AIM Lab Summer 2018 Assistantship Report

May-July 2018

Ken Iiyoshi (ki573@nyu.edu), supervised by :
Muhammad Hassan Jamil (mhj5@nyu.edu)
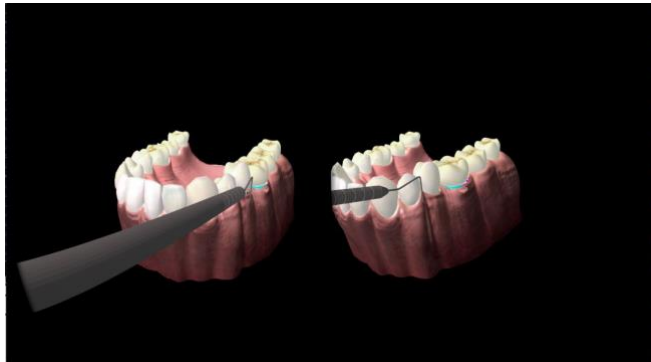Professor Mohamad Eid (mae8@nyu.edu)

Figure 1. Demonstration of the Project

Abstract

A configuration GUI was developed for a haptic-based virtual reality dental simulator. The GUI can currently create tooth pockets around tooth 19, with a nearly completed smoothing function. The added features were well received by the dentists from NYU College of Dentistry. Obtaining a new haptic device and a software for retopologizing the teeth 3D model is in the works. Future work includes improving the smoothing function and the GUI, applying mesh deformation to every teeth, and adding a gel-like deformable texture to the gingiva.

Files and Documentation:

The following link contains the documented program for Haptodont:

https://drive.google.com/drive/folders/10aplxAEiLPE0ouHzThiA3V6rk77tWH_I?usp=sharing

Introduction / Assigned Task

My role during the assistantship was to develop a haptic-based virtual reality dental simulator called the Haptodont, which is intended to provide a learning platform for dental students / clinicians (See Figure 1 for simulation demonstration). The periodontal simulator will allow trainees to learn performing diagnosis and treatment procedures of different periodontal diseases. The following tasks were assigned, with a plan to test it on dental students and clinicians after completion:

1. Building a configuration graphical user interface (GUI) that allows the trainer to set configuration parameters before starting dental simulation e.g. dental pocket locations and depths.
2. Building a recording window to record the measurements taken during the dental probing procedure.

3. Building an evaluation window to give performance evaluation of students based on the difference between the actual and recorded measurements.
4. (Optional) Work on integrating speech recognition system to recognize commands to record the measurements.

The first step was more time consuming than expected, as I only worked on this part during the assistantship. Nevertheless, much progress was made. I also contributed by communicating with a haptic device distributor/developer, as well as creating a website for the 4th Joint Symposium on Social Robotics.

Software, Drivers, OS compatibility

This project was developed using Visual Studio 2015 Community edition, using QS VS Tool version 5.11 (x64)1, and CHAI3D 3.2.0 under Windows 10 [1][2]. Proper drivers (including one for Nvidia Quadro Processor for the Precision 5500 desktop currently used for EEG data collection) were installed to use Novint Falcon, Geomagic Touch, and Oculus Rift as the project's controllers [3][4]. Care must be taken to conserve these software configurations in the future, if any hardware update is to be made, as manually installing new (or old) working drivers is time consuming.
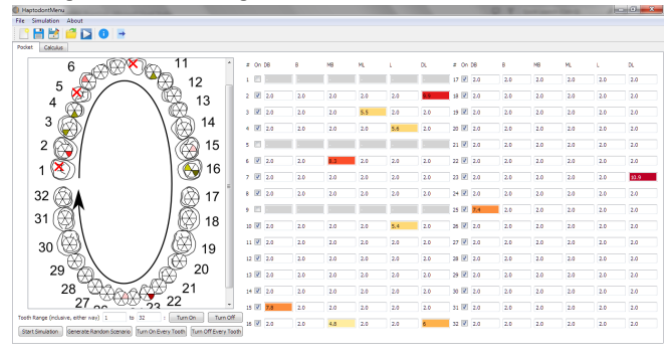
Configuration GUI using Qt

Figure 2. The Configuration GUI for Haptodont.

