Improve Content Validity of Virtual Drilling Simulator

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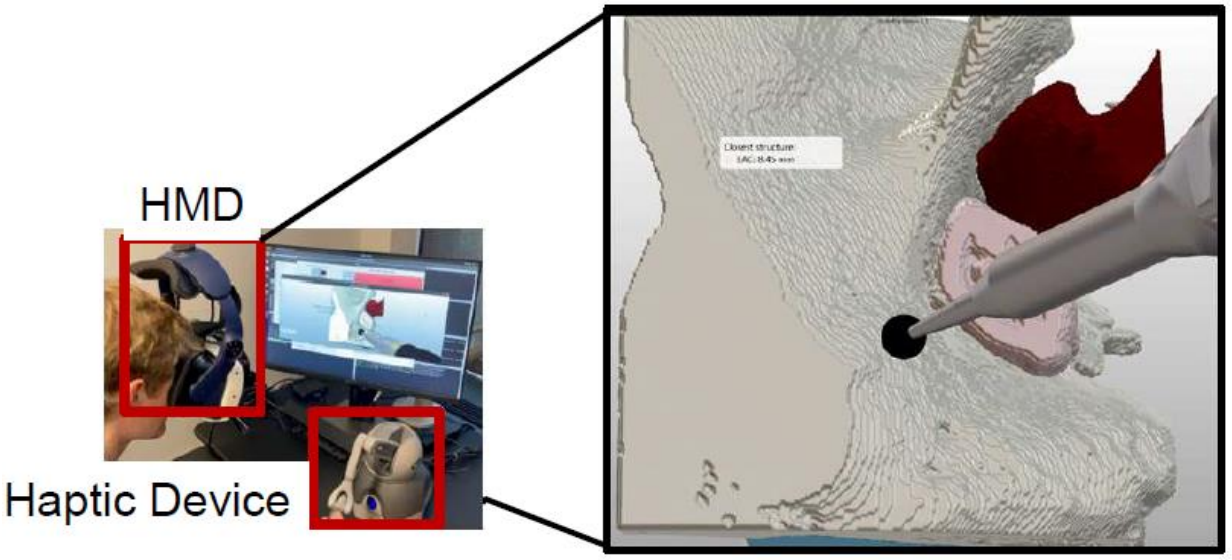
Team: 14

Problem Statement

To improve the content validity of the virtual drilling simulator, specifically focusing on the sounds and forces during the drilling process.



Virtual Drilling Simulator

Clinical Motivation

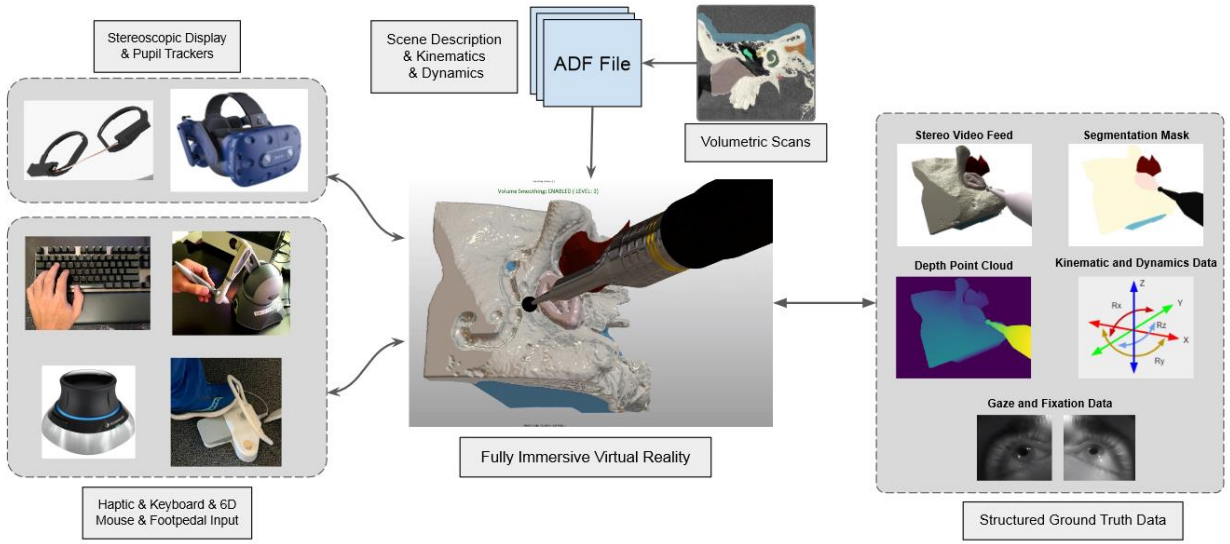
Simulators can assist surgeons in developing the surgical skills and spatial perception needed to perform an operation without the risk of accidents occurring on actual patients.

