



Geometrical Image Processing

Laboratory

Computer Science Faculty, Technion

Brain 3D anatomy

Project in virtual reality

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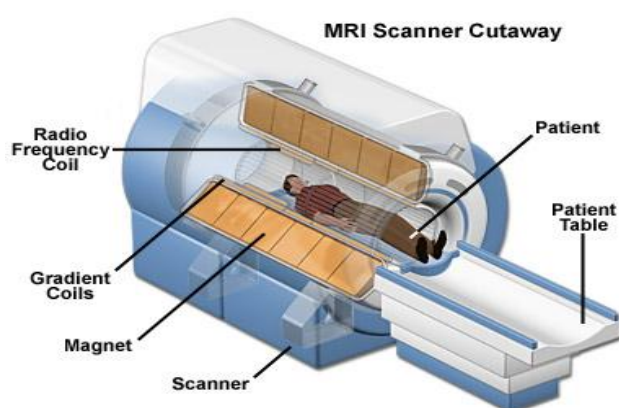
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INTRODUCTION

An MRI scan, which stands for Magnetic Resonance Imaging, is an excellent tool for aiding in diagnosis of disease and is widely used around the world from the beginning of the 1980s. This imaging method provides high quality lateral layer images without the use of x-ray or any other kind of damaging radiation. The scan uses radio waves and magnetic field. The scan provides sharp images particularly of body parts surrounded by dense bone tissue. As such, this scan is well suited for brain and spine imaging. The scan accurately shows brain tumors and shows great detail of the depth of the tumor into the brain tissue.

The scanners, based on the detection of Hydrogen atoms found in varying concentrations in the different body tissues, clearly emphasize the contrast between healthy and sick tissue. The MRI scan is highly versatile and can produce imaging of the body in every direction: horizontal, vertical or diagonal.

In the MRI scan, the body is resting in a lying position inside a high strength magnetic field. The patient must lie motionless. The scan takes approximately 45 minutes, it is painless, and the patient hears the knocking sounds of the machine.



Thanks to the high effectiveness and lack of negative side effects of the scan, great efforts and resources are invested to improve it. For example, a new MRI scanner that particularly measures brain activity is used today, which is an important tool for research as well as to detect the exact areas in the brain that are responsible for speech and hearing in order to avoid accidental damage to them during an operation. In fact, this is a regular MRI scan in combination with detection of the local changes in blood flow in the brain in order to pinpoint the neurologically active part caused by a given stimulation such as a thought of a specific subject by the patient.

When reviewing the MRI scan, the neurologist or neurosurgeon see only a 2-dimensional image on a screen taken from the 3-dimensional MRI scan, which might be detrimental in the analysis of the image. The doctor has to imagine the 3-dimensional organ in his mind's

eye, based on his knowledge and studies of the body, and gather the information from a partial view of the image at any given time. This could lead to lower accuracy in detection by inexperienced doctors, or in the worst case, a wrong diagnosis.

In our project, we chose to concentrate our effort on MRI scans of the brain, for which this imaging method is particularly revealing. The brain is the most important part in the body's nervous system, it regulates and controls the activity of the different body functions and therefore the precise reading of the MRI scan results is crucial.

We attempted in this project to create a new visual tool that will enhance the tools that are already in wide use by doctors around the world today, and give a new understanding of the brain imaging to doctors, patients and students alike. It uses the current cutting-edge Virtual Reality tools of today, namely the "HTC vive" system. We hope to bring the brain image to life, to give it a realistic view, and to create a more accurate tool for doctors, that will bring the trusted old MRI to the 21st century.

SYSTEM OVERVIEW —

TOOLS AND DEVELOPMENT ENVIRONMENTS:



Matlab - A multi-paradigm numerical computing environment and fourth-generation programming language. A proprietary programming language developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages.



Unity - A cross-platform game engine developed by Unity Technologies and used to develop video games for PC, consoles, mobile devices and websites.

In our project we used version 5.1 of Unity.



HTC vive - a virtual reality headset developed by HTC and Valve Corporation, released on 5 April 2016. This headset is designed to utilize "room scale" technology to turn a room into 3D space via sensors, with the virtual world allowing the user to navigate naturally, with the ability to walk around and use motion tracked handheld controllers to vividly manipulate objects, interact with precision, communicate and experience immersive environments.

