Brainyology

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Abstract

Brain tumor is collected of abnormal cells; it is a major dangerous disease in the world. Normally tumors are identified by CT and MRI which results in 2D images. The main problem that faces doctors is the calculation of the tumor volume. By calculating the accurate volume doctors will be to predict the degree of the tumor will affect which part of the patient body. We are proposing a system that will help the doctors to calculate the tumor volume. Our system depends on MIR images the system detects the tumor form the images, calculate the volume of the tumor, reconstruct a 3D model for the brain and the tumor and then the doctor will be able to interact with controller device for intuitive fast mapped to a real brain model.

Acknowledgment

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Chapter 1

Introduction

1.1 Introduction

1.1.1 Introduction

The brain tumor is a collection of abnormal cells. There are two types of brain tumors primary and secondary brain tumors. Primary brain tumor is the tumor which begins in the brain. This type can be either Malignant which is a tumor contain cancer cells, or Benign which is a tumor do not contain cancer cells. If a cancerous brain tumor starts anywhere else in the body and end up growing in the brain then this is a secondary brain tumor. The Brain Tumor are usually identified by Computed Tomography(CT) and Magnetic Resonance Imaging (MRI). Most of the doctors prefer MRI since it has a much greater range of available soft tissue contrast, depicts anatomy in greater details, and is more sensitive and specific for abnormalities within the brain itself [1]. One of the main problems that face doctors is the calculation of volume of the brain tumor through those 2D MRI images. To identify a brain tumor, the doctor makes a mark in suspicious section and then calculates the area and the volume of the brain tumor manually. This method is not accurate 100% to detect the volume of the tumor. Our proposed system is automatic tumor detection and volume calculation applications that aim to get more accurate volume. Then the system will construct w 3D model for the brain and the tumor, finally the doctor will be able to interact will the 3D model using controller device for intuitive fast mapped to a real brain model.

1.1.2 Motivation

According to Cancer Statistics [2], the number of new cases of brain was 6.4 per 100,000 men and women per year. The number of deaths was 4.3 per 100,000 men and women per year. The present of surviving from brain cancer in the last 5 years was 33.6%. Our proposed system will decrease the death rate since it gives the doctor the accurate volume of the tumor. It’s medically essential for the doctors to know the volume of the tumor. Knowing the accurate volume and the position of the tumor are key information. Doctors need to know which part of the patient body will be affected. Moreover, they will be able to plan treatment and can predict the stage of the tumor. On the other hand the market shows that presence of the technology in the brain tumor field makes the curing possibility very high.

1.1.3 Problem Definitions

The main problem that faces doctors is the calculation of the tumor volume through those 2D images. Doctors will have to make a mark in suspicious section and then calculates the area and the volume of the brain tumor manually to identify a brain tumor. This method is not accurate 100% to detect the volume of the tumor and it takes lots of time. Here in Egypt there is just one application that calculates the tumor volume atomically and convert MRI 2D image to 3D model which is applied on heart at Magdi Yacoub’s heart foundation. But there is no application in Egypt for calculating the brain tumor volume and convert 2D MRI images of brain tumor to 3D model and intuitive controller interactivity. Usually, the doctors don’t buy an application with the same functionality because it’s very expensive, not accurate enough and the processing speed is very low.

1.2 Project Description

We are introducing a system that will help the doctor in the calculation of the brain tumor volume. The system is depending on the MRI images which will be the input to our system. Some image processing technics as preprocessing, segmentation, feature extraction and classification are applied to detect the tumor from the MIR images. After detecting the tumor from the images the system will be able to calculate the tumor volume. Then the systems will construct a 3D model for the whole brain and the tumor. The doctor will be able to interact with the 3D model using a controller device for intuitive fast mapped to a real brain model. So the proposed system is divided into 3 main targets to meet. Detecting the tumor from MRI slices, Calculate the volume of tumor, Construct a 3D model of the brain to give the doctor the flexibility to interact with it using controller device.

1.2.1 Objective

This system is developed to help doctors to give accurate diagnose to the patient. It also can be used for creating teaching materials for the medical science or even surgical studies in metal implants.

1.2.2 Scope

"BRAINYOPLY" is a system that aims to target the adult male and female brain tumor patients. Our research scope is MRI images and Detect brain tumor only. We will be working on detecting the volume of the tumor. We will integrate this system with many hospitals. The main objective of the proposed system is helping doctors to give accurate diagnose to the brain tumor patient. Calculation of the tumor volume enables the doctors to predict the degree of the tumor will affect which part of the patient body. It will be accurate with low cost and high processing speed.

1.2.3 Project overview

The proposed system is an interactive solution for detecting and calculating the volume of the brain tumor automatically here in Egypt which will be very useful for the doctors. Thus our system will construct a 3D model for the brain and the tumor and the doctor will interact with the 3D model using a controller device for intuitive fast mapped to a real brain model which will be useful for creating teaching materials for the medical science or even surgical studies in metal implants.

Chapter 2

Literature Work

2.1 Similar System Information

2.1.1 Similar system Description

Researches as M.Fathima Zahira and M.Mohamed Sathik [3] introduce the some techniques used to detect the brain tumor MRI images. Their proposed system composes of four main phases, Preprocessing, segmentation, feature extraction and classification. They made a comparison between different segmentation algorithms and found that unseeded region growing segmentation algorithm has the highest accuracy “89.6%”, they also made a comparison between different classification algorithms and concluded that supported victor machine has the highest accuracy “97%”. In paper [4] Author Kavita A. Ugale used two segmentation algorithms; unseeded region growing segmentation and threshold based segmentation followed by support victor machine classification, highest accuracy “93%” was achieved by unseeded region growing segmentation followed by support vector machine. Naveenkumar R. and Sanjay S [5] used morphological erosion followed by connected segmentation algorithm and they got the highest accuracy “94%”. Nathan Moon, Elizabeth Bullitt, Koen van Leemput authors in paper [6] introduced another segmentation algorithm which is expectation maximization which has been previously developed by Leemput van, Maes K., Vandermeulen F., Suetens D.in [7] ,[8] and [9]. In paper [10] Roy Sudipta, Sadhu Shayak, kumar Samir introduced the steps to calculate the tumor volume. Their system first detects the tumor images. Then calculate the area and find the area between two consecutive slides using interpolation points in a graph plots. Then take each point of the consecutive slices. Finally calculate the tumor volume. The research made in paper [11] by Linköping University support the steps mentioned before for tumor volume calculation.

2.1.2 Experiments form pervious systems

The following tables show experiments made in the systems mentioned in the previous section.

Table 2.1: The applied segmentation experiments in the previous similar systems

Segmentation Type	Accuracy
OTSU's Thresholding	87.5
Unseeded Region Growing	89.5
K-mean Clustering Algorithm	84.3

Table 2.2: The applied Classification experiments in the previous similar systems

Classification Type	Accuracy
Hyperbolic Hopfield Neural Network (HHNN)	86.5
SVM	92.5

2.1.3 Screen Shots from previous systems

The following figures how screen shots from systems mentioned in the previously.

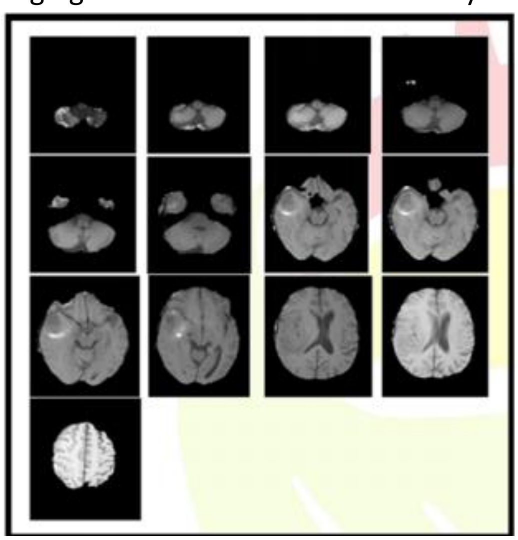


Figure 2.1: Illustration of 3D Reconstruction

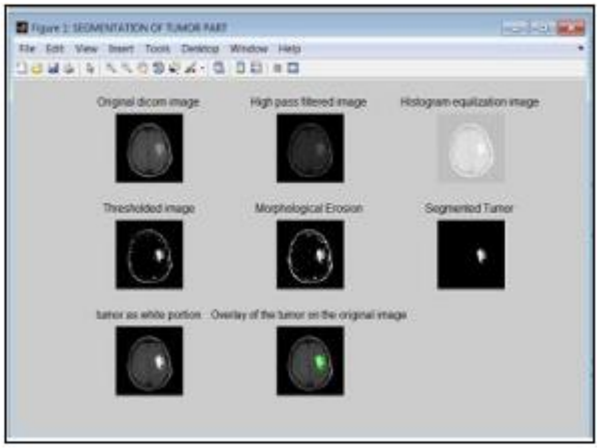


Figure 2.2: Illustration of Segmenting process of single slice

2.2 Project Management and deliverables

2.2.1 Budget

Table 2.3: The table of the proposed system budget

Item	price
x-imu	**£249.00**
18 push buttons	18 LE
PCP board	15 LE
2 encoders	12 LE
6 pin headers	10 LE

Chapter 3

System Requirements Specifications

3.1 Introduction

3.1.1 Purpose of this chapter

The purpose of this chapter is to present a detailed description of the proposed system “Brainyology”. It will explain in more details the purpose, the features and the interface of the system.

3.1.2 Business Context

Many Countries are moving too far from ordinary traditional techniques and methods. As result of our aim is to enhance the experience of doctors with through treating with MRI scans of brain tumor. Though the traditional method is holding up, a lot of complaints are received due to lack of efficiency. The introduced system would avoid a lot catastrophic disadvantages of the old techniques and method, such as the wrong diagnosis and wasting time. As matter of fact, the proposed system will ensure full satisfaction for doctors and patients.

3.2 General Description

3.2.1 Product Functions

Brainyology is a system that aims to help the doctors to calculate the brain tumor volume automatically through MIR images. The system aims to reduce the time that doctors waste marking the suspicious section and then calculates the area and the volume of the brain tumor manually. The proposed system also constructs a 3D model for the brain and the tumor which will give the doctor a better view to the brain and the tumor. Another advantage of the system that is not only meant for doctors and hospitals but it also would be for creating teaching materials for the medical science or even surgical studies in metal implants.

3.2.2 User Characteristics

There are four Types of users to interact with the proposed system. First the Radiologist who is the first one to review the patient's MRI images and writing a report after calculate the tumor volume. Second the Neurologist who is the doctor that following up the patient medical case and he will calculate the volume to be able know which part of the patient body will be affected. Moreover, they will be able to plan treatment and can predict the stage of the tumor. Third the Brain Surgeon who will be able to interact with the 3D model of the brain to study the case and know where exactly is the tumor before operating and finally the professors and the teaching assistants will be able to create teaching materials for the medical science or even surgical studies in metal implants.

3.2.3 User Problem statement

Surveys have showed that similar system with the same functionality is not available here in Egypt except at Magdi Yacoub's heart foundation and it's applied on heart, and usually the doctors don't buy an application with the same functionality because it's very expensive, not accurate enough and the processing speed is very low.

3.2.4 User Objectives

The system is to be devolved to avoid the waste of the doctor's time in marking the suspicious section and then calculates the area and the volume of the brain tumor manually. And it's medical essential for the doctors to know the accurate volume of the tumor. Knowing the accurate volume and the position of the tumor are key information. Doctors need to know which part of the patient body will be affected. Moreover, they will be able to plan treatment and can predict the stage of the tumor.

3.3 Function Requirements

This section lists the functional requirements in order. Function requirements describe the possible effects of a software system. In other words, what the system must accomplish.

3.3.1 Doctor Authentication

Criticality	High
Input	-Name -Email Address -Mobile Number -User Name -Password -Hospital Name -Hospital Address -Department Name
Output	Once confirmed, registration will then be approved and doctors can use the available services
Description	New doctors are required to register as members before they are allowed to use the application, this procedure to keep doctors' details into a database. Doctors are given the choice to create their username and password, as for the password field, doctors is required to key in the password twice for confirmation purposes. If a repetition of doctor login name is found in the system, then the system will inform the doctors of the error, and the doctor will be required to re login again. Doctors need to provide their particular details such as name, e-mail address, mobile number, user name, password, hospital name, department name.
Priority	10/10
Priority Reason	Essential requirement that must be included in the system so the doctor can check his history and for the patient privacy.
Preconditions	Doctors information
Post-conditions	A profile created with the doctors information

3.3.2 Doctor Login

Criticality	High
Input	-User Name -Password
Output	Once login, user name and password will be checked and then doctors can use the available services
Description	Existing doctors have to login to system in order to use the application. Doctors need to provide their username and password in the username field and password field. If doctors provide the wrong username or password, the

	system will prompt out an error message telling the doctor to re-enter their username and password again. If doctors forget their password, they will be able to reset the password.
Priority	10/10
Priority Reason	No doctor will be allowed to use the application unless he registered first then login and the patient information and condition will kept confidential
Expected Risks	Doctors may enter the wrong password or user name
Preconditions	Doctors user name and password
Post-conditions	Availability to use the system

3.3.3 Add, Edit Patient

Criticality	High
Input	-Patient name -Age -The date of visit -The date of the MRI -The MRI images. -Some other important question will be included int the form.
Output	A profile for every patient includes his information, diagnoses and MRI images.
Description	Doctors will be able to add patient to his list of patients, the doctor will add some information to the patient his name, age, the date of visit, the date of the MRI and the MRI images, The patient information will be added to a data base connected to the data of the doctor so the doctor will keep track of his patient and he will be able to update any of the patient information and add comments about the patient's condition.
Priority	10/10
Priority Reason	Each doctor will know the condition of his patient. He will be able to track the dates of the MIR.
Expected Risks	Doctors may fail to save the information
Preconditions	Patients Information and MRI images.
Post-conditions	A profile created with the patients information

3.3.4 Data input and refining of image

Criticality	High
Input	The minimum number of 2D MRI images is 297 and maximum number is 501.
Description	The doctor will be asked to import MRI images so the system will be able to operate the processes. Each patient should have a folder with his name that contains the MRI images. When the doctor clicks on import images button the system will ask him to point to that specific folder that he wants to import after pointing to the specific folder the system will be able to import the images.