Auditory feedback has great potential in surgical simulators that aim at training surgeons associated to the correct interpretation of anatomy from sounds. (Hoffmann, Pablo Faundez et al. (2009))

Prior Work

FIVRS or Fully Immersive Virtual Reality System was introduced in previous works related to this project.

FIVRS combines high-fidelity surgical simulation software with a realistic hardware setup to provide a scalable and cost-effective alternative to cadaveric training for skull-base surgeries.



Fully Immersive Virtual Reality for Skull-base Surgery

Audio Feedback

In the current FVIRS, the cutting force alters the pitch of the drill audio signal using the following equation:

$$p = A_{audio} - \| \vec{F}_{collision} \| / \vec{F}_{max}$$

Where,

p : Signal's pitch

A_{audio} : Custom maximum audio amplitude

$\vec{F}_{collsion}$: Force generated from the collision detection algorithm

$\vec{F}_{max}$: Maximum force thresholds for the haptic device

Goals

In this project we aim to extend the simulator to provide more accurate audio feedback. This goal can be broken down into the following components:

1. Collection of two sound-force data sets.
2. Modelling of collected data sets.
3. Implementation of the function created.
4. Evaluation of the functionality in the simulator.

Technical Approach

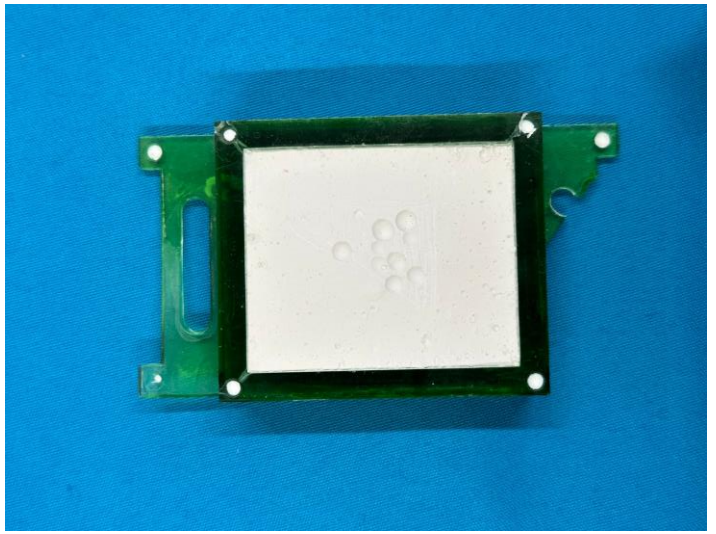
Data Collection : Two data sets will be collected during this project. Drilling will be done with certain constraints to the environment such as :