The first few weeks was spent on developing a graphical user interface (GUI) that configures the tooth model used for the periodontal simulation.

Each row of checkbox and text inputs (QCheckBox and QLineEdit in Qt terms), corresponding to the tooth number of the teeth image, allows the user to turn the given tooth on or off and set the pocket depth of its six regions (DB- Distal Buccal, B-Buccal, MB-Mesial Buccal, ML-Mesial Lingual , L-Lingual, and DL- Distal Lingual respectively). Note that the range of allowed input is 2 to 12 mm. This is ensured by using QValidator, which restricts what number can be typed into the box. The buttons on the lower left allows additional controls, such as turning on or off a range of teeth or all at once and generating pockets randomly for selected teeth. To start the simulation, the 'start simulation' button is pressed. Depth of pockets are inputted in millimeters. The highlighted colors indicate the severity of the pockets. Undo , Redo, Cut, Copy, and Paste are included as shortcut keys. Save,

Save as, New, and Load function works as well. These functions are also accessible from the toolbar and menu on the top left of the GUI.

The GUI is still in the process of development. For example, it has to be be applied to every tooth model once they are created. Also, the checkbox function needs to be implemented in the code, and the placeholder visuals for the dental pockets should be improved.

Mesh Deformation using CHAI3D

Before the development of a GUI, the dental pockets in the simulations were premade through a 3D modelling software called 3DS Max. However, this was only done as temporary measure. In order to create dental pockets based on the GUI, I explored several options, assuming that the basic approach was to move the vertices of the tooth model during the beginning of the simulation based on a 2D map that is applied on the model. Figure 3 shows an example of this. After exploring several methods, I settled on the following concept for each tooth:

1. Within 3DS Max, add a gingiva region attached to the the tooth's root (not actually attached: it just overlaps with the tooth 3D model). The region itself is separate from the rest of the gum, which is recognized as a "mesh" within the Chai 3D Coding Library.
2. Color in each dental region of the surface. (See Figure 4)
3. The program can then identify each region of each "mesh" .
4. The deformation basically looks as if each vertex of the mesh becomes "detached" from the tooth. To do this, each deforming vertex is translated on a XY-plane in the direction of its innately assigned normal vector.
5. Smoothen the transition between each dental region (referred as "cliffs") by adjusting its vertices.
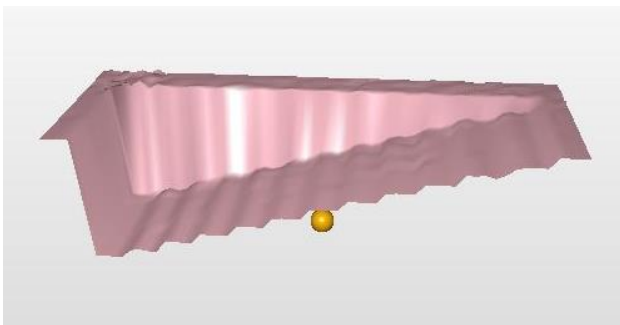

Figure 3. Example of how different regions of the gingiva can be deformed in various amount. The texture map used here was a gradient.
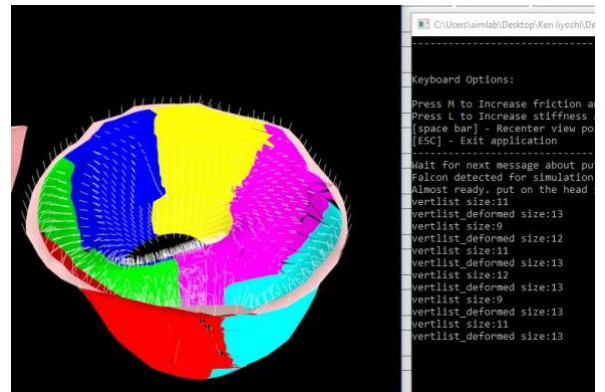

Figure 4. Colored Model of Tooth 19's Gum Region, with visible normal vectors. The window in the right is used for debugging.