Priority	10/10
Priority Reason	If there are no images the system will not be apple to processed to the next process. All the images must be of the same format and dimensions.
Expected Risks	System fails to import all the images
Preconditions	MRI images.
Post-conditions	MRI images are added to the patient information and the system will start working with it.
Code	P.2.1

3.3.5 Prepressing

Criticality	High
Input	The minimum number of 2D MRI images is 297 and maximum number is 501 with the same dimensions and format.
Output	2D gray scale images all the images are of the same size and format, with sharpen edges, and improved contrast and separation between the light and dark ration.
Description	After the images are imported the system will start with the initial process which is processing in this process the system will convert the images into gray scale. Then the system will use high pass filtering for sharping the edges, then contrast enhancement that attempts to improve the contrast in images and finally, Threshold methods for separation of light and dark regions.
Priority	10/10
Priority Reason	Essential requirement must include in the system to reduce the noise in the image, to improve the accuracy and to reduce the processing time.
Expected Risks	System fails to implement preprocessing filters to all of the images
Preconditions	MRI images.
Post-conditions	2D gray scale images all the images are of the same size and format the filters are applied.

3.3.6 Segmentation

Criticality	High
Input	2D gray scale images, with sharpen edges, and improved contrast and separation between the light and dark ration.
Output	Images with is divided in to multiple segments the brain is separated from the back ground.
Description	After the preprocessing process the system will applies the segmentation process which it is the process of separating the brain form the background there is four popular algorithms for segmentation which are unseeded Region growing, OTSU'S thresholding, kmean and Connected component (We applied Kmeans and Connected component and the results of Connected component were better than kmeans).

Priority	10/10
Priority Reason	Essential requirement must include in the system to divide the image into multiple segments.
Expected Risks	System fails to apply the same segmentation algorithm on all the images.
Preconditions	MIR images passed through the preprocessing filters.
Post-conditions	Images with the brain separated from the background

3.3.7 Feature Extraction

Criticality	High
Input	A 2D gray scale images, with sharpen edges, and improved contrast and separation between the light and dark ration. Each image is dividing into multiple segments.
Output	Images with some selected features which have been extracted.
Description	In this process the system will extract some features using WV_GLCM mechanism for the feature extraction process. This includes combined process of both GLCM and Wavelet process which results are effective results w extract some features as Entropy, Contrast, Variance and Correlation. As for Feature selection part, it's the process of selecting features which has been extracted. it helps to reduce features by improving the prediction accuracy and reduce computation time.
Priority	10/10
Priority Reason	Essential requirement must include in the system it helps to reduce features by improving the prediction accuracy and reduce computation time.
Expected Risks	System fails to Extract accurate features.
Preconditions	Images with the brain separated from the background
Post-conditions	Images with some selected features and file with the features calculations.

3.3.8 Classification training phase

Criticality	High
Input	Computed Features.
Output	Grouping the features as features of tumor and features of no tumor
Description	In the training phase the system will use the computed features to indicate the tumor features and the non-tumor features and the in the testing phase the system should recognize the images with the tumor and the images that don't have the tumor.
Priority	10/10
Priority Reason	Essential requirement must include in the system to train the features and test them.
Expected Risks	The system fails to group the features.
Precond	File with computed features.

itions	
Post-conditions	Grouping features.

3.3.9 Classification testing phase

Criticality	High
Input	The training data from Classification Training phase
Output	Indicating whether the testing images include tumor or not.
Description	After the training phase the system will enter the new images to indicate whether it include tumor or not.
Priority	10/10
Priority Reason	Essential requirement must include in the system to detect the images which include the tumor
Expected Risks	The system fails to indicate whether the new images are with tumor or not.
Preconditions	Grouping features
Post-conditions	Images with tumor.

3.3.10 Tumor volume calculation

Criticality	High
Input	Detected tumor images
Output	The calculation of the tumor volume.
Description	The system needs to calculate the volume of the king binary images from tumor detection process as an input. System will use binary image as a matrix then the system will calculate the total volume of whole tumors in pixels using binary images and distance between two consecutive slices. If there are unknown slices the system will use the concept of linear interpolation to find the area of the unknown slice by plotting obtained value in are vs. slide number
Priority	10/10
Priority Reason	Essential requirement must include in the system to calculate the tumor volume.
Expected Risks	There is no tumor detection images
Preconditions	Tumor detection images
Post-conditions	The accurate volume of the tumor

3.3.11 Create a voxel images

Criticality	High
Input	-Points: matrix with 3D points -Voxel Size: vector with voxel Size. -Color: Face Color. -Alpha: Opacity.

	-Edge_color: Edge Color.
Output	-Vertices: matrix containing the vertices of the voxels. -Face: matrices containing indexes of the vertices.
Description	A direct consequence of this difference is that polygons are able to efficiently represent simple 3D structures with lots of empty or homogeneously filled space, while voxels are good at representing regularly sampled spaces that are non-homogeneously filled.
Priority	10/10
Expected Risks	Voxels size are not scalar, all edges won't have same length.
Preconditions	Matrix with 3D points must be satisfied.
Post-conditions	Voxel images will be created in cube shape.

3.3.12 Construct Meta

Criticality	High
Input	-Dims: a vector of finite positive integers specifying the desired length of each dimension "Size of the array that include MRI scans" -Mask: a binary vector specifying which voxels should be included.
Output	A Struct contain the following fields: - Nvoxels: total number of voxels containing brain. - coordToCol: dimx by dimy by dimz matrix of voxel numbers. - ColToCoord: nvoxels by 3 matrix of voxel location.
Description	Meta is a mesh box that will collect all co-ordinates of all 3D matrices slices in stack considering the spaces between the slices.
Priority	10/10
Expected Risks	Missing data between the slices, such as: missing value of area between 2 consecutive slices.
Preconditions	Make all input images in standard size.
Post-Conditions	Plot the matrix considering separation between the slides and get an actual 3D figure.

3.3.13 Calculate Interpolation between Brain's Slices.

Criticality	High.
Input	Area of slice and number of slice in the stack.
Output	Get the missing values between 2 consecutive slices.
Description	In the normal, there are spaces between each slice of MRI scans. So, the system needs to calculate the interpolation between 2 consecutive slices to restore the missing data which increase the accuracy while calculating the volume tumor.
Priority	Extremely High.
Expected risks	Get unsatisfied value, because the values of 2 consecutive slices must be converted to mm.
Precondition	Put MRI scans in stack.
Post-condition	Put the output values in 1D matrix X[1:x] which will contain all values of area

	of all slides where x is the total number of slides.

3.3.14 Plot 3D brain

Criticality	High
Input	-Output of Construct meta. -Erode Layers: Optional argument specifying how many layers to make much more transparent. This allows patterns beneath the surface of the brain to be more-easily seen.
Output	3D model of the brain.
Description	Make a 3D model of the brain from the input images “MRI scans”.
Priority	10/10.
Expected risks	Bug in 3D visualization of the object or on the face color of the voxels In the images
Precondition	Meta must be satisfied
Post-condition	The model will be saved in database as an image.

3.3.15 Rotating

Criticality	High
Input	A GUI button press
Output	A 3d model for the brain that rotate exactly as the dummy head rotates in the real life
Description	The 3d model rotates exactly as the dummy head rotates in the real life
Priority	10/10
Expected risks	The X-imu might not be well calibrated with the 3d model
Preconditions	The 3d model’s file supported by XNA library
Post-conditions	The 3d model loaded correctly and interacting with the dummy head
Dependencies	3d model file codec: fbx,blend

3.3.16 Zooming

Criticality	High
Input	A dummy head button press
Output	Zoom in and out the 3d model
Description	When the zoom button pressed it will allow the user to zoom in and out the 3d model by the x-imu sensor instead of rotating
Priority	10/10
Expected risks	A data corruption while sending the zoom button interrupt
Preconditions	An interrupt
Post-conditions	The interrupt safely reach the system

3.3.17 Pitching

Criticality	High
Input	One of 4 arrows buttons on the dummy head pressed
Output	The whole 3d model moves left ,right ,up or down
Description	The user will press one of the four arrows buttons on the dummy head so the whole 3d model will move
Priority	10/10
Expected risks	A data corruption while sending the arrows buttons interrupt
Preconditions	Interrupts
Post-conditions	The interrupts safely reach the system

3.3.18 Highlighting

Criticality	High
Input	One of 10 buttons that represents the brain anatomy pressed
Output	A 3d model
Description	The system will hide the current 3d model and view the chosen 3d model according to the button id interrupt
Priority	10/10
Expected risks	A data corruption while sending the anatomy buttons interrupt
Preconditions	Interrupts and 3d model's file supported by XNA library
Post-conditions	The interrupts safely reach the system

3.3.19 Patient report

Criticality	High
Input	-Patient data -Tumor volume calculation -Doctor comment
Output	A 3d model for the brain that rotate exactly as the dummy head rotates in the real life
Description	A report with the patient condition, tumor volume calculation and the doctor comments and Update Patient entry in the database.
Priority	10/10
Preconditions	The Tumor volume calculations and the doctor comments.

3.4 Interface Requirements

This section describes how the software interfaces with other software products or users for input or output. Examples of such interfaces include library routines, token streams, shared memory, data streams, and so forth.

3.4.1 User Interface

The system expects doctors to use and interact with the interface and all of the available tools. Meaning when a Doctor login to the system he will view his list of patient and he will be able to edit or add new patients if he choose to add a new patient he will be able to add the patient information and upload the MIR images then he will be able to use the system tools which is tumor volume calculation, 3D construction and interaction.

3.4.1.1 GUI

1. Welcome screen: when the website is opened the following screen is shown. Two options are given either logging in or singing up

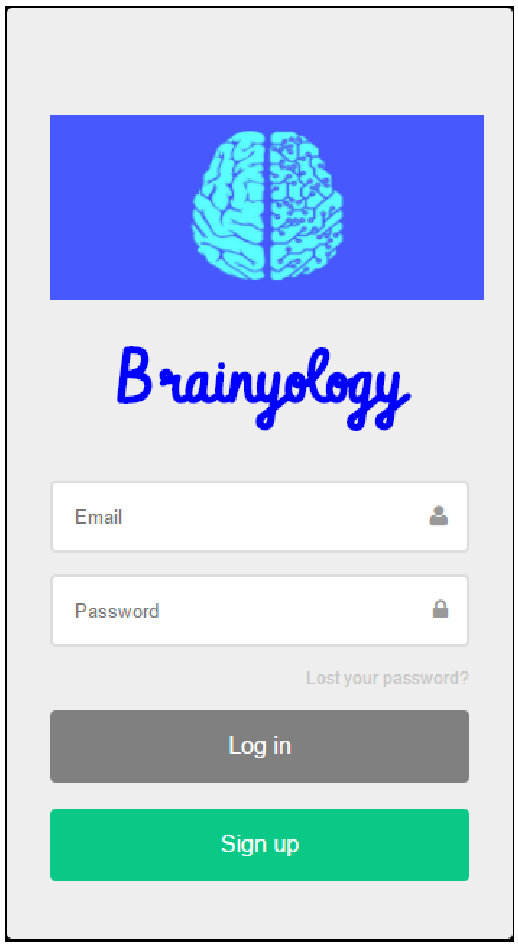


Figure 3.4: Welcome screen

2. Signup: Where the doctor will be able to add his information to login in to the system.

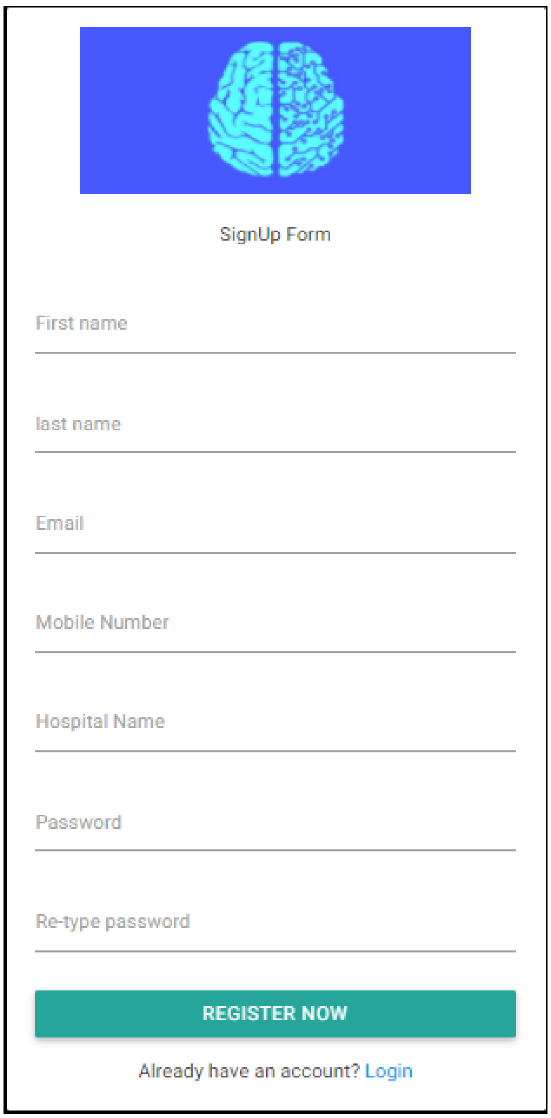


Figure 3.5: Signup Page

3.4.1.2 Communication Interface

There are two types of networking in the proposal system, at first there's a connection between the system and the database that takes control of sending and receiving data to be stored. Important data such as logging in and add, edit patients. The second type of connection is the link between the system and its correspondent which meaning the connection between the system and the doctors. The connection allows the doctors to import the patient MRI images, show the results of volume calculation and interact with the 3D model using the control device.

