized result in 3D.

Jakob Weiss and Nassir Navab et. al (2021), Complex relations where the system learned to discriminate between larger and smaller vessels to only highlight the artery. This act of inferring the 3D semantic that the user is looking for, and adapting the visualization accordingly, will be an immensely powerful tool to enable future intuitive user interaction with complex dimensional data.

Ji Ma et. al (2021), Accurate extraction and visualization of the target features allows the user to depict a meaningful view of their targets. The conventional methodology to generate visualization results is 1D TF-based volume visualization, which uses a 1D -TF to determine the optical properties of each voxel. Using the traditional transfer function at times might fail to extract some of the important target features and generate less accurate results. It is proposed that extracting and segmentation techniques based on K-means algorithm allows the users to segment and enhance single or multiple targets by means of a single point to view the features in three-dimensional view.

Nadin Kokciyan et. al (2021), Digital signal systems are widely applied in the medical domain, due to the complexity of the domain and to maintain the sheer volume of data that render the manual processing of grayscale 2D images difficult. This article proposes a metalevel argumentation-based decision-support system that can reason with heterogeneous data (inclusive of: body measurements, electronic health records, clinical guidelines), while incorporating the preferences of the human beneficiaries of those decisions. The system constructs template-based explanations for the recommendations that it makes.

Pavlov Mykhaylov et. al (2021), This method is for visualizing multi-volume data and function-based surfaces using a GPU proposal. It involves the provision of visualization of functionally defined grayscale surfaces, complex semi-transparent volumes, including intersections of volumetric data in structural solid modeling. Rendering different volumes at the same time is more difficult than rendering a single volume, because intersecting and blending operations are required. Function-based surfaces are used to visualize implants. The method uses bounding three-dimensional texture shells.

Simone Bianco et. al (2015), Users are often allowed to choose colors in such a way that cannot be reproduced, distinguished by the human eye, or which are easily misinterpreted. The broad range of variables involved, as well as the interactions and the trade-offs amongst them, pose threats in selecting specific colors, in predicting their appearance when they are seen in with respect to others, and in predicting the observers' interpretation and reaction to them. The goal of the proposal is to critically discuss how a color scale should be designed to effectively represent both qualitative and quantitative information.

Sudha Rani et. al (2021), It includes the computation of accurate volumes of tumors from 2D MRI images. In MRI images, the presence of tumor differs significantly and discretely due to the variation of the tissue cells. A perfect segmentation technique includes the separation of the tumor tissue from the neighboring healthy brain tissue to extract precise volumetric models. This research explains an effective technique for volume rendering of brain from 2D MRI slices. For medical research, the assessment of the pre-operative volume of tumor is highly essential.

Xianhua Zeng et. al (2020), The pre-existing medical imaging technologies. Classical hand-craft features-based methods have obtained some unsatisfactory results in coloring medical radiological images. Moreover, these methods ignore the deep feature of medical images that represent pathology and have little consideration on color information, thus most of medical images are on a grayscale color information. This paper has a proposal of a novel methodology that iteratively colorizes grayscale medical images under preserving content in fine-tuned deep neural network. To the best of our knowledge, there is no currently work that

attempts to colorize the medical image by using deep neural network. Specifically, Y-loss which is defined as nonlinear combination of ℓ_1 and ℓ_2 norm to preserve content invariance between target and colorized medical image.

Xinmei Fu et. al (2021), Aims at improving the efficiency of medical visualization for computer aided surgeries, a fast and unsupervised 3D-CNN based non-local feature learning network. The proposed network consists of an encoder and a decoder structure. The encoder of the network projects the cube into a high-dimensional feature space, and the decoder of the network works to reconstruct the cube from the feature space. The decoder of the network serves to be as a dictionary shared by the cube to enforce the features for similar parts to be similar although they may distribute at disjointed locations. With such structures, the network is able to extract non-local features of the entire data.

Yifan Wang et. al (2021), present an end-to-end deep learning method, VC-Net, for robust extraction of 3D microvascular structure through embedding the image composition, generated by maximum intensity projection (MIP), into the 3D volumetric image learning process to enhance the overall performance. The core novelty is to automatically leverage the volume visualization technique (e.g., MIP - a volume rendering scheme for 3D volume images) to enhance the 3D data exploration at the deep learning level.

CHAPTER 3

AIM AND SCOPE

3.1 AIM:

- To use Colour Coding Algorithms in order to strengthen the prediction of the severity levels of spinal stenosis and intradural tumours.
- Raw image is to be obtained, augmented and filtered using median filtering method to retain the sharpness of the image.
- To validate the spinal stenosis caused using surface and volume rendering techniques.
- To give haptic input volumes to get real time imaging output and colour code them based on the severity levels.
- Usage of MATLAB R2021a version to simulate the haptic signals and for filtering, augmentation, and segmentation of the raw image.

3.2 SCOPE:

- In this thesis filtering, segmentation, distance calculations and color-coding of the distance from the centerline of the vessel to the background are to be implemented.
- The narrowing can occur from a variety of things including disc herniations, disc bulges, abnormal alignment, scoliosis, and bone spur formation.
- Depending on the position of stenosis, it is categorized as Foraminal, Central Canal, or Lumbar Stenosis. The layers of the Intervertebral disc (IVD) include Nucleus Pulposus, Annulus, Cartilaginous Endplate, Anterior Longitudinal Ligament (ALL), and Posterior Longitudinal Ligament (PLL).
- A Colour coding algorithm has been initiated using haptic interfaces that can aid in teleoperated surgeries.

