Hacettepe University

Computer Engineering Department

BBM479 End of Term Development Report

Project Details

Title	A labeling, learning, and visualization tool for brain imagery
Supervisor	Erkut Erdem

Group Members

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Current State (/ 40 Points)

Explain the current state of the project. By giving references to the plan proposed at the beginning of the project, explain what is achieved so far. Provide details of what has been done by explaining the technology and methodology used. Is the current state of the project in line with the plan? If you are behind the schedule, explain in detail the reasons.

Currently, we are working on the labeling tool that the researchers will use to annotate brain MRIs. We mostly finished investigating the capabilities of the 3DSlicer tool together with the MONAILabel widget. We are able to do with the 3DSlicer tool the following:

- Annotate parts of the brain and send them to the MONAILabel server to actively train a segmentation model while labeling other samples
- Use the recently trained model with the latest samples to segmentate the brain MRI for an initial segmentation and then processing it
- Using different strategies for active learning to label the samples that the model would mostly benefit from (in terms of learning)
- Investigated the annotation tools offered by both the 3DSlicer (Grow from seeds functionality) and the MonaiLabel (Scribbles functionality). The scribbles functionality seems to perform badly when the resolution of the slices is low, which was the case we experienced with the images contributed by Dr. Şahin. We are currently planning on using *'Grow from Seeds'* functionality as it works better with our samples.

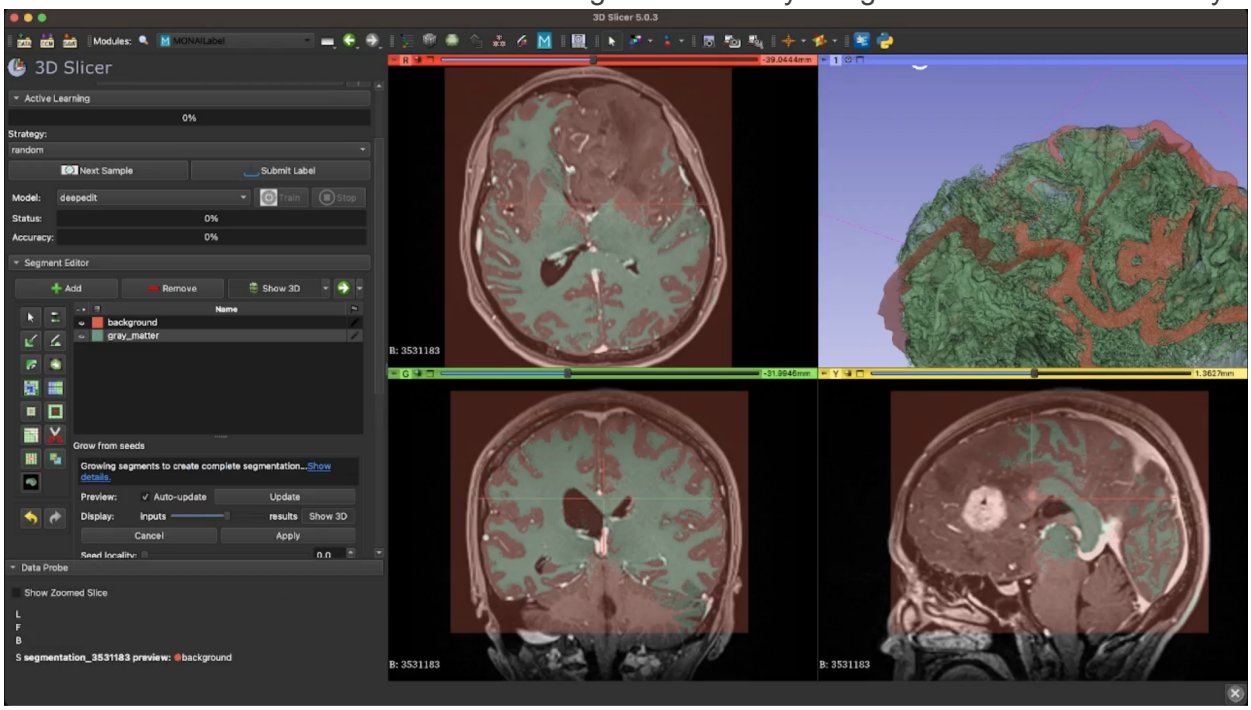
Apart from investigating the functionalities of MonaiLabel we also came across several issues that have affected the process:

- Connection issues over two clients. As the MonaiLabel server needs to be run on as a host with available GPUs to handle deep learning tasks we used **H**acettepe **U**niversity **C**omputer **V**ision **L**ab's (HUCVL) computer to set it up and ran the 3DSlicer on our local computers. Setting up this connection requires learning the basics of networking which we were not familiar with.
- Issue of file formats. For radiology, the DICOM file format is one of the popular choices for storing records. However, the DICOM file format is different compared to the usual image formats we were familiar with (.png, .jpg, etc.). DICOM file format has lots of subfile with .dmc extension and to open up a DICOM image it is necessary to work with its metadata. We currently set up a DICOM server using Orthanc (an open-source project for DICOM Server) for the complexity of this issue.
- MonaiLabel project is still a project currently in active development without a 1.0 version. The main problem we had with this particular issue was having broken MonaiLabel apps between different weekly releases of the library. Hence to use this library for our workflow, it is needed to closely follow the updates and changes in the library.

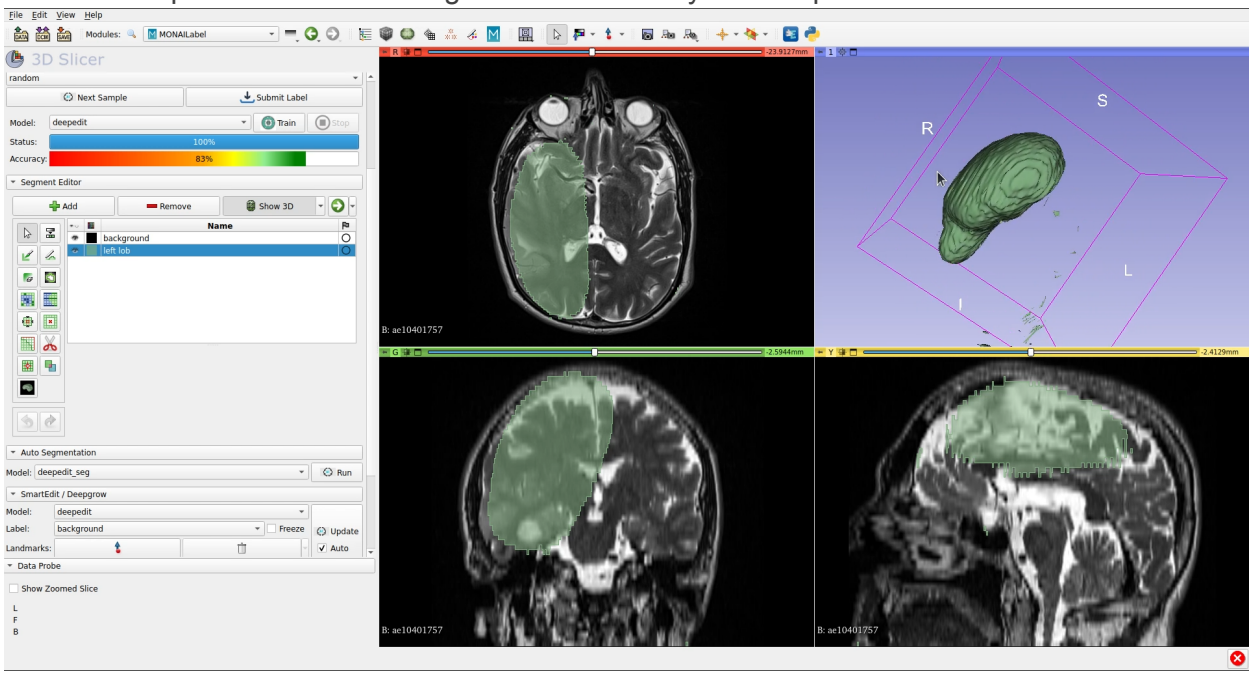
We didn't set a plan with strict dates in our previous report, instead, we introduced three steps for our project. We think that we could have done the first step much quicker than we did, but due to the issues of the server and MRIs, we lost quite a time. Even though we think that we are in line with the timeline we had in our mind.

We also share some of the annotation sessions we made to give a understanding of the things we have done:

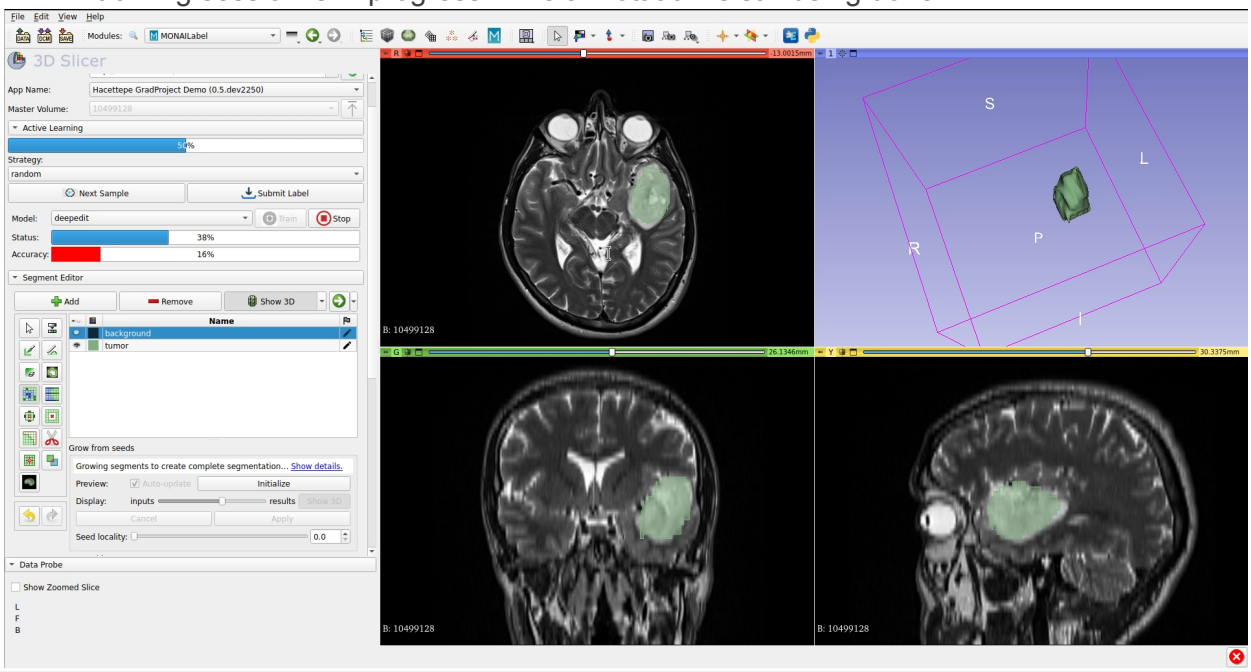
1. Annotation of white matter and creating a 3d model by using ‘Grow Seeds Functionality’



2. Example of initial model segmentation done by the DeepEdit model



3. Example of an annotation session done to annotate brain tumor. Grow from seeds functionality is also show in the upper right side of the screen. This frame also shows the training session is in progress while annotation is still being done.



Continuous Learning (/ 25 Points)

You have been working on the problem for almost 3 months. In these 3 months, what did you learn about this problem that you didn't know at the beginning? Did this new knowledge change your perspective on the problem? What else do you need to learn in the future?

Since we have worked the labelling tool mostly, the concepts we learned are related to servers and the tools specifically, but we also did some annotation to demonstrate the capabilities of the annotation tool so we also learned several things about brain in medical terms.

List of things we have learned are the following:

- We have worked with MonaiLabel library throughout the semester to master this framework as much as possible since this library is the core for our annotation tool and very important for other steps to work. We learned how to create annotation applications with this framework (which can be thought as working environment for a problem setting, so each app is unique for the problem domain) and change functionalities in it. For example, it is very important to be able to integrate our own deep learning model into this framework so that when we have enough data we can also train and run our model while annotating, and we learned this feature.
- We have worked with 3DSlicer annotation tool to annotate the brain MRIs. Since we need to make demos and example usage videos about the tool we also needed to learn this tool. We learned its capabilities, offered tools and how it is easy to configure for new widgets etc.
- We learned about the real life problems of radiology. Our DICOM images that Dr. Şahin contributed aren't perfect and has several problems. For example, it is usually the case that the different axis of the same series has different resolution. Resulting in bad annotation sessions and bad performing functionality. Specifically, the scribbles tool offered by MonaiLabel library seems to be affected from the different resolutions a lot, even returning a empty annotation sometimes. This issue opened up several risks that we have didn't thought about before. For instance, now that we faced an image property related issue, how we are going to set a image specification when we are collecting images? What are the tradeoffs, do we have enough MRI machines available to collect data that fits into our constraints etc.
- We learned more about how the previous solutions are working without an artificial intelligence model. Since we did example annotations using our tools, we noted that it could be possible to separate the parts of brain using simple pixel value thresholding (which is the current solution used by our client). We haven't talked about this thoroughly, but learning more about the problem domain helped us to understand the core problems more and why the previous solutions worked.

The things we specified above are all beneficial to our progress in our opinion. Apart from the points we specified, we also learned and used special image servers to set up a MonaiLabel. We didn't go into details of Orhanc, but since it is much likely that we are going to set up a server for the whole annotation process we think that what we have learned so far has been very beneficial to us.