3.5 Performance Requirements

The System needs a high speed processor to overcome the processes of image processing techniques and generating 3D model. The system needs a high performance of memory to be able to store the amount of data sets for different patients.

3.6 Design Constraints

The intention of the system is to segment the anatomy of the brain and segment the brain tumor then create a 3D model for the brain and calculate the volume of the tumor then finally allow the user to interact with the 3d model by a TUI, therefore the internal structure of the system should be designed in such a way that the system shall be using the least possible complexity to reduce the time of rendering for the 3d construction and the system should be in a real time in the TUI part. Every single process of segmentation will be based on data set gathered from specialists and doctors especially for the brain anatomy segmentation. This product is initially being developed for a non-profit with a limited budget, and therefore is constrained to low-cost methods of implementing the system.

3.7 Other non-function attributes

Specifies any other particular non-function attributes required by the system.

3.7.1 Security

Description	The main security concern is for doctor's

	account and which includes the patient information and conditions the system will use proper login mechanism will be used by doctors to avoid hacking
Priority	10/10

3.7.2 Performance

Description	The loading time of the system must be small and the response time for the doctor should be acceptable. Also any operation must be done in fewer steps as possible in order to increase speed and ease of use.
Priority	10/10

3.8 Preliminary object-oriented domain Analysis

The data flow diagram shows the flow of data between the system processes, it shows what will be the input to the next process and what will be the output of this specific process.

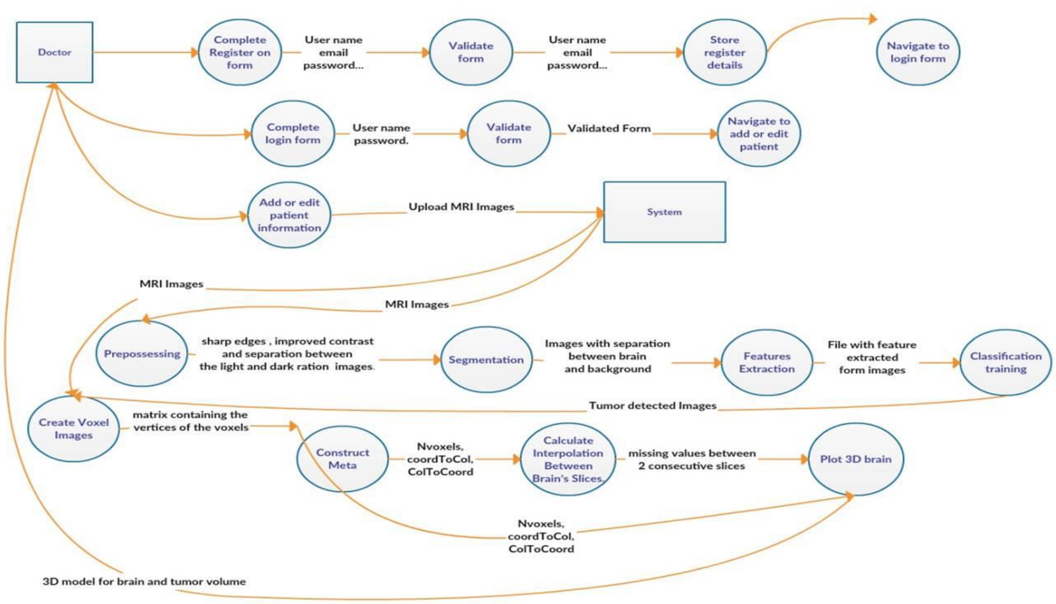


Figure 3.6: Data Flow Diagram

3.9 Operational Scenarios

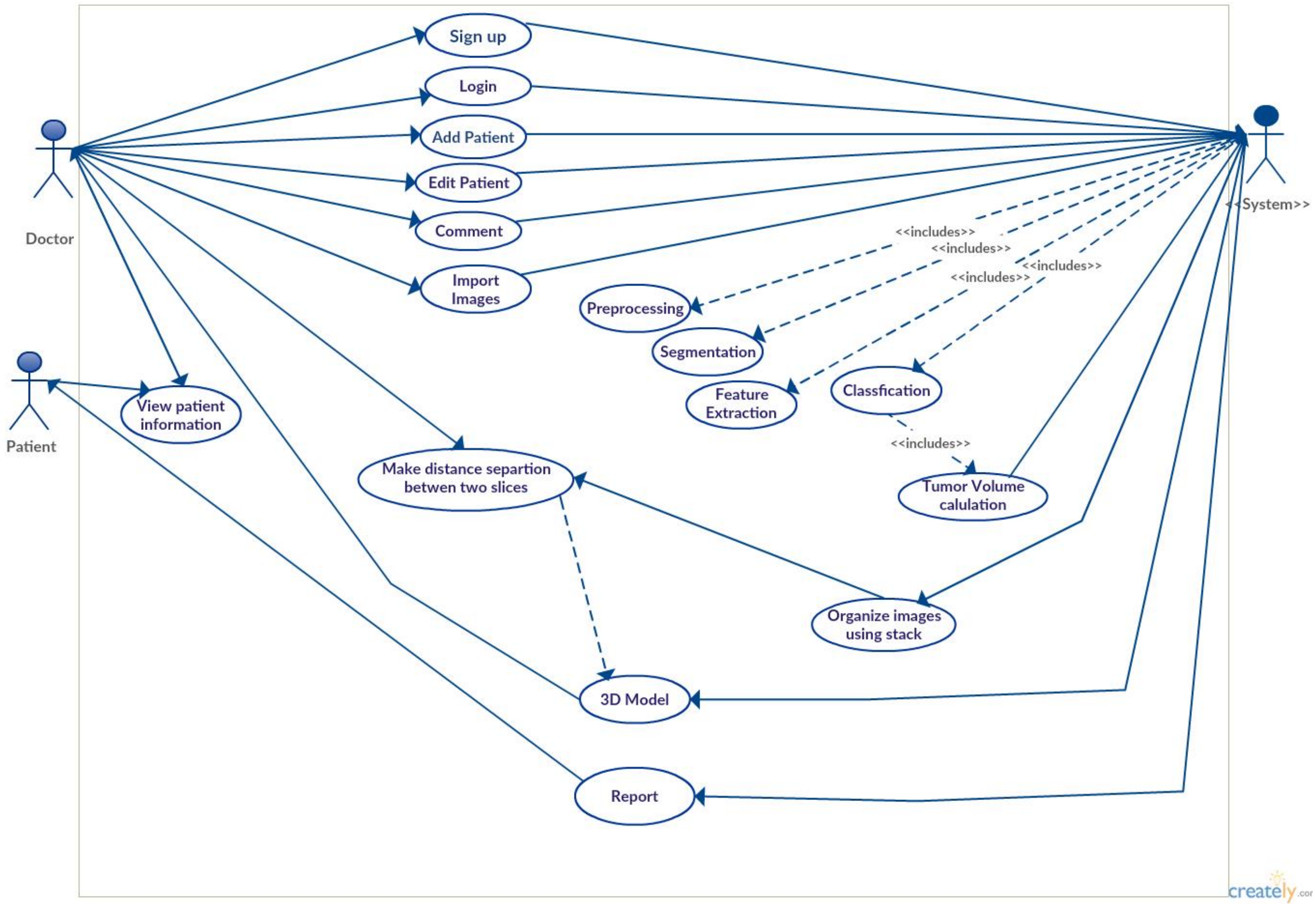


Figure 3.7: The system Use case

Chapter 4

Software Design Documentation

4.1 Introduction

4.1.1 Purpose

The purpose of the Software Design document is to provide a full description of the proposed system “BRAINYOLOGY” and how it is expected to be built based on the use cases shown previously in the Software Requirement Sheet document. Information such as sequence diagram and class diagram are deeply explained. Also, this document defines the functional requirements and their impact on the system architecture and design. Moreover, it shows the functionality of each subsystem and component. On the other hand, how components interact with each other.

4.1.2 Scope

“BRAINYOPLY” is a system that aims to target the adult male and female brain tumor patients. Our research scope is MRI images and Detect brain tumor only. We will be working on detecting the volume of the tumor. We will integrate this system with many hospitals. The main objective of the proposed system is helping doctors to give accurate diagnose to the brain tumor patient. Calculation of the tumor volume enables the doctors to predict the degree of the tumor will affect which part of the patient body. It will be accurate with low cost and high processing speed.

4.1.3 Overview

The Software Design document is divided into 7 sections with different subsections. First section is an introduction that provides a brief description of the project including its purpose, scope, objectives. The second section includes the System overview which includes a comprehensive description of what is we are building, including options and features. The third section is the system Architecture; it includes “BRAINYOLOY” Architecture Design including a high level overview of the system, class diagram and sequence diagram. Fourth section is mainly the Data Design, describing how the data is processed, stored and handled in the system. Fifth section consists of Component Design; a closer look is taken of each component giving it a description and a pseudo code. The user interface is briefly shown the six sections. Finally, the seventh section provides the requirement matrix.

4.2 System Overview

BRAINYOLY” is a simple solution for doctors for brain tumor volume calculation. Since tumor volume calculation is a trivial task for the doctors to do from the MIR images the proposed system is aiming to make this task a lot easier by using MRI slices, which will be the input to our system. We will calculate the volume of the tumor, and construct a 3D model for the whole brain and for the tumor using 2D input slices, and then the doctor will be able to interact with controller device for intuitive fast mapped to a real brain model. The system will be implemented to help doctors to give accurate diagnose to the brain tumor patient. Calculation of the tumor volume enables the doctors to predict the degree of the tumor will affect which part of the patient body. It will be accurate with low cost and high processing speed. The importance of the system that according to Cancer Index Organization (1), People newly diagnosed with brain cancer are 108,600 and those who died in the year 2015 as a result of brain cancer were 72,300. Consequently, doctors will have an application for the first time in Egypt that will calculate the volume of the brain tumor and convert the 2D MRI images to 3D model and the most important it will not be expensive.

4.3System Architecture

4.3.1 Architectural Design

4.3.1.1 Images processing technics layered in more detailed

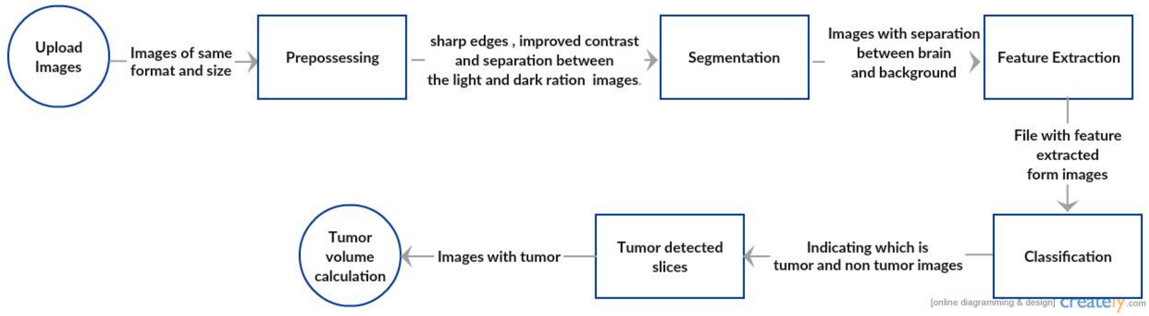


Figure 4.1: Image processing layer using pipe filter.