- Haptic inputs sense the depth of stenosis using surface and volume rendering techniques and then colour coded based on the severity levels of stenosis and tumours.
- This success in the production of 2D colored modules not only increased the reachability of performance but also employed the use of some rendering algorithms that previously could not be used for real time rendering.
- The newly developed graphics cards present larger texture memories, with increased programmability and flexibility of the Graphics Processing Unit (GPU) including transfer functions, shading, and filtering. These developments gave a new environment for the researches to develop new techniques for implementing interactive volume rendering with a high performance and quality.
- Development and testing phases for the implementation has been done on Microsoft Windows XP, and Windows 2000 operating systems. MATLAB2021a, which was the latest development kit provided by the MATHWORKS company the start of the project, have been used.
- The Maximum Intensity Projection (MIP) is visualizing the brightest voxel value along the light ray for each pixel of the output image. MIP is a contrast enhancing operator; structures with higher alpha values tend to stand out against the surrounding data.

CHAPTER 4

MATERIALS AND METHODS

4.1 MATERIALS USED:

The salient material used to carry out this project includes the software MATLAB R2021a and the magnetic resonance imaging datasets and a GUI module integrated with the software for running the datasets.

4.1.1 MAGNETIC RESONANCE IMAGING DATASETS:

Magnetic Resonance Imaging, MRI, is a technique that uses a strong magnetic field to create images of the inside of the human body. MRI was developed in the beginning of the 1970's and was built upon nuclearmagnetic resonance, NMR, a phenomenon that was discovered in the late 1940's by F. Bloch and E. Purcell. NMR arises in the nuclei of certain atoms when they are immersed in a static magnetic field (MR- camera) and exposed to a second oscillating magnetic field.

Nuclei with an odd number of protons, and/or an odd number of neutrons have a nonzero nuclear spin. Spin is a property of nature like electrical charge. One of the atoms that have a nonzero nuclear spin is hydrogen, which occurs frequently in our body tissues. The protons become capable of receiving and then transmitting electromagnetic energy. The strength of the transmitted energy is proportional to the number of hydrogen protons in the tissue. This information is used to produce an image. The spinal stenosis data that are processed in this thesis were acquired in a 3T scanner (GE signa) from the SIMS hospital, Vadapalani.

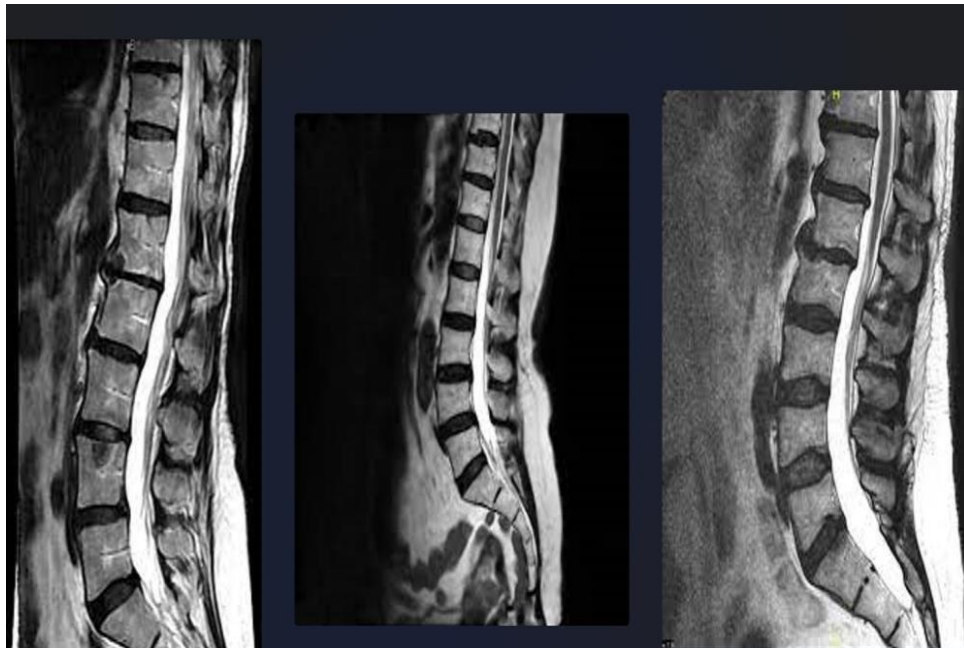


Fig 4.1 MRI 2D Spinal Stenosis Images collected from 3T GE Signa

4.1.2 SOFTWARE USED:

Since the motivation for this implementation is to build an application that uses PC graphics hardware for rendering volumetric datasets, an application programming interface (API) that gives an interface to communicate with the graphics processing unit had to be used.

On par with a subtle volume rendering database, MATLABR2021a has been used in this thesis to carry out all the process of pre-processing, segmentation, thresholding, calculating distance transform from the centerline of the blood vessel to the periphery of the bone and render volume to get the colour coded final output.

4.1.3 GUI MODULE:

A graphical user interface, GUI, was implemented to make the manipulation of parameters more manageable. The GUI is demonstrated in fig 4.1.2. The GUI consists of a load button, to load a new data set, a section of parameter settings, a section of render settings, a render button and a MIP display.

Load volume: A new volume is loaded. The maximum size is 256x256x256 voxels.

Select noise removal filter: A suitable filter is chosen. There are four filters to choose from. An averaging filter in 2D, a median filter in 2D, a median filter in 3D and a Wiener filter in 2D. Generally the 3Dmedian filter gives the best result but is also the most time consuming.