3D Modelling and Texture Mapping using 3DS MAX

The current mesh deformation requires 2 3 types of editing of the teeth model provided from NYU's College of Dentistry via 3DS Max.

One is to add a gingiva region attached to the each tooth root (referred to as a "pit", as that is how it looks for example in Figure 4). This requires a copy of the tooth root, since each pit needs to be "attached" to the original teeth when the configuration is set at a health parameter (2mm pocket). This pit has to have a smooth transition to the main gingiva body holding the teeth, but be detached from it at the same time to be considered as a separate "mesh" by the code. To achieve this, a copy of a tooth root is manually and smoothly connected to the main body, and then detached to create a fine border. This process is time-consuming.

The second type of editing, which is more time-consuming, is to retopologize the copy of the tooth root before attaching it to the main body. Most parts of the 3D teeth model currently has diagonally arranged vertices and edges. However, the current deformation method works well only when the vertices of these models are vertically and horizontally aligned like a straight grid (the grid-like plane in Figure 5 is a good representation.). Manually redrawing the edges and vertices for each dental pocket region is extremely time consuming. For example, manually retopologizing a surface for Tooth 19 took around 2 hours. It is thus highly recommended to use a software that has an automated retopology feature

The third type of editing is the coloring of each dental pocket region. Instead of using the original texture map image of the tooth root, a new texture image is set through 3DS Max's material editor and recolored through the viewport campus. In order to color in comfortably, the "unwrap UVW" modifier is applied to the model so that it's unwrapped UV map is applied evenly to the texture map image.
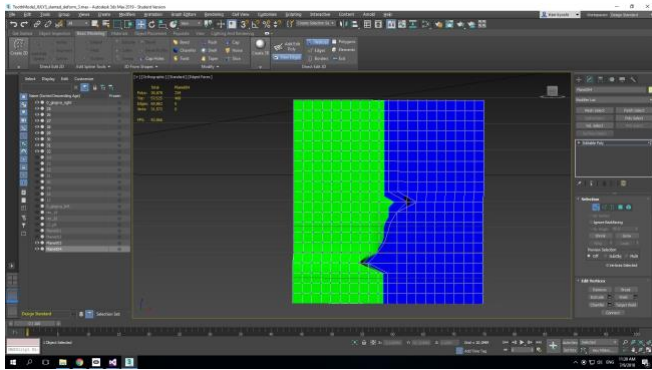
Figure 5. 3DS Max GUI. Displayed is a Plane simulating a smoothened "cliff" between dental pockets of varying depth.
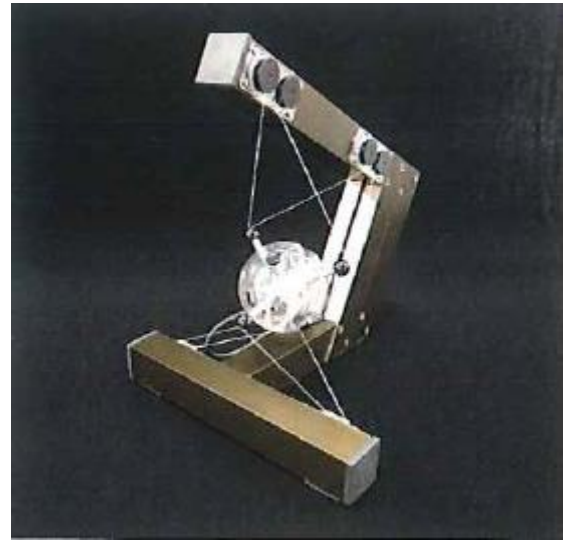
Smoothing

Developing the code for smoothing the cliff was code-wise the most challenging aspect of the project (and is still in need of improvement). The basic concept of smoothing is to locate the vertices that make up the "cliff"-like transition between two dental pockets and to deform it into a smoothened slide-like shape. A cliff consists of two vertically aligned rows of vertex connecting the bottom areas of adjacent pockets, where each row belongs to one of the two sides of the transitioning border. For example, one side of the cliff is smoothened in each cliff in Figure 6 (The current code allows both side to be smoothened).