4.3.1.2 3D construction layer in more detailed

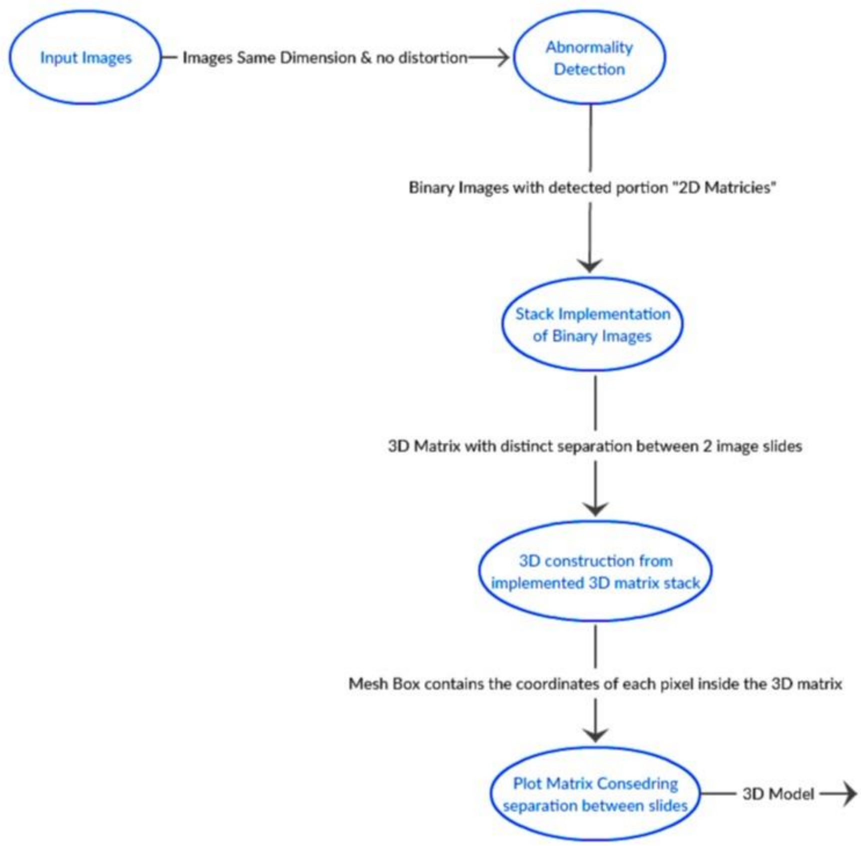


Figure 4.2: Tumor detection and 3D reconstruction

4.3.1.3 Hardware architecture diagram

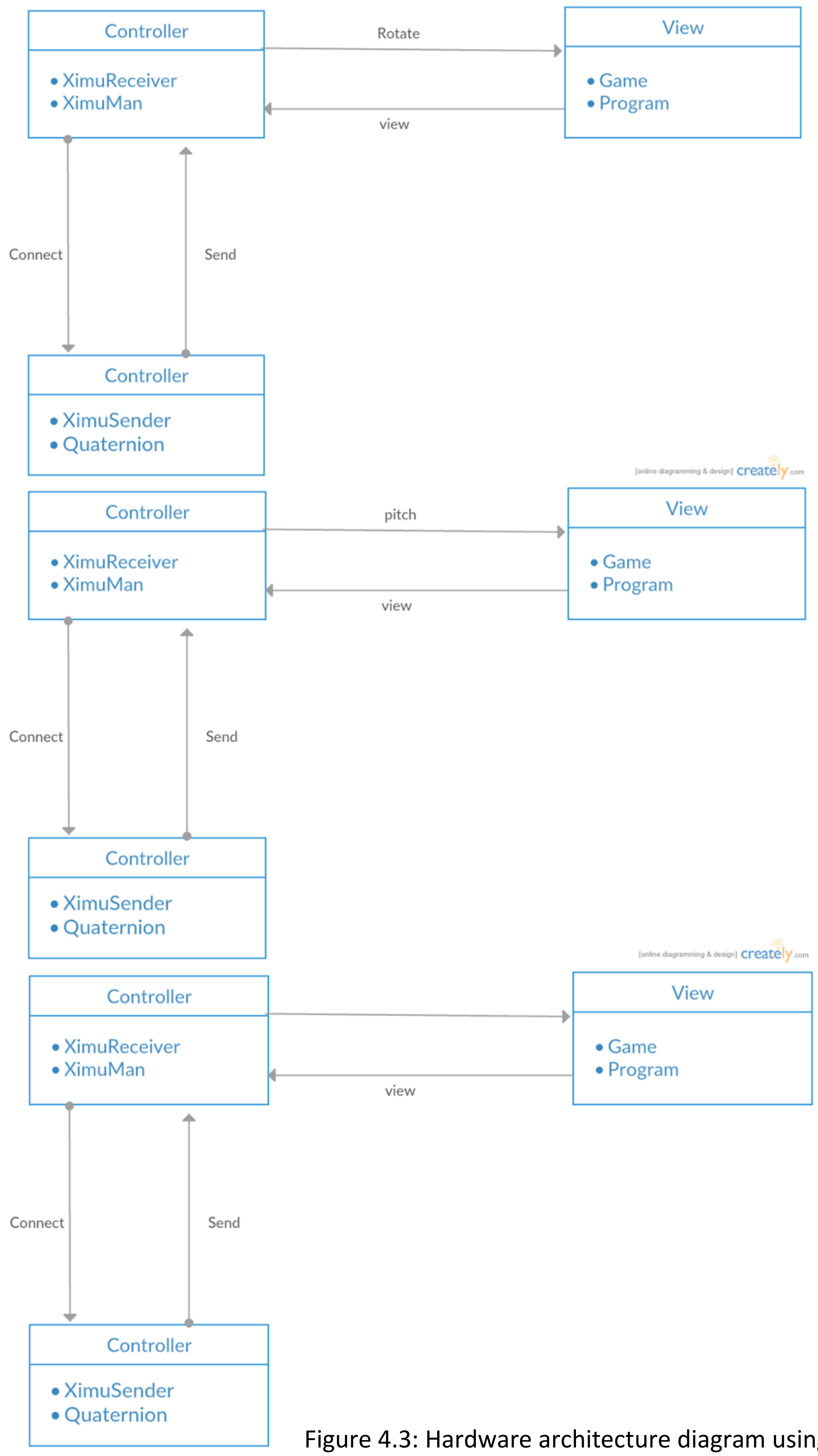


Figure 4.3: Hardware architecture diagram using MVC.

4.2.2 Decomposition Description

4.3.2.1 Tumor detection Sequence diagram

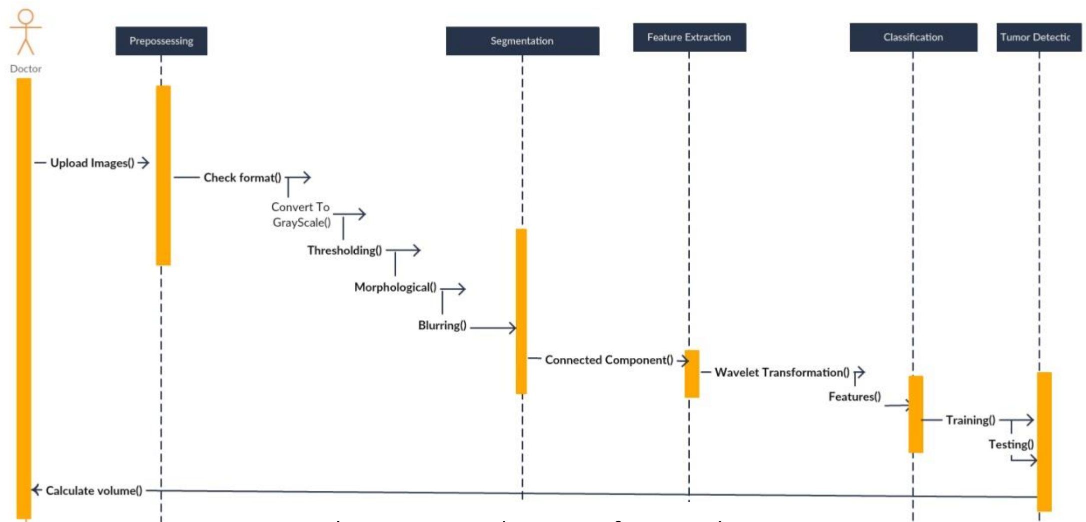


Figure 4.4: The sequence diagram of tumor detection.

4.3.2.2 3D construction sequence diagram

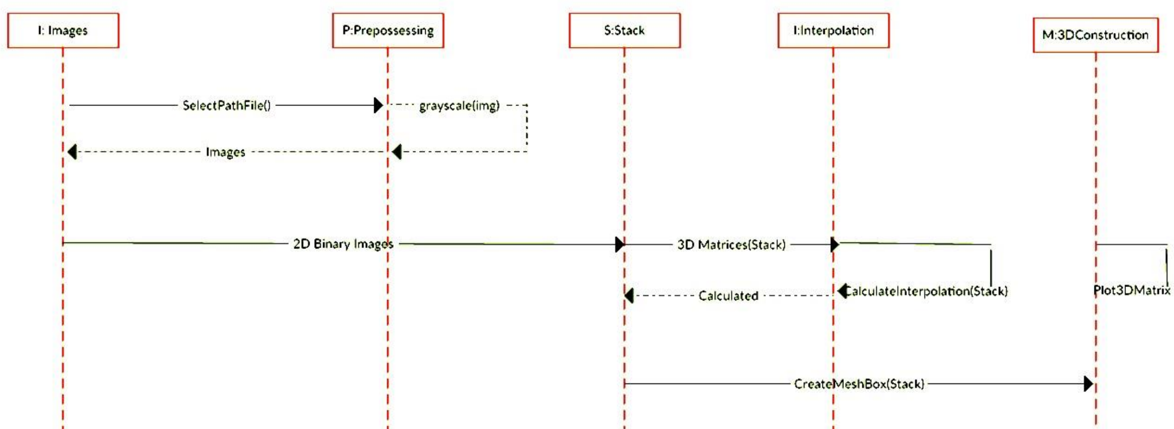


Figure 4.5: The sequence diagram of 3D construction.