1. Constant RPM of the drill
2. Normal direction of the tip to the phantom while drilling

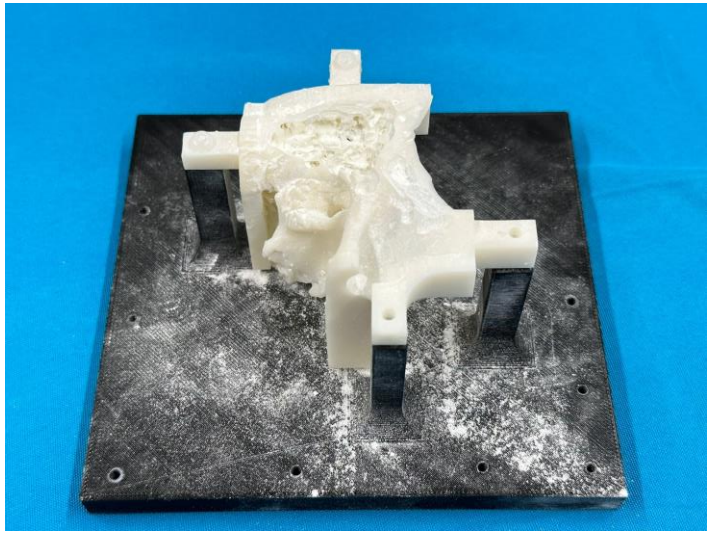
The second data set might have different constraints. Phantom 1 will be used for Data Set 1. Data Set 2 might use Phantom 1 or Phantom 2.

The collected data will be modeled to relate the sound of the drill to the force.

Modelling Data : The function relating sound and force will be implemented into the simulator. Function focuses on generating audio frequencies according to the forces being applied.



Phantom 1



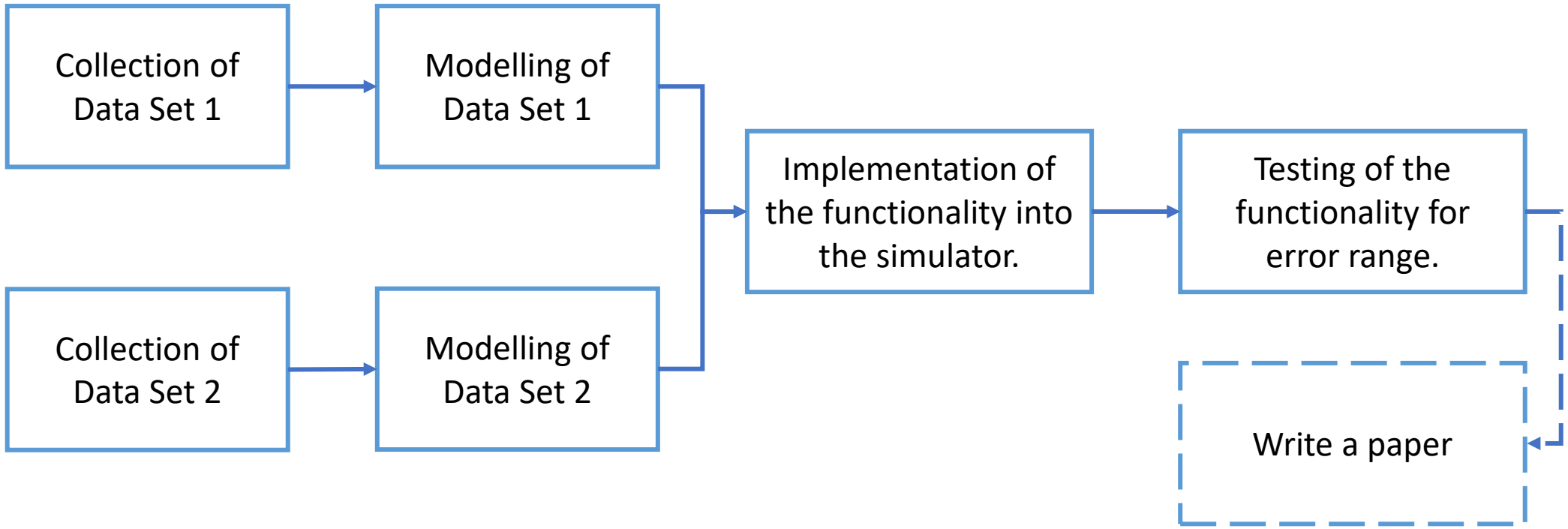
Phantom 2

Technical Approach (Continued)

Implementation : The function relating sound and force will be implemented into the simulator. Function focuses on generating audio frequencies according to the forces being applied.

Testing :Testing of the function will be done by recreating the same conditions as data collection within the simulator. Error between the collected and observed values will be studied.

