Hacettepe University

Computer Engineering Department

BBM479 Project Proposal Report

Project Details

Title	A labeling, learning and visualization tool for brain imagery	
Short Description (max. 200 words)	In this project, the students are expected to develop an image labeling, learning and visualization tool that allows the users to respectively create annotated brain images, train deep segmentation models for clinical analysis, and visualize certain brain areas of interest.	
Supervisor	Erkut Erdem	
Technical and Scientific Difficulty	( ) Easy ( ) Mediocre (X) Challenging	
External Support	( ) Yes ( ) No	
If yes,	**Type**	**Details**
	( ) Company Funding / Support	Company name: Amount:
	( ) TÜBİTAK Project Fund	Type: Amount:
	( ) Other Fund	Source : Amount:

Group Members

	Full Name	**Student ID**
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Project Summary (/ 20 Points)

Explain the project in summary, including your motivation to do the project, your solution plan in short and your expected outcome and impact. You have to summarize your project between 200-500 words.

The aim of the project is to ease the process of preparation for brain surgery for the brain surgeon. At the time, there is already a process ongoing that is proven to be working. This process involves training personnel for labeling the parts of the brain on a 3 dimensional (3D) model constructed by brain Magnetic Resonance Imaging (MRI) images from the different axes. Later on this 3D model is uploaded to an online-hosted website to inspect the constructed 3D model on a 2D screen (monitor, telephone etc.). However the process of learning to label those brain parts for a person that is uninformed about the brain in medical terms takes about 1-2 years and even after the labeling process, there is still a need to check and correct even the millimetric mistakes done by the annotator before the brain surgery operation. Currently, with personal that is trained and have been doing this labeling process for at least 4 years, it takes around 2-3 hours to convert a set of MRI images to a 3D labeled brain model.

In this project, we aim to do this operation in an end-to-end autonomous manner, where a set of MRI images are fed into a deep learning model (whenever we are going to say an artificial intelligence model we are going to include its adjective to resolve the ambiguity between 3D models and artificial intelligence algorithms) to make segmentation of brain parts, then construct a 3D model by either using an existing tool and at the end converting this tool to a file format compatible with Virtual Reality (VR) thus enabling the surgeons to investigate the patient's brain using VR tools.

We believe that, even after the labeling process of a deep learning model, we will still need post-processing by an expert in the brain medical domain to correct the little mistakes made by the deep learning model. This belief is caused by the fact that even tiny mistakes (scale about mm^2) can cause enormous hardships for the surgery as it prevents the surgeon from creating a correct surgery plan and current state-of-the-art (SOTA) model's inability to make clear predictions in that scale.

We expect our solution to at least be able to segment 1 region of a brain (tumor, gray matter etc.) significantly well and be able to provide the facility for brain surgeries by using VR tools. We are also going to provide a labeling tool for labeling the parts of an MRI image either by using an existing tool or creating a one for it, so as to increase performance of the deep learning model by providing an online learning methodology.

Our intended impact is to minimize the overall time goes into training a personnel for labeling the brain parts, segmenting and constructing a 3D model of a brain and provide a better inspection in VR environment.

Problem Definition and Literature Review (/ 20 Points)

Define your problem as clearly as possible. Explain your inputs, your context, your outputs and your limitations. Try to use a scientific language as much as possible. Where necessary use citations to existing literature to create context and clarify the problem. Equations, flow charts, etc. are welcome.

Surgery is the first and most common treatment for most people with brain tumors. Brain surgery is one of the most challenging surgeries due to the nature of the operation. To be able to remove the tumor, the brain should be examined in very detail to minimize the damage of the normal brain tissues and other brain lobes that are critical to the patient's daily life. The surgeon takes years of education to be able to correctly examine the brain scannings, which also takes weeks for them to examine even after many years of education, and to gain enough competence to perform surgery.

In the past few years, several accomplishments have been done to help the surgeons on examination and visualizations of the brain scannings. The most important accomplishments, and the one we focus on most, is the 3D modeling and segmentation of the brain. These tools have proven their effectiveness by taking place in real world surgeries and they showed significant improvement in decreasing examination time while increasing the interpretability.

The accomplishments have proved their usefulness however, they are still working in smaller scales and adhoc ways. For example, to generate only one well-segmented 3D model of the brain these methods will require an expert surgeon, an annotator, a lot of one-to-one sessions between annotator and expert for correcting and all within the time range of weeks. It is easily observable that this does not scale well, when the number of samples are increased.

In this project we will make use of Deep Learning based segmentation models to discover ways to generate this segmented 3D brain models in automated or semi-automated way by removing (or minimizing) the need for the expert and the annotator, which will result in a more scalable solution. Due to high complexity of the brain, required expertise in the domain and the lack of the corresponding data we will work with limited segmentation classes instead of whole possible segmentable classes in a brain until we are satisfied with the segmentation of our limited classes. There has been research on the problem such as 3D UNet by Olaf et al. We will closely follow the academic research while examining and experimenting with the tools for segmentation in this part. And later we will work on tools to provide visuals about the 3D segmented brain models.