Select uniform opacity max value/Keep original opacity: It is possible to keep the original opacity in the dataset i.e. the opacity is set to correspond to the gray value in the voxel. Otherwise, the opacity is set to a value from 0-255.

Select intensity threshold: The intensity threshold should be very carefully chosen so that no important information is lost.

Go: When all the parameters are set the “Go” button can be pressed and the computer calculates the distance transform of the filtered, threshold volume.

Select color map: The color maps to choose from vary in both color and continuity.

Select distance max: The distance max is chosen so that the color map can be controlled depending on how deep the vessels of interest are.

Render: When the render settings are chosen the information is sent to the volume renderer.

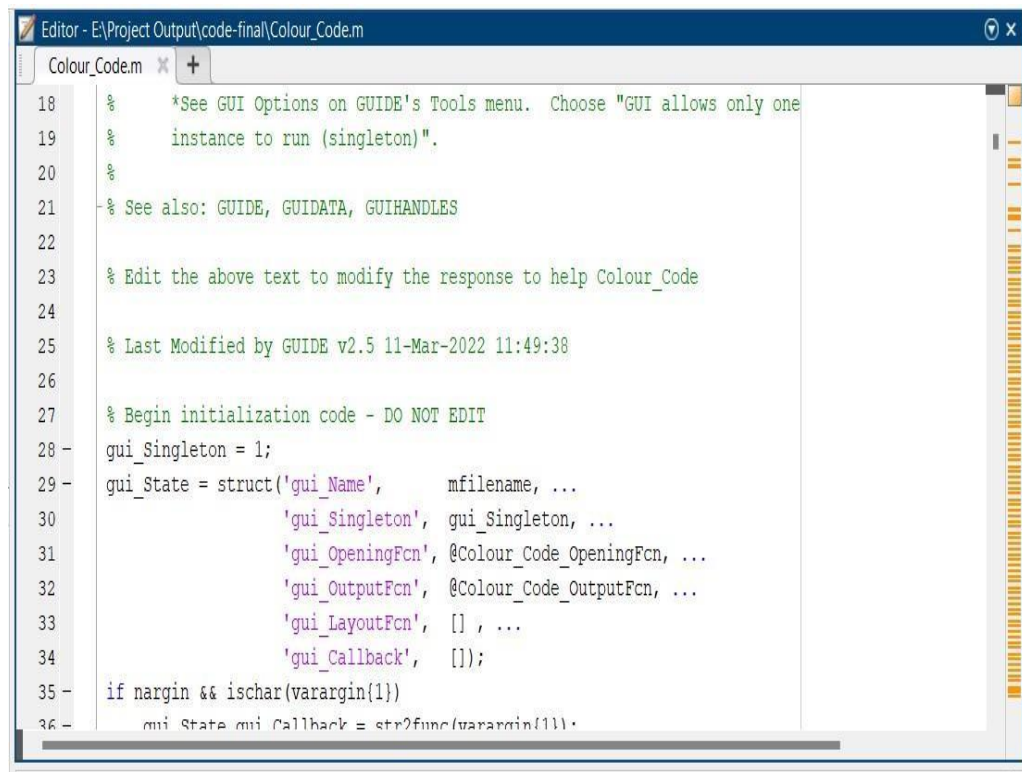


Fig 4.2 GUI module from MATLABR2021a

4.2 METHODOLOGIES USED:

The image processing toolbox present in the MATLAB2021a has wide methodologies to equip the efficiency of image processing. They include segmentation, thresholding, depth shading, volume rendering, inducing haptics and color mapping.

4.2.1 SEGMENTATION:

Image segmentation is a commonly used technique in digital image processing and analysis to partition an image into multiple parts or regions, often based on the characteristics of the pixels in the image. Image segmentation could involve separating foreground from background, or clustering regions of pixels based on similarities in color or shape.

4.2.2 THRESHOLDING:

Image thresholding is a simple, yet effective, way of partitioning an image into a foreground and background. This image analysis technique is a type of image segmentation that isolates objects by converting grayscale images into binary images. Image thresholding is most effective in images with high levels of contrast.

4.2.3 DEPTH SHADING:

The value of each pixel of the output is a function of depth. The distance of the first renderable voxel along the ray casted from the image plane is rendered with its depth value. So, the voxels that appear more far from the image plane are rendered as darker and the nearer are rendered as brighter. Analyze 5.0 has an option for this method that computes the results according to the gradient of the surface.

4.2.4 VOLUME RENDERING:

Volume rendering refers to a collective methodology of computer graphics to represent a 2D image that is conventionally processed from a 3D database. Surface-based methods work best with solid, nontransparent objects. When surfaces are transparent, geometric rendering techniques may not be the best choice because this is particularly true when a space is occupied by varying densities of semitranslucent material (e.g., human body when viewed via X-rays, MRI scans, or CT scans).

4.2.5 TEXTURE BASED VOLUME RENDERING METHODS:

Texture based volume visualization technique is composed of these phases: First, the volumetric data is sampled as planes and these samples are sent to the texture memory of the graphics hardware, in order to be used for mapping the polygons as textures. Then planes which are placed parallel to the image plane (result image to be viewed), are mapped with the texture. These planes are rendered as polygons and they are clipped by the limits of the texture volume. The resulting slices of

polygons are blended together by back to front order, and while each polygon is rendered, its pixel value is blended into the frame buffer with the appropriate transparency, and the volume is visualized.