4.3.2.3 Inter module Dependencies

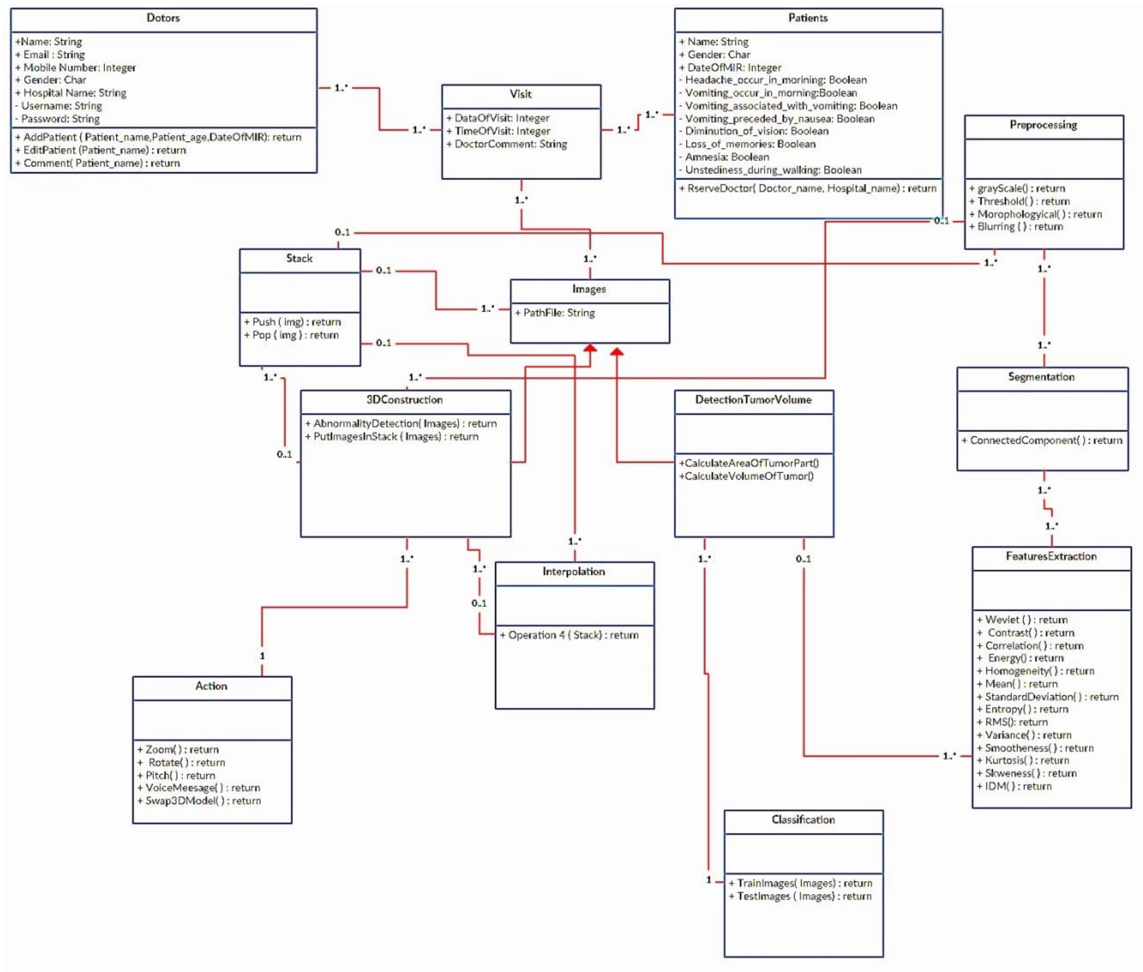


Figure 4.6: Class diagram

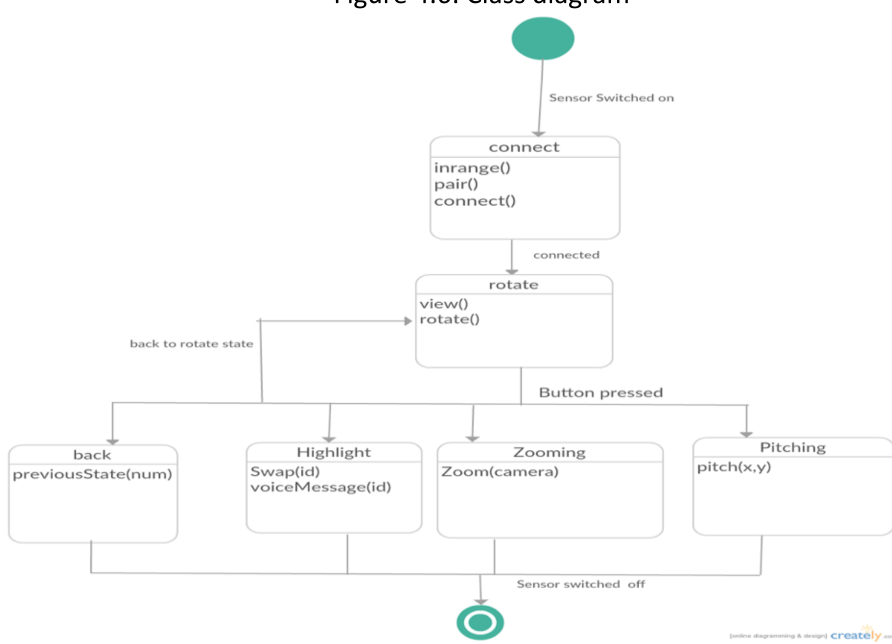


Figure 4.7: State diagram for TUI

Table 4.1: The state definition

States	Definition
Connect	The sensor will connect to the device using fastConnect() function
Rotate	The current shown 3d model will rotate exactly as the sensor current orientation using all of the functions rotateX(),rotateY(),RotateZ()
Zoom	When the button zoom pressed on the dummy head the current 3d model will zoom in or out using function zoom()
Pitch	When any of the arrow buttons pressed on the dummy head the current shown 3d model will pitch from it's current location to the arrow direction.
Back	The system will go back to the rotating state
Highlight	When the anatomy buttons pressed the system will swap the current 3d model to another 3d model using swap() function

4.4 Data Design

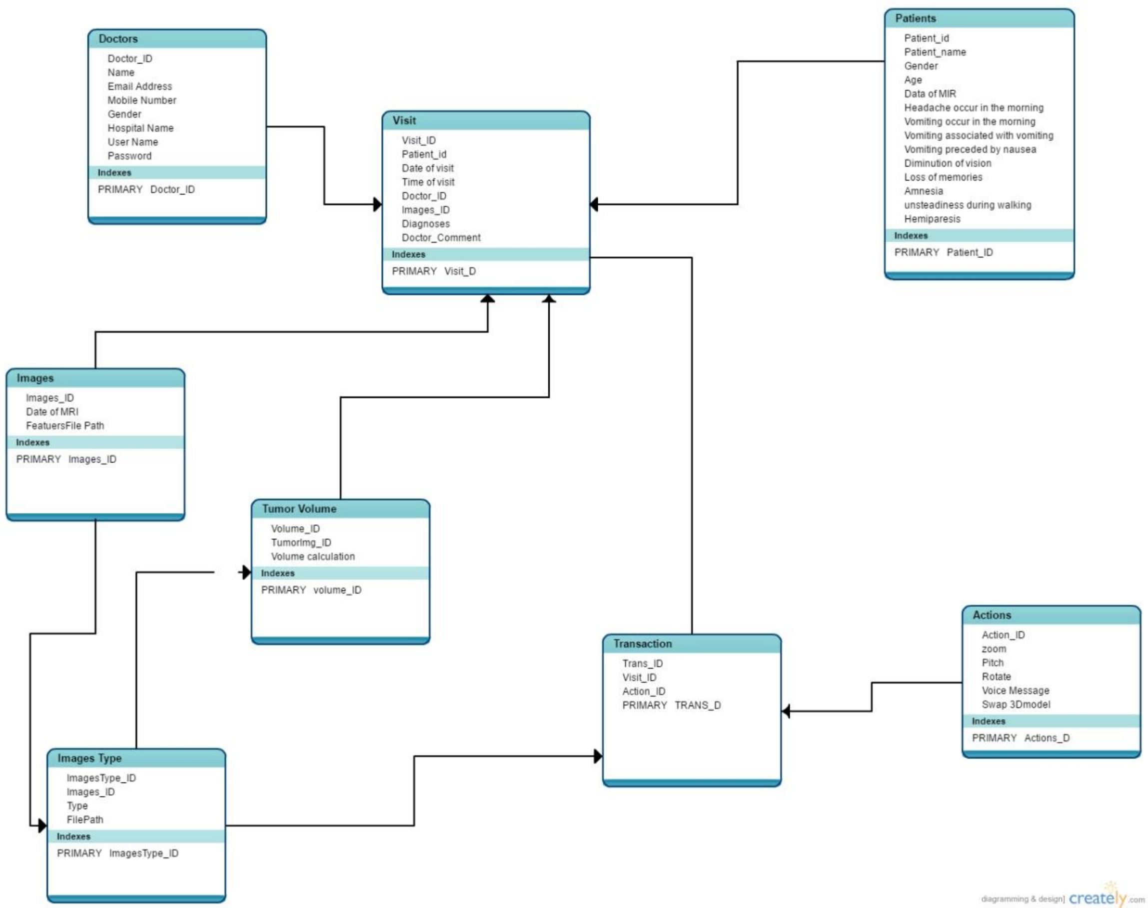


Figure 4.8: Database Tables

4.4.1 Data Description

Brainyology is a desktop application which needs a database to save the doctors information along with their patient's information, the form that the patient will fill it. For each patient there will be a visit or more where the doctor can save the patient the date and time of the visit the patient's MRI images, the tumor images and the tumor volume calculation, the doctor will be able to add a comment in each visit. Doctors will be able to add or edit patient's information along with MRI images. For the 3D construction part it will be save in a file that which it's path will be added to patient' visit. For the Interaction part there will be a table which saves the action taken by the hardware device as rotate, zoom and pitch.

Table 4.2: Structure of table Doctor

Column	Type	NULL	Default
Doctor_ID	Int(11)	NO	
Name	Varchar(25)	NO	
EmailAddress	Varchar(75)	NO	
MobileNumber	Int(11)	NO	
Gendenr	Varchar(25)	NO	
Hospital	Varchar(25)	NO	
UserName	Varchar(25)	NO	
Password	Varchar(25)	NO	

Table 4.3: Structure of table Patient

Column	Type	NULL	Default
Doctor_ID	Int(11)	NO	
Name	Varchar(25)	NO	
Gender	Varchar(75)	NO	
Age	Int(11)	NO	
Date ofMRI	Int(11)	NO	
Mobile Number	Int(11)	NO	
Headache occur in the morning	BOOLEAN (3)	NO	
Vomiting occur in the morning	BOOLEAN (3)	NO	
Vomiting associated with vomiting	BOOLEAN (3)	NO	
Vomiting preceded by	BOOLEAN (3)	NO	

nausea			
Diminution of vision	BOOLEAN (3)	NO	
Loss of memories	BOOLEAN (3)	NO	
unsteadiness during walking	BOOLEAN (3)	NO	
Hemiparesis	BOOLEAN (3)	NO	

Table 4.4 Structure of table Visit

Column	Type	NULL	Default
Visit_ID	INT(11)	NO	
Patient_ID	INT(11)	NO	
Doctor_ID	INT(11)	NO	
DateOfVisit	Varchar(25)	NO	
TimeOfVisit	Varchar(25)	NO	
Diagnoses	Varchar(25)	NO	
Images_ID	INT(25)	NO	
Volume_ID	Int(11)	NO	
Comment	TEXT(25)	NO	

Table 4.5 Structure of table Images

Column	Type	NULL	Default
Image_ID	Int(11)	NO	
Date	Varchar(25)	NO	
Images	Varchar(75)	NO	
FeaturesFilePath	Text(25)	NO	

Table 4.6 Structure of table Image_Type

Column	Type	NULL	Default
Image_Type_ID	Int(11)	NO	
Image_ID	Int(25)	NO	
Type	Varchar(75)	NO	

Table 4.7 Structure of table tumor volume

Column	Type	NULL	Default
Volume_ID	Int(11)	NO	
Image_Type_ID	Int(25)	NO	

Image_ID	Int(75)	NO	
Volume cal	Int(25)	NO	

Table 4.8: Structure of table Actions

Column	Type	NULL	Default
Action_ID	Int(11)	NO	
Zoom	Text(25)	NO	
Pitch	Text(75)	NO	
Rotate	Text(25)	NO	
Voice Message	Text(50)	NO	
Swap 3D model	Text(50)	NO	

Table 4.9 Structure of table Transaction

Column	Type	NULL	Default
Trans_ID	Int(11)	NO	
Image_Type_ID	Int(25)	NO	
Visit_ID	Int(75)	NO	
Action_ID	Int(25)	NO	
DataFile	Text(50)	NO	

4.5 Component Design

Our proposed system is divided into three important parts here will be the explanation of each component used in those three parts provided with the most important algorithms, equation, pseudo code and sources of information

4.5.1 First part Tumor detection

4.5.1.1 Data input and refining of image

In this algorithm we enter a series of magnetic resonance imaging (MRI) which might contain tumor regions in them. Now all images will go through a series of process. First the images will be checked for dimension. If it is not of the same dimension they are made into same dimension by resizing them into a standard size. The final obtained images will be checked for its type. If it is other than gray scale image it is converted into gray scale image which will be our input for the next part of the process.

4.5.1.2 Preprocessing

After the images has been resized and converted in to gray scale. A thresholing equation will be applied to separate between dark and light regions. We will use morphological and erosion algorithms. That sharps the edges of the image and then removes all the noisy parts. Using Gaussian algorithm for blurring to smooth the images will be the final out of the preprocessing process and the input to the next process. Figure 5.1 shows an example of the input images. And the results of preprocessing phase after applying Threshold and morphological algorithms.

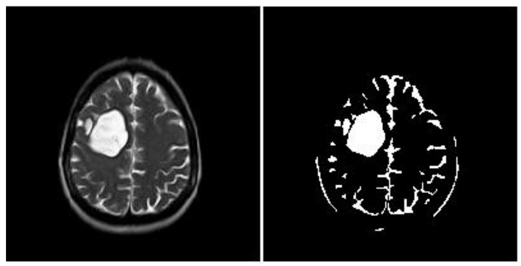


Figure 4.9: Input and output of preprocessing.

4.5.1.3 Segmentation

The preprocessed images will be the input to the next phase. The Segmentation process produces a binary image with detected portion as the white region and rest of the part is blackened region. There are two algorithms to apply this phase the first one is region growing algorithms. It's classified as a pixel-based image segmentation method since it involves the selection of initial seed points. This approach to segmentation examines neighboring pixels of initial "seed points" and determines whether the pixel neighbors should be added to the region, the system is using this algorithm to be able segment the brain from the skull and this algorithm is the best to achieve this approach. The second algorithm is connected component algorithm. It's grouping together all pixels with the same class that are touching each other. Each set of pixels representing a segment is often referred to as a connected component. The system is using this type of segmentation to be able to segment the tumor out of the segmented brain. Figure 4.7 shows an example of the input images to the segmentation phase and the results of the segmentation phase after applying connected component algorithm.

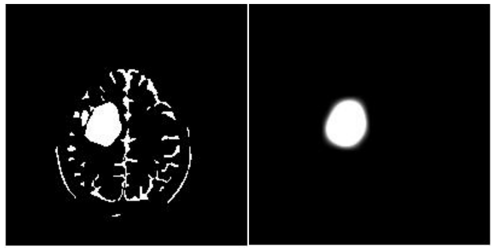


Figure 4.10: Input and output segmentation.