For the later stages of the project we need to learn about the tools for visualization of 3d models in VR environment and how to integrate these environments with real life tools.

Risk Assessment and Management (/ 20 Points)

Try to identify the potential risks in the rest of the project. Were you able to identify these risks at the beginning of the project, or did you recently recognize them? What are your proposed solutions to each risk item? Are there any risks that will require a significant change in the project? If so, explain how this will affect the end results (also, outline your proposed revisions in the next section).

There are several risks that we didn't think about it before and came across while developing the project. These risks are the following:

- The problem of integrating our developed project with real-life environment. We didn't really think about the problems we could face when we deploy our project to a hospital, but now that we worked with real data we are most likely to work with, we have a broader view of the topic. First of all, there is the issue of resolution between different axis. Some of the tools we used are very sensitive to resolution, resulting in bad output in the case of low resolution. This fact proved to be quite a problem for us since we don't have much options in terms of annotation tools, so to solve this task we may need to set some specifications for collecting brain MRIs that will work with our design. However, this also adds the problem of decrease a in available machines that can satisfy our constraints. For instance, if we were to set these constraints there would be a decrease in operations that could be benefit from our solution in different hospitals, we should aim for such a balanced solution so that hospitals with low quality equipments also be able to use our solution. We don't think this problem will cause a significant change in our project plan, but it is definitely a case that we should address before moving on to other steps.
- Image servers and data anonymization. Our image format of interest is **D**igital **I**maging and **Co**mmunications in **M**edicine (DICOM) file format. This file format uses files with the `**.dcm**` extension and names a single MRI (collection of .dcm files) as a **series**. To build up series, we use meta-information placed at the head of these files, and to anonymize our data we need to work with this meta-information. It is quite time-consuming task to anonymize this information, so we may need to add this problem task as a subjob before moving into developing a deep learning model since we need to collect data for our training process.
- The issue of setting up an environment for all of our operations locally in the hospital. As we said before, we are currently developing our project in HUCVL and eventually, we need to move our project to an environment running locally in the hospital both for security and ease of work reasons. We will add this step as the last step for our project development.

Revisions (/ 15 Points)

If you feel like you need to revise your earlier plan, suggest your changes here. These changes may include changes in the outcomes of the project, changes in milestones, changes in the calendar, changes in workload distribution, etc. If you do not present any revisions here, at the end of the project you will be responsible for all the proposed outcomes in the Project Proposal.

In our previous report, we stated the main steps of our project, but we didn't go into detail about each step. Now, we revise our steps with the details mentioned in this report in previous sections and detail the main steps of our project.

1. Discovering and experimentation with the annotation tools
    - 1.1. Exploring the annotation tools available to use for our problem domain, which is radiology. Which tools require significant hardware requirements on the client side?
    - 1.2. Experiment with the annotation tools that have been collected. Target the tools that have active learning as an option.
    - 1.3. Focusing on one annotation tool and investigating its capabilities thoroughly.
    - 1.4. Prepare a demo for a sample annotation session with the selected tool and show it to clients. Get feedback, and improvise if necessary.
2. Learning **state-of-the-art** (SOTA) techniques and models through academic research
    - 2.1. Investigate the performance of SOTA techniques for brain MRI segmentation and determine if the performance satisfies our requirements.
        - 2.1.1. If requirements are not satisfied, research for a deep learning model will be necessary. The research for a deep learning model that satisfies our requirements is not one of our goals, but we are planning to also improvise the SOTA models if we have enough time.
    - 2.2. Select a handful of models that satisfy our performance requirements. In our project, we also plan to use active learning features which combine the deep learning model training process with annotation sessions, enabling the annotators to use deep learning models on the go for an initial segmentation while still annotating the images. To achieve this, we need to select at least one model for annotation sessions and one model for the heavy training session which will be used out of the annotation sessions.
3. Building visualization tools using VR/AR/MR technologies
    - 3.1. Extraction of model segmentations to VR/AR/MR environments. After the inference session of our trained deep learning model, it is necessary to find ways to convert the model output to a VR/AR/MR environment.
    - 3.2. Setting up a VR/AR/MR playground for investigating the segmented 3D brain MRIs. Our project's goal is to eventually provide brain surgeons to use these segmented models to understand the patient's brain better, to do this we need to provide surgeons with capabilities in VR/AR/MR environments such that they can interact with the model. Enabling or disabling view of several parts of the brain (e.g. don't show gray matter), drawing lines on the 3d model to take notes/attract attention, etc…
    - 3.3. Integrating our VR/AR/MR playground with physical tools. After the development of the environment of the playground, it is necessary to integrate it with the VR/MR/AR tools to enable surgeons to interact with the 3d models.