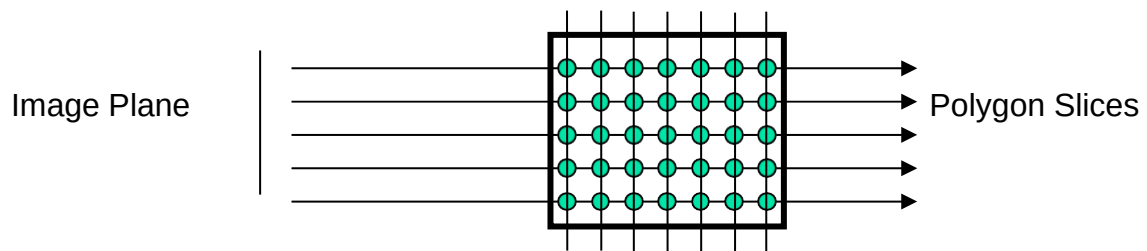


Fig 4.3 Polygonal slices that are mapped with textures.

4.2.6 VOLUME RENDERING USING 2D TEXTURES:

Volume rendering using 2D texture mapping is supported by most of the graphics hardware. Volumetric dataset is sampled into two-dimensional array or digital images, according to the number of slices to be used while rendering. These images are sent to the texture memory for mapping the polygonal slices as shown in the Figure 4.4.

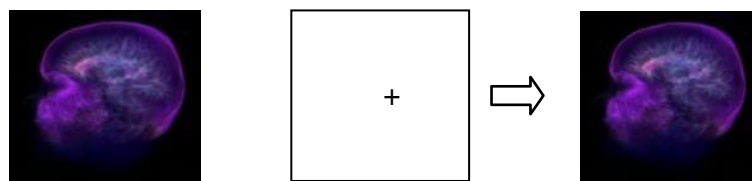


Fig 4.4 Texture Mapping

Using the texture mapping, the performance of graphics hardware allows interactive rendering of the scene. This means that, without resampling the volumetric data and sending the images of slices to the texture memory, the scene can be rotated by applying a transformation to the polygons or changing the eye position as shown in Figure 4.5.

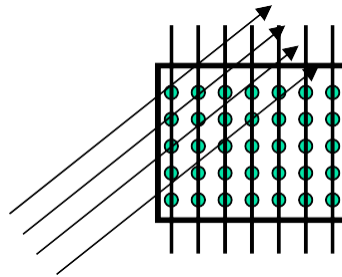


Fig 4.5 Rotated view

However, when the slice planes become parallel to the view of direction, the user cannot see anything in the rendering result, as shown in Figure 4.6.

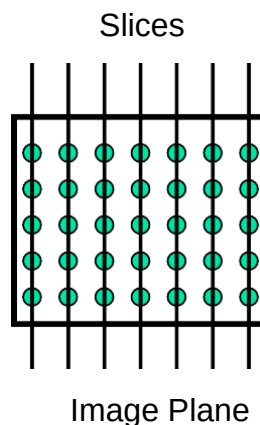


Fig 4.6 No rendering result

In order to solve this problem, during the first stage that the volumetric dataset is sampled as two-dimensional slices of images, three different set of slices of images are sampled along each x, y and z axis as shown in Figure 4.7.

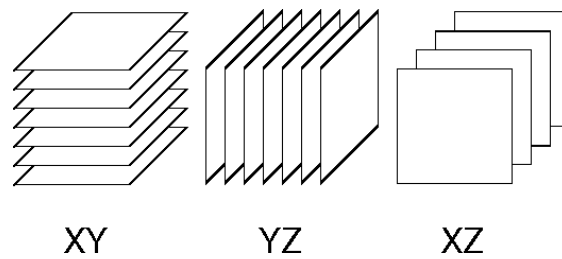


Fig 4.7 Slice sets parallel to the three coordinate planes

After sending each three set of slices to the texture memory, the set of most suitable that is the most perpendicular slices of 2D texture set according to the viewpoint and view direction is chosen to be rendered. When the position of the viewpoint changes with respect to the volume, 2D texture set that is most closely aligned with the view direction is used. Each slice of polygon that was mapped with texture is rendered from back to front using an appropriate blending method.

Disadvantages of this method are: The sampled images for the slices from the volumetric dataset, occupy three times time more space in the texture memory as three sets of textures have to be produced. The sampling rate of the resulting render image changes according to the perpendicularity of view direction to the slices shown in Figure 4.8.

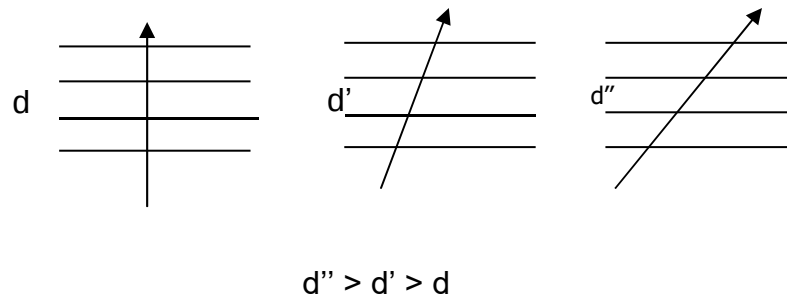


Fig 4.8 Sampling artifact

When the slice set use changes during the rotation of the model, there is a change occur in the intensity of the results as the sampling rate according to the view direction changes. This is called *popping effect* shown in Figure 4.9.