4.5.1.4 Feature Extraction

The segmented objects obtained from the last process will use to extract some algorithm used for feature extortion is Single-level discrete 2-D [1]. This algorithm is the Inverse of Direct wavelet Transformation (IDWT). It is defined as:

$$W\varphi(j0,k)=\frac{1}{\sqrt{M}}\sum_{z} f(x)\varphi j0k(x) \qquad (1)$$

$$W\varphi(j,k)=\frac{1}{\sqrt{M}}\sum_{z} f(x)\varphi jk(x) \qquad (2)$$

$$f(x)=\frac{1}{\sqrt{M}}\sum_{K} W\varphi(j0,k)\varphi jok(x)+\frac{1}{\sqrt{M}} \qquad (3)$$

Discrete variable x = 0,1,2,…,M−1. Normally we let j_0 = 0 and select M to be a $M = 2^J$) so that the summations in Equations (1), (2) and (3) are performed over x = 0,1,2,…,M−1, j = 0,1,2,…, J−1, and k = 0,1,2,…,2^j − 1. The coefficients defined in Equations (1) and (2) are usually called *approximation* and *detail coefficients*, respectively. The features which are extracted from the images defined as he following equations.

Contrast (4)

$$\sum_{i,j} |i-j|\ p(i,j)\text{^}2$$

P= pixels.

Correlation (5)

$$\sum_{i.j} \frac{(i-\mu i)(j-\mu j)p(ij)}{\sigma i \; \sigma j}$$

μ = mu

σ = Sigma

Energy (6)

$\sum_{i,j} p(i,j)\hat{}2$

P= pixels.

Homogeneity (7)

$\sum_{i,j} \frac{p(i,j)}{1+|i-j|}$

P= pixels.

Mean (8)

$\mu = (\Sigma X_i) / N$

μ = mu

Standard deviation (9)

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^{N} (xi-\mu)\hat{}2}$$

Variance (10)

$\sigma^2 = \Sigma (X_i - \mu)^2 / N$

Root Mean Square (RMS) (11)

$\sqrt{\sum_{i=1}^{n} \alpha i\hat{}2}$

Smoothness (12)

1-(1/(1+Sum{k}))

Kurstosis (13)

kurtosis(double(G(:)))

Skewness (14)

skewness(double(G(:))

Inverse Difference Movement (15)

G(i,j)./(1+(i-j).^2)

4.5.1.5 Classification

After obtaining the segmented object features. System will process to the next process in image processing technics which is classification. The classification is divided into two phase. The training phase and then the test phase. In the training phase the system will use the computed features to differentiate between tumor features and non-tumor features. In the testing phase the system should recognize the images with the tumor and the images that don't have the tumor. The algorithm used in the classification phase is support victor machine (SVM) [3]. This algorithm plots each data item as a point in n-dimensional space where n is number of features you have with the value of each feature being the value of a particular coordinate. Then, we perform classification by finding the hyper-plane that differentiates the two classes very well. Figure 3 shows an example of hyper-plane .Support Vectors are simply the co-ordinates of individual observation. Support Vector Machine is a frontier which best segregates the two classes (hyper-plane/ line).

4.5.2 Second Volume Calculation.

4.5.2.1 Cross section Area of the tumor.

After obtaining the slides which contain tumor from image processing techniques, we will apply “Sobel” algorithm to sharp the edges of the tumor in each slice. After applying sobel, the last step is applying “chain code” algorithm which is used to select the points on the boundaries of tumor part and transmit its coordinates. These coordinates help us to get the cross section area of the tumor in all slices [4].

4.5.2.2 Calculation of area of slides in between two given consecutive slides.

We convert 1mm to 3.77952 pixels which is multiplied to the distance between two consecutive slides to get the number of pixel between two slides. Now we consider each pixel as an individual slide we can get the volume by adding areas of the slides. But if there is a missing area of some slides, so we can use method called”interpolation”. In this method we plot the obtained value in are vs sliding number graph to get the area of missing slices [4].

4.5.2.2 Volume estimation using area from each slice

From the above obtained area we use the concept of stack to calculate the volume of the tumor content in the slices.Each slice is given by: I[1:M,1:N] and the total height is “x”, then the volume is “V”, M → Number of rows , N → Number of columns [5].

$$V = \sum_{m=1}^{M}\sum_{n=1}^{N} I_1[m,n] + \sum_{m=1}^{M}\sum_{n=1}^{N} I_2[m,n] + \sum_{m=1}^{M}\sum_{n=1}^{N} I_3[m,n] + \ldots + \sum_{m=1}^{M}\sum_{n=1}^{N} I_x[m,n] \quad (16)$$

$$V = \sum_{K=1}^{x}\sum_{m=1}^{M}\sum_{n=1}^{N} I_K[m,n] \quad (17)$$

$$V = \sum_{K=1}^{x} X[K] \quad (17)$$

Where

$$\sum_{m=1}^{M}\sum_{n=1}^{N} I_K[m,n] = X[K] \quad (18)$$

4.6 Human Interface Design

4.6.1 Overview of User Interface

Brainyology take advantage of new technologies that helps making medical technical support help possible. This system aims to make it easy for doctors to calculate the brain tumor volume, construct a 3D model for the whole brain and interact with the 3D model using a TUI. The system can work with any kind of MRI images for any patients. The system consists of four main functions, the segmentation, the tumor volume calculation, the 3D construction and the TUI. First the Doctor will login to the system, the he will be able to add new patient of edit a patient. If he chooses add a new patient a form will appear to him, he will have to answers all the questions. After the doctor will fill the form a new page will be open. This new page will typically have buttons as the picture provided below for functionalities like uploading patient folder, calculate the tumor volume, reconstruct the 3D model and interact with the 3D model using the TUI.