Solution Plan (/ 20 Points)

Explain the potential paths to solution. You should propose at least one solid plan to attack the problem. Dissect your plan into steps and clearly identify the inputs and outputs of each step. You are not expected to provide the technical details of each step. Provide a weekly timeline/Gantt chart displaying the relevant weeks for each step.

The problem can be divided into 3 sub-problems; Machine Learning models for 3D segmentation of the brain, an annotation tool for the 3D model of the brain, and visualization of the 3D model using VR/AR/MR technologies. The details about the first two can be found in the above paragraph. The last one consists of building the tools for visualization of the 3D segmented brain images. In this sub-problem there are two different goals; the first one is to improve the overall visualization for the surgeons which will result in more efficient and less time usage compared to the looking at 2d individuals or using 3D viewing tools, which also has a steep learning curve. And the other one is to create a virtual operation room with a realistic brain image where the intern doctors, or other surgeons can experiment and learn outside of the real surgeries.

Our prioritization is as follows:

1. Discovering and experimentation with the annotation tools
2. Learning state of the art techniques and models through the academic research
3. Building visualization tools using VR/AR/MR technologies

We expect to spend the first term working on our first priority: Discovering and experimentation with the annotation tools. Since the success of the project is dependent on the generation of 3D segmented brain models, it is reasonable to prioritize the annotation tools. The latter ones require some baselines, which we expect to have at the end of the first sub-problem.

We will do research about the annotation tools that are available, and make experiments, with experiments we are referring to the use cases, with them. While researching about the tools and their use-cases we will also compare them with solutions (tools) we have experimented so far. At the end of the first term, we expect to decide on a tool, later to work on improving it as described in sub-problem 2. We will work on visualization tools (the latest sub-problem) when we are satisfied with our 3D segmentation results.

During these research and experimentation trails, we will conduct biweekly meetings with our supervisor, Erkut Erdem, to share our results and to ask for feedback. Our solutions and results will progress in an iterative way where we will decide on new steps based on past steps and feedback we will take from our supervisor.

Methodology (/ 20 Points)

Explain the methodology you will use in each of the steps you have described under your solution plan. Here, you are expected to give more technical details about each solution step. Also explain how each member of the project will contribute by assigning members to steps. If you are assigning more than one member to a step, explain their specific role and how the work will be divided among them.

In the first step of our project, we are going to experiment with annotation tools. Since the users of annotation tools are the domain experts (e.g. surgeons, and volunteer medical students…) we may need to iterate over all the processes until the domain experts are satisfied with the tool. For this step, we think that the agile development process suits more compared to other available methods.

In our second step, we need to develop a 3D segmentation artificial intelligence model and integrate it with the data we have in our hands. This step has both research and experimenting in it, as we need to experiment with the available SOTA models and take action if the available methods don't offer sufficient performance. Furthermore, even if the available methods would offer sufficient performance, if we have enough time, we can try to come up with an improved architecture over the SOTA models for our problem domain.

In the last step, we will construct a visualization system available for inspection using VR/AR tools. For visualization of the segmented outputs of our artificial intelligence we need to develop software that combines the MRI images and the segmentation outputs, and then outputs a 3D model that is usable in a VR/AR environment. Next, there is also a need for an inspection tool for 3D models in a VR/AR environment. This step can be daunting as the users of the VR/AR tools may want extra features on the road such as making specific parts of the brain transparent so that the surgeon can inspect the desired region better. We believe that the agile development process suits us better here, because of the reasons we have talked about.

Each member of the project will take part in each step as each step is from a different domain and requires extensive discussion before moving on to the next step. However, members of the project can individually work on different steps at the later stages of the project.

Outcome and Impact (/ 20 Points)

Explain the expected outcome of your project. If it is a software product, try to include example screen designs, if it is a hardware product, try to provide detailed technical specifications, if it is research output try to explain the outcome's contribution to the field. Also, explain the potential impacts of your results. These may be how the result will be used in real life, how it will change an existing process, or where it will be published, etc.

We believe that the project offers a great improvement over the current process of brain surgery explained in the previous sections. These improvements are:

- Decreasing the time needed to raise a brain surgeon eligible to take part in brain surgeries by improving the educational material since our project will offer 3D models of patients' brains available for inspection.
- Decreasing the time needed for a brain surgeon to do brain surgery. Currently, brain surgeons take approximately 2 weeks to prepare for single brain surgery because of the hardship that comes with the interpretation and visualization of 2D MRI images.
- Improving the overall success of brain surgery. As we said, the current process involves the interpretation and visualization of MRI images combined with some other technical scans of the brain, and it is very difficult for a brain surgeon to come up with a precise solution about the patient's brain just with these resources. However, with the help of our product, the surgeon will now be able to get a better view of the brain and construct a better surgery plan.

We also expect that the project may infer other parts of the medical domain to develop a similar workflow.