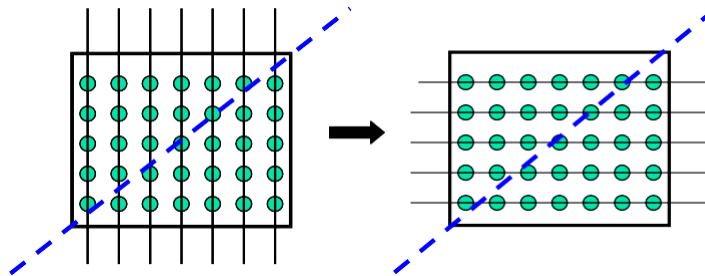


Fig 4.9 Artifact during the change of the slice set.

4.2.7 SAMPLING FREQUENCY:

Both in 2D and 3D texture mapped volume rendering, sampling frequency is an important variable on the quality and performance of rendering process. Sampling frequency is the obtained by the number of slices that are mapped with the texture. There are some factors to be considered while choosing the number of slices to be used in rendering.

4.2.8 PERFORMANCE:

Implementations using hardware accelerated volume rendering method may have two modes for rendering, interactive and detail modes. In the interactive mode, less number of slices can be used in order to increase the frame rate of the rendering process, but that shall lead to a low frequency of sampling which may lead to decrease in the quality of the rendering. Detail mode can render many numbers of

slices and obtain higher quality render results with more detail but with lower frame rates of rendering.

4.2.9 VOLUME SIZE:

While rendering a cubic volume with a view position at the front side, a good rendering quality can be achieved by using number of slices equal to number of voxel count on the view direction axis. However, the dimension of the volume may differ from an axis to another, so making an approximation in the number of slices to be rendered according to the major axis is a good method.

4.2.10 TRANSPARENCY ISSUE:

It is said that, increasing the number of slices which would increase the sampling rate to be rendered, increases the quality of the final render result. This is not true after a rate that exceeds the original sampling rate of the volumetric dataset. Increase in the sampling rate more than the sampling rate of the original dataset does not give more details. Moreover, over operator used while rendering back to front is not a linear operator. In other words, when more than one sample is taken for a voxel that is semi-transparent, the opacity for that voxel would increase at the render result, as it is sampled for more than one and the transparency is decreased. If the sampling rate is to be changed, the alpha values should be rescaled because of this issue and should be taken care that it doesn't affect values

CHAPTER 5

RESULTS AND DISCUSSIONS

The main purpose of the implementation is to present an environment that is able to read and visualize volumetric datasets. The motivation for building this implementation is to use the graphics hardware of an ordinary desktop computer that is being used today, and implement a volume rendering application for this hardware and give an interactive environment with some visualization techniques for the user.

5.1 RESULTS:

GLCM Parameters (Energy, Correlation, Contrast, And Homogeneity) were Extracted for Each color component of the images taken for the investigation. Contrast, Correlation, Energy, And Homogeneity represent the Coarseness, Linear Dependency, Textural Uniformity, and Pixel Distribution of The Texture, respectively. Based on all these it is classified into Normal, Stage 1 and Stage 2 of spinal stenosis.

Depth penetration level of the spinal stenosis has also been calculated in the Stage 1 and Stage 2 outputs, thereby giving a clearcut clarity on what kind of treatment a patient with spinal stenosis can undertake.

Validation of severity levels of spinal stenosis and intradural tumours from the inputs based on MRI and PET scans.

Instead of wiener filter, making use of median filtering would be very effective in noise removal and filtering process and proves certitude in maintain the sharpness of the image by removal of mean extreme values.

Colour coding algorithm has been initiated using haptic interfaces that can aid in teleoperated surgeries.

Haptic inputs sense the depth of stenosis using surface and volume rendering techniques and then colour coded based on the severity levels of stenosis and tumours.