4.6.2 Screen Images

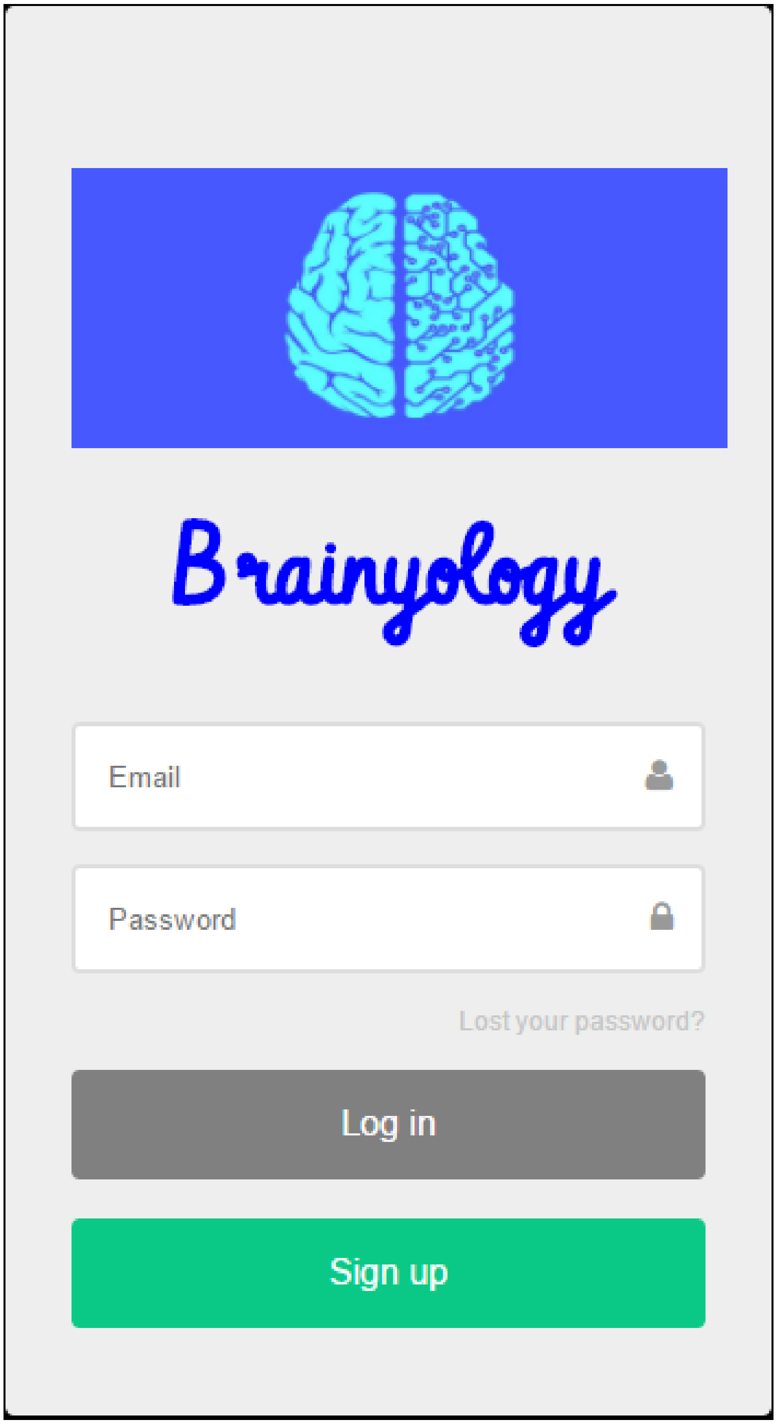


Figure 4.11: Welcome page

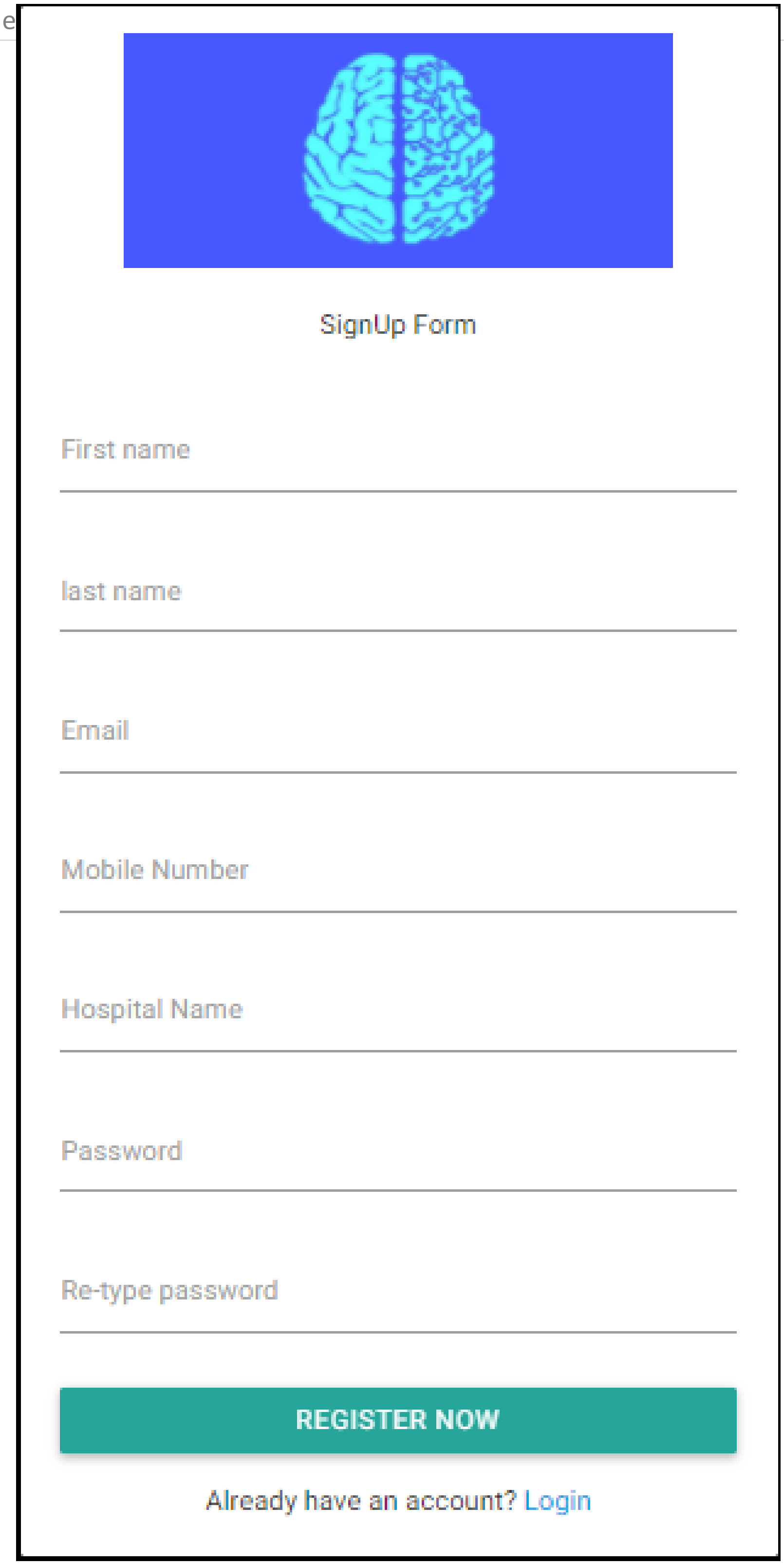


Figure 4.12: Sign up page

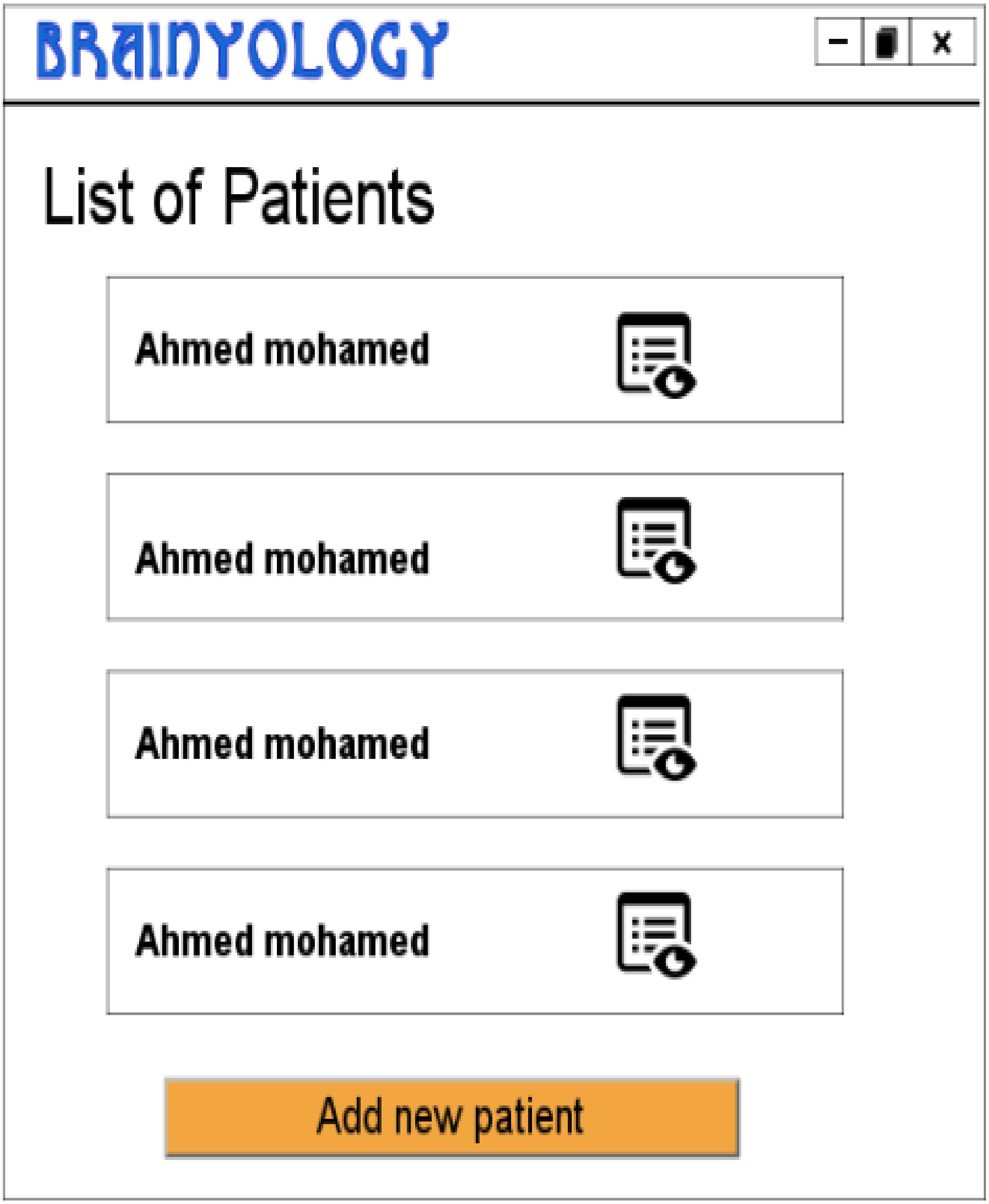
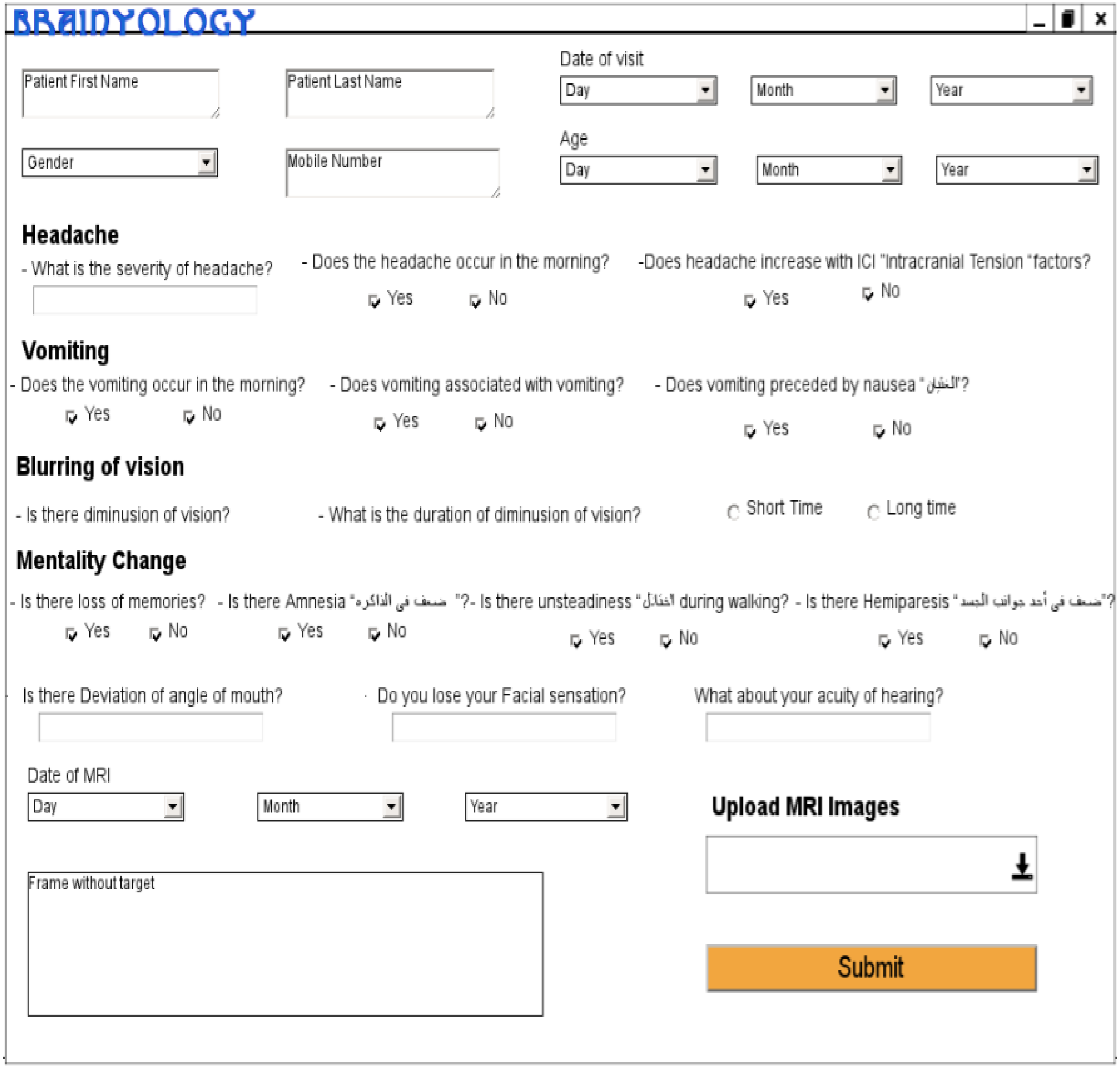


Figure 4.13: Add or Edit patient



BRAINYOLOGY

Patient First Name

Patient Last Name

Date of visit: Day / Month / Year

Gender

Mobile Number

Age: Day / Month / Year

Headache

- What is the severity of headache?

- Does the headache occur in the morning? Yes / No

-Does headache increase with ICI "Intracranial Tension "factors? Yes / No

Vomiting

- Does the vomiting occur in the morning? Yes / No

- Does vomiting associated with vomiting? Yes / No

- Does vomiting preceded by nausea "الغثيان"? Yes / No

Blurring of vision

- Is there diminusion of vision?

- What is the duration of diminusion of vision? Short Time / Long time

Mentality Change

- Is there loss of memories? Yes / No

- Is there Amnesia "ضعف في الذاكرة"? Yes / No

- Is there unsteadiness "اختلال" during walking? Yes / No

- Is there Hemiparesis "ضعف في أحد جوانب الجسد"? Yes / No

Is there Deviation of angle of mouth?

Do you lose your Facial sensation?

What about your acuity of hearing?