One issue with the code right now is that the smoothing at the top and bottom of the cliff is irregular, creating a sharp bump that interfere with the probe's movement. This can most likely be fixed by redefining the scope of vertices that are deformed as part of the cliff.
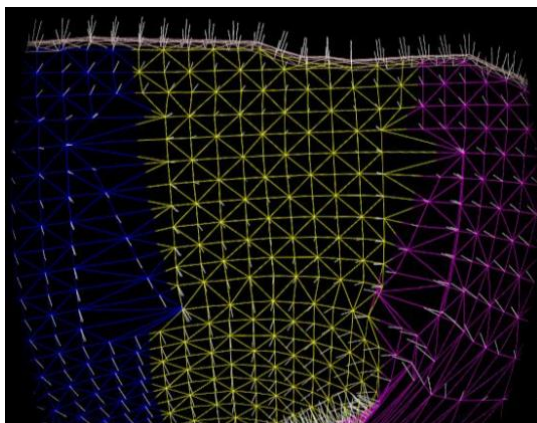

Figure 6. Tooth 19's pit in wire mode showing smoothing between DB(blue) & B (Yellow) and B & MB (Magenta) region.

Dr. Makoto Sato, Nihon Binary, and SPIDAR-GII

Figure 7. SPIDAR-GII Developed by Dr. Makoto Sato.

A purchase of a new haptic device for the dental simulation has also been in the works. Unlike the existing haptic devices in our lab, SPIDAR-GII, which is the device needed for the dental simulation, is cheap, compact, and rotationally controllable. The device was developed by Dr. Makoto Sato, a recently retired Professor from Tokyo Institute of Technology, and is planned to be distributed by Nihon Binary, a Japanese company based in Tokyo that supplies Japanese institutions and companies with robotics and haptic-related products. My role in this process was to communicate with the representative of this company in Japanese. After almost two months of communication, the status of the purchase is in the stage of managing vendor registration of Nihon Binary.

Feedback from Dentists and Design Artist in NYU College of Dentistry

The features and status above were well received by the dentists from NYU College of Dentistry. Most of their feedback was generally related to making the experience more realistic, such as by getting a haptic device with 2 points of interaction (rotational feedback), a realistic depth setting for healthy gingiva, an adjustable viewing angle of the simulation, and a gum-like texture of the dental pockets.

JSSR Website

The website in the following link has been developed through NYU's Wordpress website in preparation for the Fourth Joint Symposium on Social Robotics, which is to be held at NYUAD and UAE University on February 3-6, 2019:
https://wp.nyu.edu/jssr/
Contents will be routinely added and updated as the before, during, and after the symposium.

Conclusion and Future works

In conclusion, bulk of configuration GUI has been developed, while the mesh deformation for the simulation, despite its progress, is still in development. In addition to the development of the project itself it is crucial to obtain SPIDAR-GII

and a retopolization software in order to push the project forward in a timely manner.

Once the smoothing of the dental pockets is completed, the next step is to create a deformable texture for the gingiva. For example when a probe is inserted into the pocket, the gingiva should ideally move around the probe at real-time. One option for achieving this is to use the GEL library (Located in GEL folder inside CHAI3D 3.2.0 Download folder) within the CHAI 3D library, where a gel like texture can be added to a 3D model. This could create a more realistic experience for the dental simulation, and could address the chronic issue of a probe passing through the 3D model during the simulation. Either before or after including the GEL library, the smoothing function should be applied to all 32 teeth.

At the same time, the configuration GUI's interface should be brushed up. The interface would most likely include the recording and evaluation feature.

The status of the procurement process for SPIDAR-GII will be updated on a periodic basis.

References

[1] https://www.qt.io/qt5-11
[2] http://www.chai3d.org
[3] See the zip file in the documentation section link for novint falcon and geomagic touch driver. These drivers can also be found online through both official and unofficial websites.
[4] For Nvidia processor, an older version of driver (for Windows Vista) was installed since the GPU was not compatible with Windows 10.

Acknowledgement