PERFORMANCE OVERVIEW:

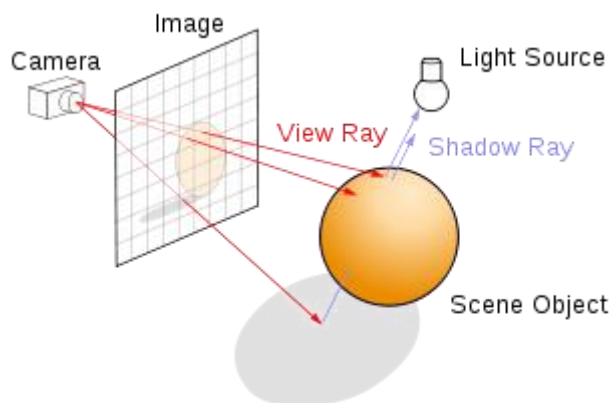
Algorithms used:

Ray Marching – The purpose of the algorithm is to generate an image from a 2-dimensional or 3-dimensional model.

In the algorithm, we select a position for the camera, put a grid in front of it, send rays from the camera through each point in the grid, with each grid point corresponding to a pixel in the output image.

The entire scene is defined in terms of a signed distance function, which gets coordinates of a point in space and returns the shortest distance between that point and some surface. The sign of the return value indicates whether the point is inside that surface or outside.

The algorithm used such a function in order to find the intersection between the view ray and the scene: we start at the camera, and move a point along the view ray, bit by bit. At each step, we ask “Is this point inside the scene surface?”, or alternately phrased, “Does the function evaluate to a negative number at this point?”. If it does, we’re done! We hit something. If it’s not, we keep going up to some maximum number of steps along the ray.



Project description

Our system consists of three main parts:

The first one is to receive a Nifti MRI file, containing the 3-dimensional matrix that is the MRI scan of the brain.

We used Matlab in order to create 2-dimensional images from the given matrix. Each image was saved as a PNG file and is a specific slice of the brain.

The second part is to load the images into Unity, change each one of the PNG images to 2D read/write enabled textures and create a 3-dimensional object from them. In Order to build this object, we used the Ray Marching algorithm.

The last part was to implement the ability to present the object in virtual reality using HTC vive and allow features which will give the user the feeling of the 3-dimensional object.

Our project supports the following features:

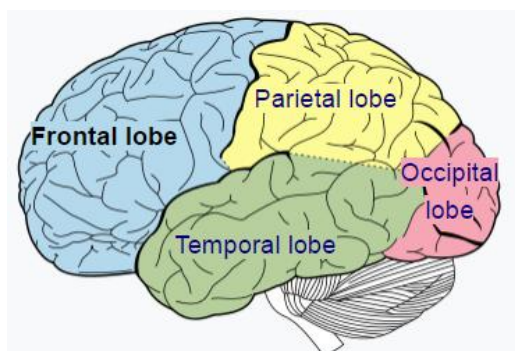
- Rotating – rotate the brain using the handheld controller.

- Zoom – zoom in and zoom out through a pull-push motion of the handheld controller.
- Cutting – Cut the brain along the three X, Y and Z axes.
- Reset button –return the brain object to the initial position in space, and reset the slicing to original position.
- Masking – using checkboxes, emphasize different parts of the brain according to the user choice in one of the two following ways:
Highlighting – coloring the selected parts

Cutting - removing the unchecked parts and see only the wanted one.

After selecting one of the above presentation methods, the user can select using the checkboxes which specific part or parts to highlight: The system provides seven different areas of the brain which the user can choose by their names:

- Cerebellum - A major feature of the hindbrain of all vertebrates. In humans, the cerebellum plays an important role in motor control, and it may also be involved in some cognitive functions such as attention and language as well as in regulating fear and pleasure responses.
- Frontal Lobe - The frontal lobe, located at the front of the brain, is one of the four major lobes of the cerebral cortex in the mammalian brain.
- Occipital Lobe - One of the four major lobes of the cerebral cortex in the brain of mammals. The occipital lobe is the visual processing center of the mammalian brain containing most of the anatomical region of the visual cortex.
- Parietal Lobe - One of the four major lobes of the cerebral cortex in the brain of mammals. The parietal lobe integrates sensory information among various modalities, including spatial sense and navigation
- Temporal Lobe - One of the four major lobes of the cerebral cortex in the brain of mammals. The temporal lobe is involved in processing sensory input into derived meanings for the appropriate retention of visual memory, language comprehension, and emotion association
- Insula - A portion of the cerebral cortex folded deep within the lateral sulcus (the fissure separating the temporal lobe from the parietal and frontal lobes). The insula is believed to be involved in consciousness and play a role in diverse functions usually linked to emotion or the regulation of the body's homeostasis.
- Precentral gyrus - Forming the posterior border of the frontal lobe, contains the primary motor cortex, which controls voluntary movements of specific body parts.



EXPERIMENTS AND DESIGN

The intended users of our project are doctors, patients, and medical students. Therefore, we tried to make the interface as simple as possible, using only one button in the handheld controller while keeping all the features we wanted the system to provide. This will allow the user to grasp the controls and interaction with the system in the shortest period of time, and with a shallow learning curve.