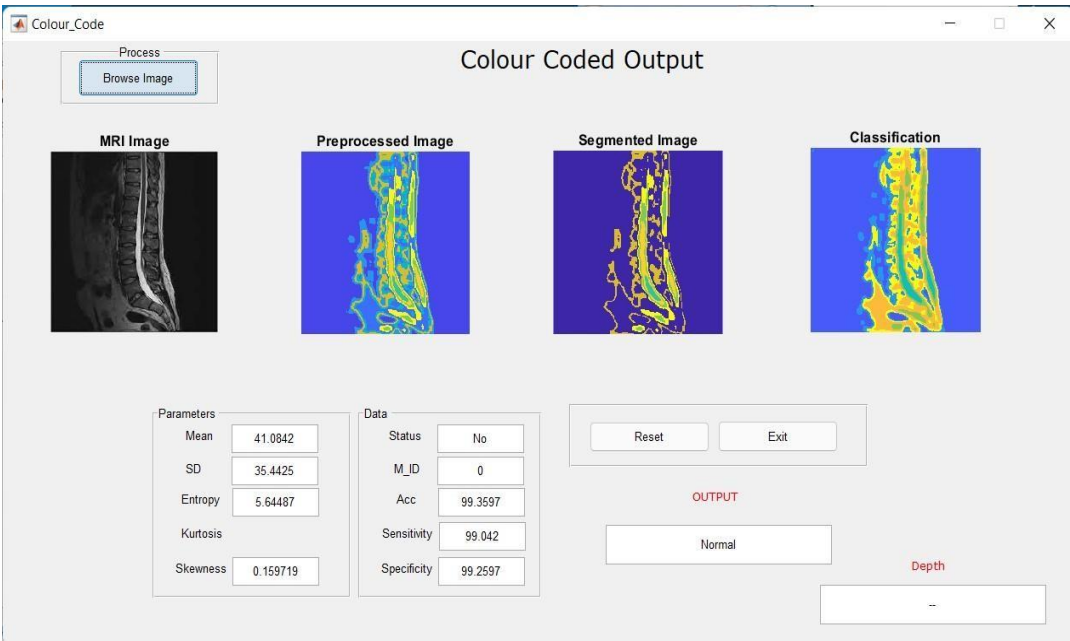


Fig 5.1.1 Classified output without any stenosis detected



Fig 5.1.2 Classified output with stage 1 of stenosis detected with 8%

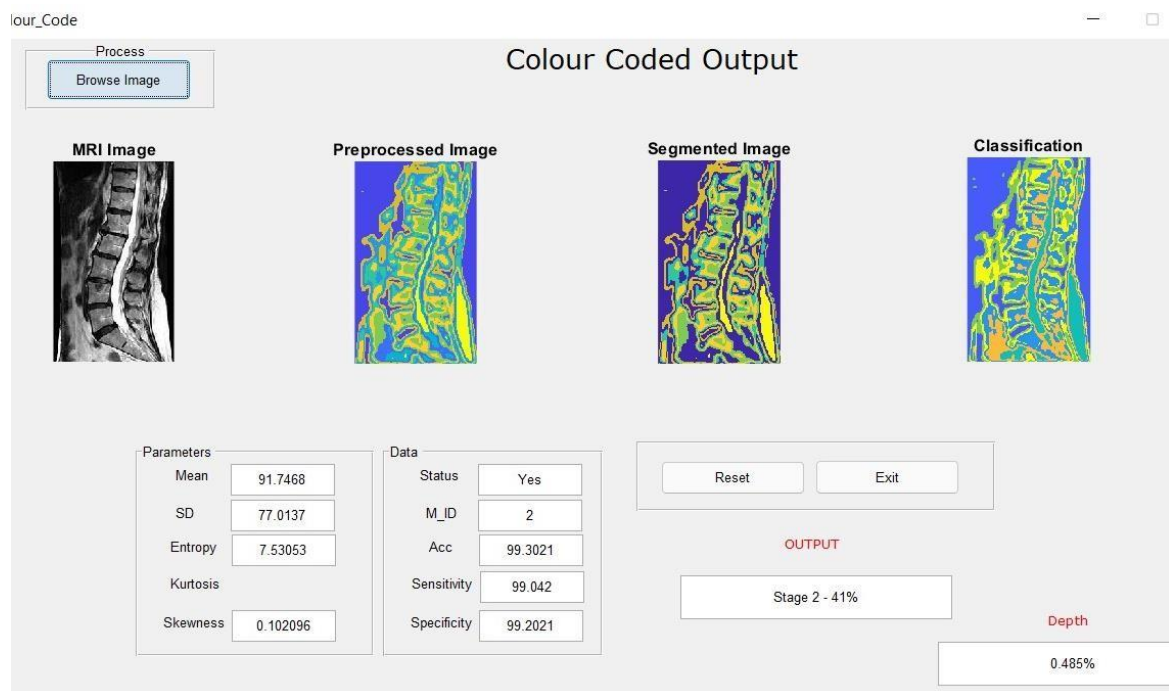


Fig 5.1.3 Classified output with Stage 2 of stenosis detected with 41%

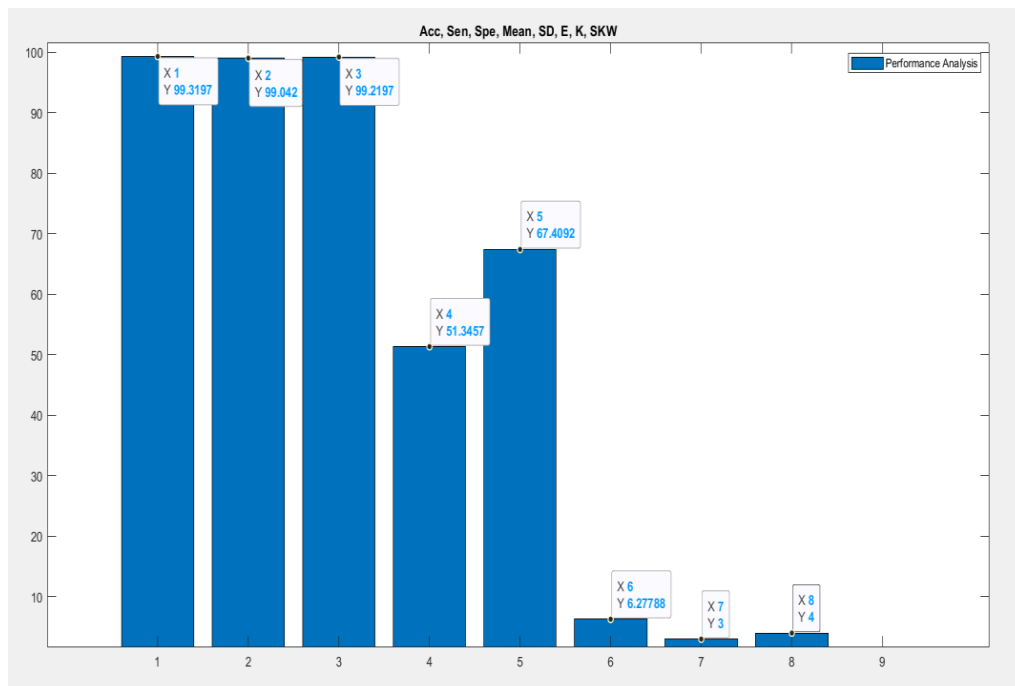


Fig 5.1.4 Normal Stenosis Parameters Output Graph.