Date of MRI: Day / Month / Year

Upload MRI Images

Frame without target

Submit

Figure 4.14: First visit Patient's form

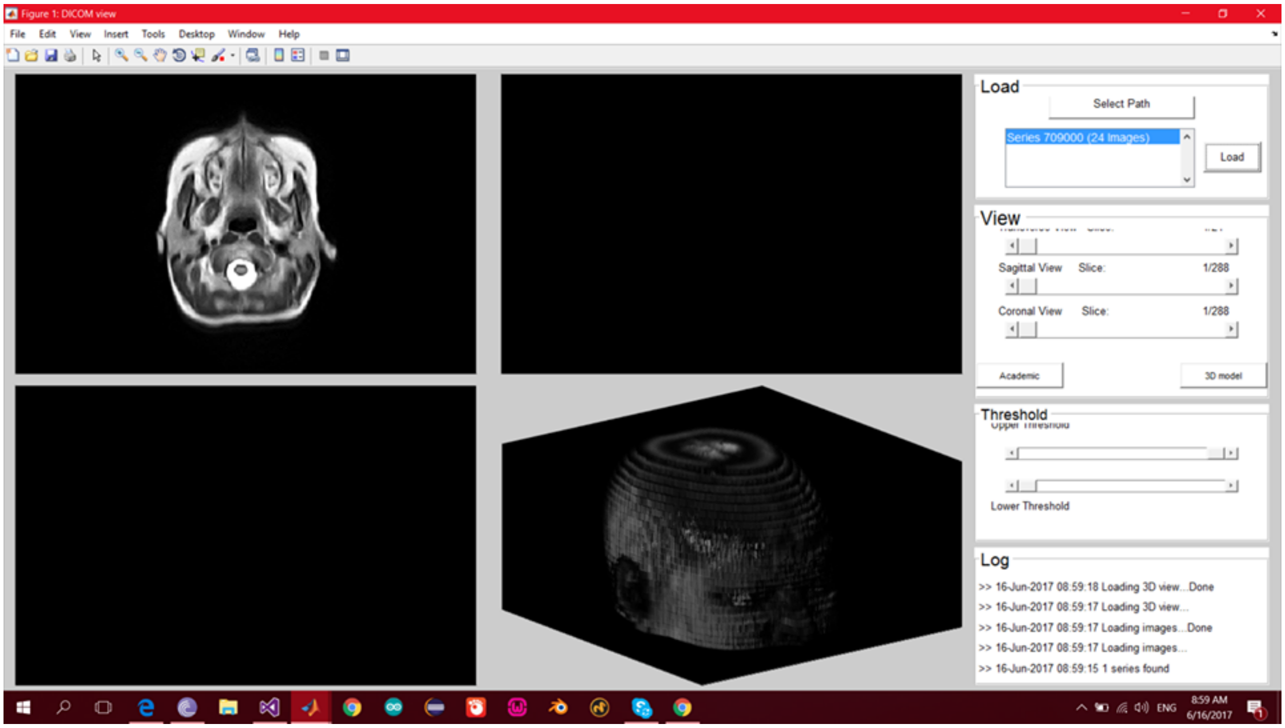


Figure 4.14: The system main GUI

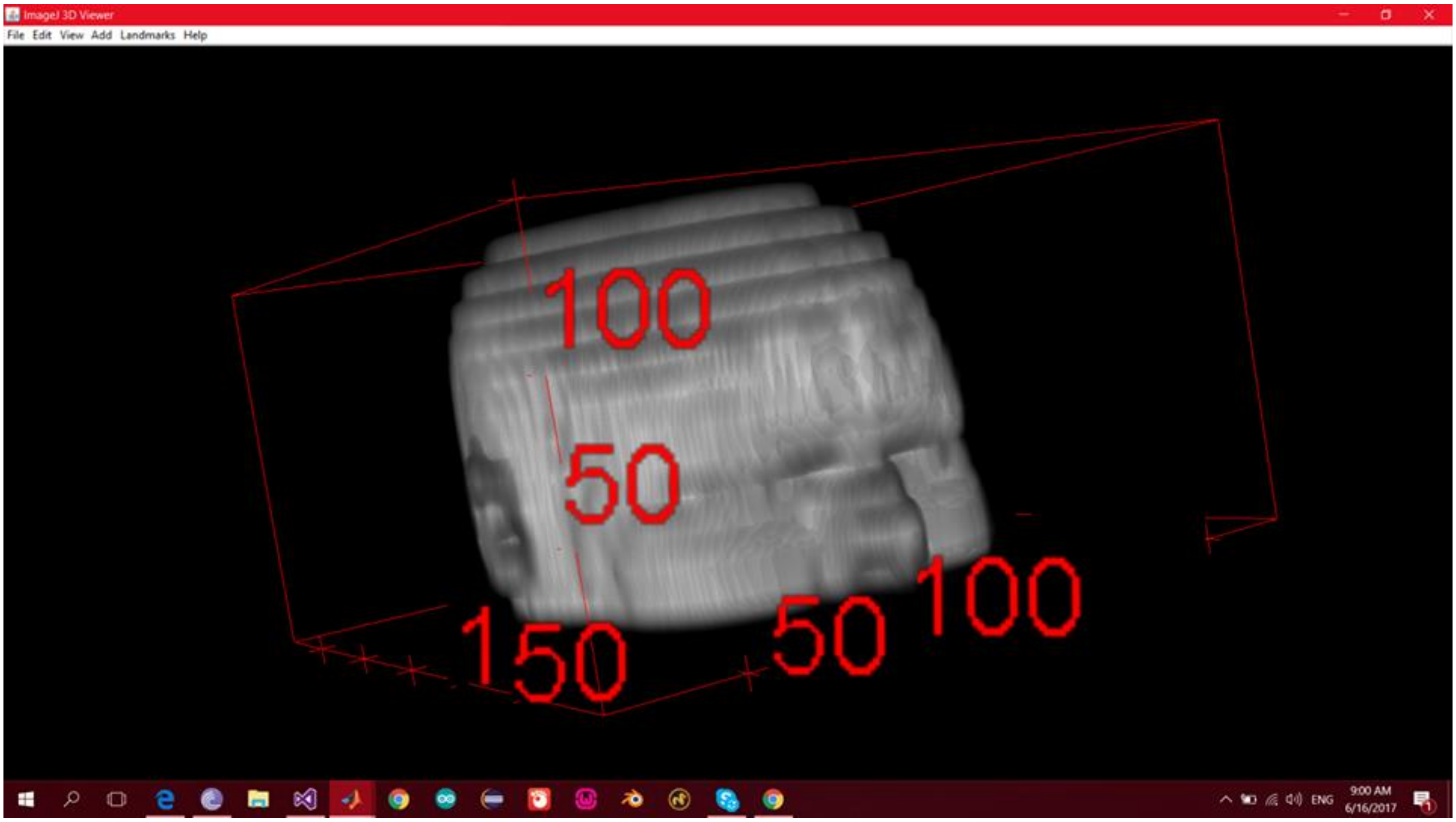


Figure 4.15: 3D construction Page

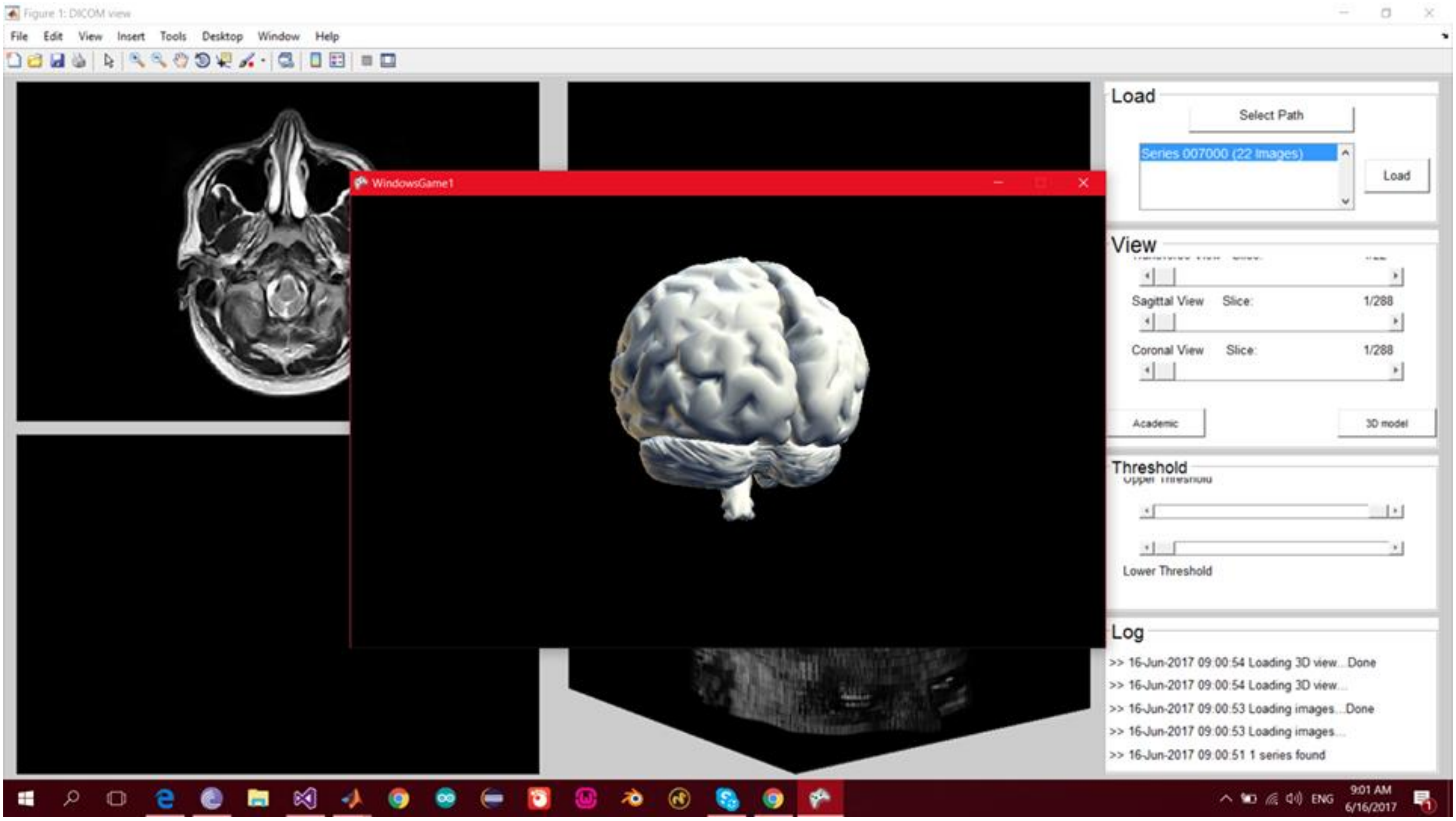


Figure 4.16: TUI Page

Table 4.10: Traceability Matrix

ID	Technical Assumptions	Function requirement	Statues	Technical Specification	Implemented in
1	The system must be able to upload MRI folder	Import Images	Testing	The minimum number of MRI images is 24 and maximum number is 60	Main Component
2	The system must be able to sharp the edges and remove the noise	Preprocessing	Testing	Sharpen edges, and improved contrast and separation between the light and dark ration images.	
3	The system must be able to segment the tumor	Segmentation	Testing	Images which is divided in to multiple segments the brain is separated from the back ground.	Main Component
4	The system must be able to calculate the tumor volume	Tumor volume calculation	Testing	The calculation of the tumor volume.	Main Component
5	The system must be able to create a voxel to construct a 3D model	Creating voxel	Testing	-Vertices: matrix containing the vertices of the voxels. -Face: matrices containing indexes of the vertices.	Main Component
6	The system must be able to plot a 3D model	Plot 3D brain	Testing	3D model of the brain.	Main Component
7	The system must be able to rotate the 3D model when the zoom button is pressed	Rotating 3D model	Testing	A 3d model for the brain that rotate exactly as the dummy head rotates in the real life	UI Component
8	The system must be able to zoom the 3D model when the zoom button is pressed	Zooming the 3D model	Testing	Zoom in and out the 3d model	UI Component
9	The system must be able to move the 3D model left, right, up and down when one of the four button is pressed	Pitching the 3D model	Testing	The whole 3d model moves left ,right ,up or down	UI Component
10	The system must be able to highlight a specific part of the brain as the user press the buttons	Highlighting the 3D model	Testing	A specific parts will be highlighted	UI Component

Chapter 5

Evaluation

5.1 Introduction

In order to evaluate the proposed system, multiple experiments were plotted to test out the features associated with the system. Comparison between our system and traditional methods is also available. Since that our system is divided in 4 parts, we divide the experiments into 4 parts. The first experiments evaluate the accuracy of the segmentation using different algorithms. The sound experiment evaluate the accuracy of the tumor volume calculation, the third experiment evaluate the accuracy of the 3Dcontruction and the TUI. 3 participants doctors volunteered to test the system along with four cases.

5.1.1 Experiment 1 segmentation algorithms experiments

The scope of this experiment is to show the effect of using different algorithm for segmentation. Accuracy is needed for segmentation of tumor to be able to calculate the volume of the tumor and get the accurate results.

5.1.1.1 Task

The task required for this experiment was to use all the segmentation algorithms (Connected Component, Kmeans, Region growing, connected Component along with region growing) with the cases.

1- Measure the accuracy of the segmentation using Tumor cases.
2- Measure the accuracy of the segmentation using non-tumor cases.

Table 5.1: Experiment 1 using case 1

Experiment 1	Segmentation	Total positive	Total negative	accuracy
Case 1 24 image 7 tumor 17 non tumor	Connected Component	4	2	57.1%
Case 1 24 image	Kmeans	3	4	42.2%
Case 1 24 image	region growing	4	2	57.1%
Case 1 24 image	region growing + Connected Component	6	1	87%

Table 5.2: Experiment 1 using case 2

Experiment 1	Segmentation	Total positive	Total negative	accuracy
Case 2 60 image 0 tumor 60 non tumor	Connected Component	5	55	92%
Case 2	Kmeans	9	51	85%
Case 2	region growing	14	46	77%
Case 2	region growing + Connected Component	4	56	93%

Table 5.3: Experiment 1 using case 3

Experiment 1	Segmentation	Total positive	Total negative	accuracy
Case 3 24 image 10 tumor 14 non tumor	Connected Component	6	4	60%

Case 3 24 image	Kmeans	5	5	50%
Case 3 24 image	region growing	6	4	60%
Case 3 24 image	region growing + Connected Component	9	1	90%

Table 5.4: Experiment 1 using case 4

Experiment 1	Segmentation	Total positive	Total negative	accuracy
Case 4 60 image 20 tumor 40 non tumor	Connected Component	15	3	75%
Case 4 60 image	Kmeans	10	10	50%
Case 4 60 image	region growing	17	8	85%
Case 4 60 image	region growing + Connected Component	18	2	90%

5.1.1.2 Results

The results of experiment 1 show that using the region growing along with the connected components gives the heights accuracy for the segmentation.

5.1.2 Experiment 2 The tumor volume calculation

The scope of this experiment is to evaluate the system accuracy of the tumor volume calculation.

5.1.2.1 Task

Volunteering Doctors are required to calculate the volume with the traditional way to evaluate the accuracy of the proposed system tumor volume calculation in this experiment.

5.1.2.3 Method of Evaluation

We interviewed three of the most qualified doctors in 57357 the childre's cancer hospital. We first interviewed Dr. Iman Mohamed Zaky the head of the radiology department in 57357, and then we interviewed Dr. Mohamed Saad Zaolo the head of the brain surgeon department and finally Dr. Khaled Mohamed Mohamed the head of the neurologists department. The three doctors calculated the patient's volume using the traditional way and compared the results with the results of the system and they all agreed that the volume is nearly accurate; but no one can be sure unless the tumor is removed is a Sergey then they can measure the volume of the actual tumor.

5.1.2.3 Results

The results of the tumor volume calculation are nearly accurate enough according to the doctors experience.

5.1.3 Experiment 3 The 3D construction and TUI

The scope of this experiment is to evaluate the system accuracy for constructing the 3D model and the user experience with the TUI.

5.1.3.1 Task

Volunteering Doctors are required to interact with the 3D constructed model from the MRI images using a TUI (Dummy head with button) and test all the Dummy head functionality.

5.1.3.2 Method of evaluation

We let the doctors interact with the 3D model using the TUI and we create a survey and gave it to the doctors to write back their feedback.

5.1.3.3 Results

Most of the doctors like the TUI part since that the original MRI application is very frustrated to use but the TUI give the doctor the ability to interact with the 3D model in an easy way. The buttons are easy to recognize they can zoom in and out, move up and down, and view a one specific MRI frame and highlighting the most important part in the brain.

Chapter 6

Conclusion

Technology is a wide pool if continuous overhauling, therefore keeping up with the pace is a must. It is the best time to step up the traditional methods and cope with the better improvements. We are offering a medical system which will reduce frustration and save doctors time. Based on the surveys the tumor volume calculation is an important phase because it may save a patient's life. The technology used in our system as TUI and 3D model is actually fun and easy to use. Our system has proved that it's solving a major problem that doctors have which is calculation the tumor volume without marking the suspicions MRI slices. Our results from carried out experiments shows that such a system is very important in the medical field as if gives an accurate results for the tumor volume calculation, as for the 3D model and TUI doctor loved the idea of interacting with the system using a dummy head because it's easy to use.

6.1 Future directions

Brainyoply probed that doctors needs such a system to make their work more accurate and to save time, some points still do need improvements. Considering our system main focus on the future would be improving the results of the volume calculation, detecting the type to the volume, and plan a treatment according to the volume of the tumor.

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