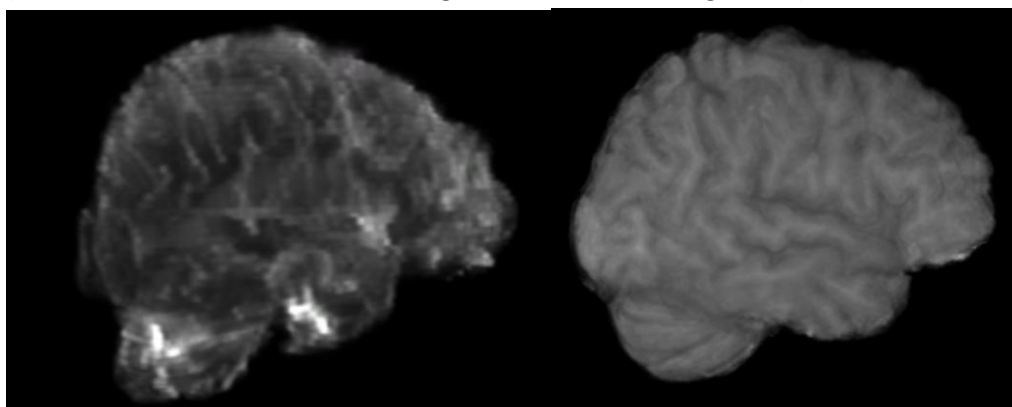
Our efforts were focused on intuitive user interface, good resolution and proportions, high quality of visualization and good run-time performance.

We started in searching for the best option for the presentation of the brain. On one hand, we wanted it to be with some level of transparency in order to see the inside of the brain, and on the other hand, we want it to be opaque enough in order to see the whole object. We made experiments in order to find the optimal parameter for transparency.

While results on the initial testing were rendering on a monitor and not the HTC Vive VR headset gave one result, on the headset we got much different results. They were more bright and opaque than those on the monitor. The culprit, as it turned out, was not the alpha transparency channel but the rendering of Unity to the VR headset. Unity gives two options, one called "Linear" and another called "Gamma". While the default was "Linear" and gave us the brighter yet different results, the "Gamma" rendering option was the one we chose, since it gives the correct image on the headset that is balancing well transparency and opaqueness.

After finding the appropriate level of transparency for the presentation of the brain, we experimented with two MRI scans with different resolutions for which we had the data. The difference between the first resolution, 72 slices, each 256x256, giving 4.85 megapixels and the second one, 244 slices, each 256x256, giving 15.99 megapixels was significant, 3.3 times more data in the higher resolution, and that gave a significant improvement in the image of the brain.

(on the left side low resolution vs. high resolution on the right side)



However, one of the major difficulties we encountered with the higher resolution image was the run-time performance while changing/adding the mask of the part of the brain we wanted to highlight/isolate.

We solved this problem in two levels:

- Preprocessing of the data – loading the main image of the brain, and all the different masks into Color data type arrays before the initial run of the program, creating a "Loading..." screen upon initial running of the program.
- Synchronization: We used coroutines and background workers, essentially Unity's way of implementing threads, to make the heavy calculations in the background while the user interface is still reactive.

SUMMARY AND PLANS FOR THE FUTURE

During the project, we tried to build a system which will ease the doctors work in interpreting MRI scans of the brain.

We think our project is innovative because it presents a brain from a real MRI scan and not just a generic model.

Further testing and input by neurologists, neurosurgeons, and radiologists is needed to improve and fine-tune the interface and visual data that is given, however.

We believe that with openness and the widespread availability of the VR technology in the future, its relative affordability, and the ease with which anyone can use and interact with it, this project could become a starting point for a new medical imaging era.

Possible features to be added for the project:

- Provide the possibility to get the input as a Nifti file in order to get the MRI scans directly from the user, without the need to convert them to a .mat file via Matlab
- Present the functionality of each part of the brain using a human demo
- Provide more information about additional parts of the brain
- Provide the possibility to cut the brain in any angle, not just in the X, Y and Z axes
- Using this tool to represent any body part that was scanned by MRI

From a personal point of view, we believe that this project provides a glance to a new technology, which can lead to a breakthrough in this branch of medical science. We are excited to take part in this beautiful new world.

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<https://github.com/brianasu/unity-ray-marching/tree/volumetric-textures>
- MRI scan and data about the different parts of the brain: Hagai Tzafrir with corporation with "Rambam" Hospital.
- VRTK - VR toolkit, a collection of usage examples of the HTC vive and interaction with the controllers <https://vrtoolkit.readme.io/>

GALLERY