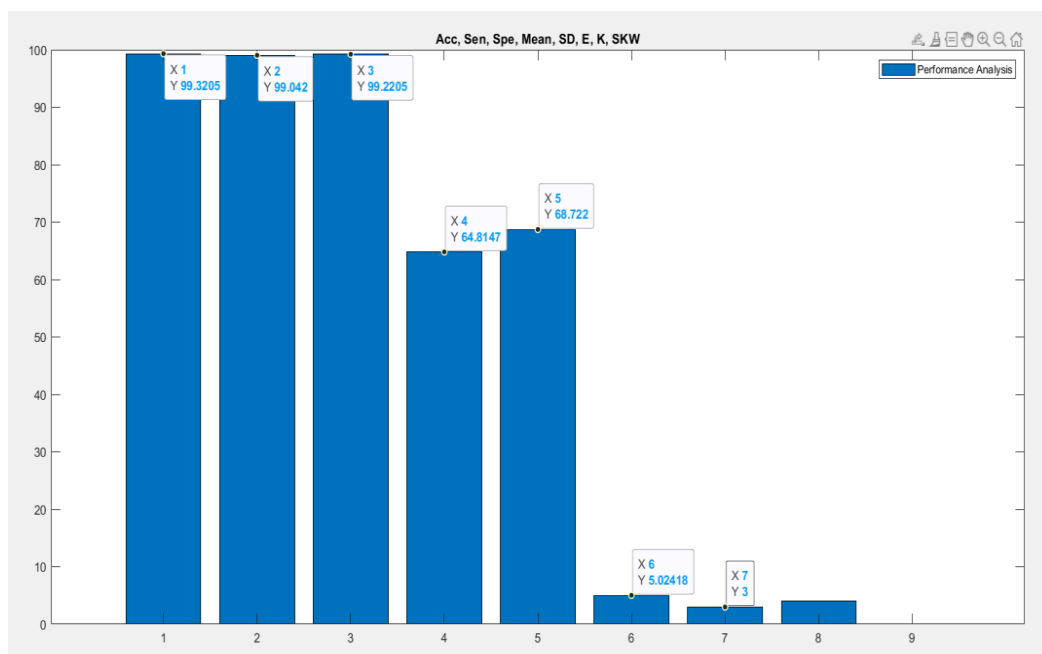


Fig 5.1.5 Stage 1 Stenosis Parameters Output Graph.

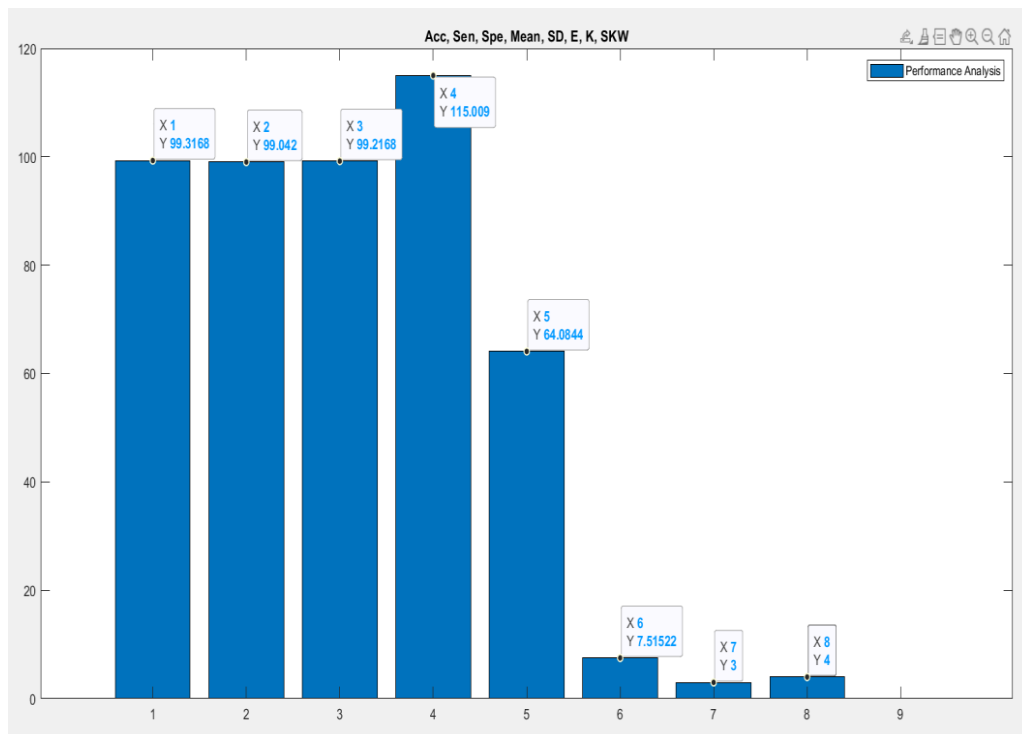


Fig 5.1.6 Classified Stage 2 Parameters Output Graph.

5.2 DISCUSSIONS:

The results acquired for the thesis is based on raw collection of 2D spinal stenosis MRI data and the processing done includes rendering of a volume-based color-coded output such that it depicts the stenosis levels.

In comparison with the previous works done, the raw images were taken in 3D format in order to match perfect MIPs for better angular views and the cases were stipulated more to Vascular Stenosis.

On par with the works carried out by Sudha Rani et. al and Fajar et. al on Identification of Brain Tumors using Volume rendering Techniques (2021) and Color Mapping for Volume Rendering Using Digital Imaging and Communications in Medicine Images (2021) respectively, the former deals with same concept of 2d volume rendering and inducing haptics in the process of classifying the severity levels of Brain tumors and the later deals with the tactics available with respect to color coding of the input MRI or CT image.

Both these references incorporated together gives us a comprehensive understanding about how color-coding process work and the scope that has in the near future. Color mapping, gradient shading module with an incorporated GUI along with Volume Rendering with haptics gives us the final result of this thesis.

The version 5.0 of the software Analyze has various kinds of properties- abilities developed for medical imaging. Analyze, *Volume Render* module has been used for capturing the results. There are many methods that have been implemented for each process of the volume rendering pipeline in Analyze software. Difference of this application from our implementation is that, no hardware acceleration method is used. The Analyze software output images used for comparison are the results which are produced by the most similar methods of volume rendering to our implementation methods.

The drawbacks include using of 2D spatial images instead of 3D images. So thereby volume rendering had to face some technical glitches due to the input images as they couldn't be rendered with MIPs properly. This further inhibited the radiologist's view from stipulated angles without any rotational movement.

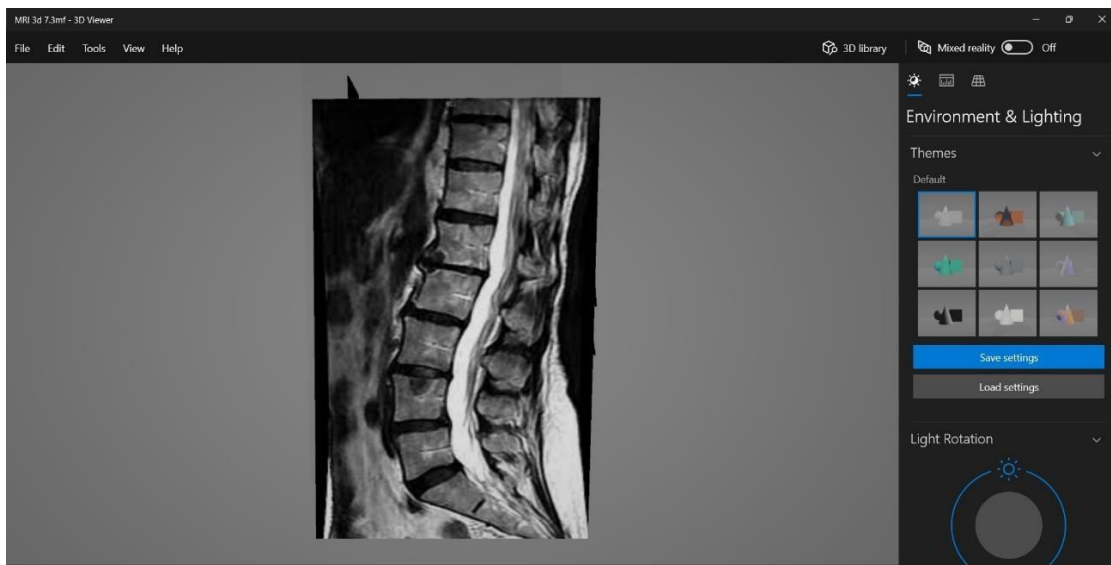


Fig 5.2 Non-Rotational 2D Dataset in Microsoft's 3D Viewer

CHAPTER 6

SUMMARY AND CONCLUSION

6.1 SUMMARY:

In a huge organization like hospitals where employing large numbers of medical staff, this method requires a huge expense for upgrading the graphics processing devices of the personal computers of the staff. A colour coding based radiological output rendering solution might decrease this expense and enables more medical stuff to have the advantage of the three-dimensional visualization. A web-based solution requires an implementation that renders the specified volumetric datasets in a server and broadcasts the rendering results as compressed two dimensional images. Thereby data of 2d MRI Spinal stenosis has been collected and from that we apply methodologies like processing, segmentation, classification based on volume rendering techniques and haptics in order to color code the input images and detect the severity and depth of the stenosis levels.

6.2 CONCLUSION:

In this study, we developed an implementation for visualizing *Cartesian grid* volumetric datasets, using GUI module from MATLAB R2021a. The entertainment market caused the graphics hardware producers to develop more sophisticated devices in the recent years. This fast evolution enables new technologies to be used in the scientific visualization field. We tried to develop an application that can be a basis for our future works for implementing end user software for visualizing medical images. By this study we gained some experience on the abilities of graphics hardware and experience on implementing real-time applications to render volumetric datasets for different clinical expectations in medical image visualization.

Testing results of the implementation shows that the performance of the rendering process is directly related with the capabilities of the graphics hardware. This gives an opportunity to achieve a high-performance rendering with a low CPU power PC. The rapid and extensive consumption and production of the graphics hardware devices makes the prices become less every day. This gives an opportunity to the users to obtain real-time rendering solutions without upgrading all of the system or spending money on high priced workstations.

Comments given by the nuclear medicine expert showed us that our implementation requires some improvements, especially for indicating the edges of the volumetric datasets and avoiding the decrease in the detail of the visualized information while increasing the smoothness of the surfaces.

In order to improve the visualization results and develop better tuning techniques, medical stuff should further use and test this software. This will also help in emergence of new ideas for future implementations. The environment we have chosen for the implementation provides a lot of flexibility in the rendering process to achieve such improvements.

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