Process Flow of a Project



Deliverables

Minimum:

1. Create or utilize the existing phantom and collect sound and force data while drilling.
2. Model the collected sound and force to relate the pitch of the drill to the force applied by the drill.

Expected:

1. Implement the functionality in the drilling simulator based on the modeled data.
2. Evaluation of the functionality by studying the error between the simulator output and expected output.

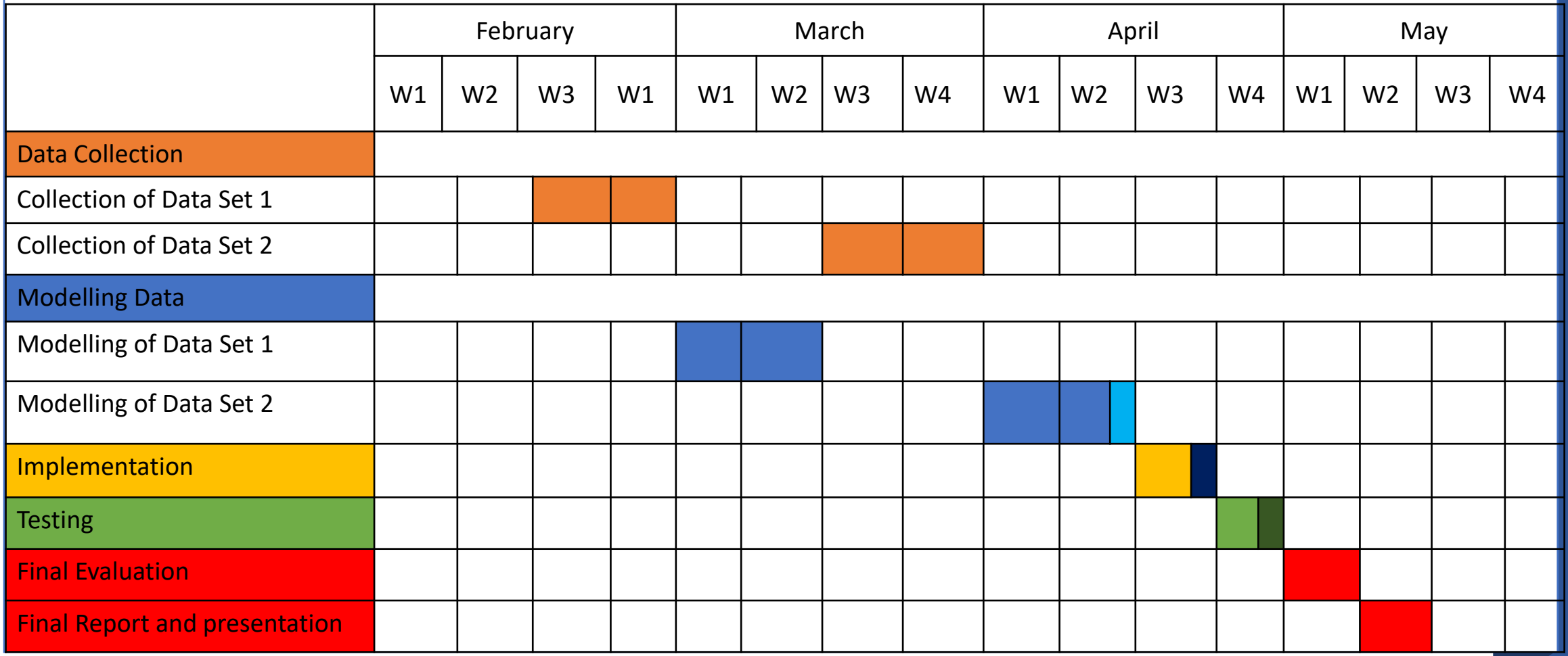
Maximum:

1. Write up a paper.

Dependencies

Dependency	Need	Status	Follow-up	Contingency Plan	Deadline
Force-sensing Drill	Force data collection	Acquired	N/A	Obtain another force-sensing drill that can fir on the Galen Robot	21st Feb
Basic Microphone	Sound data collection	Acquired	N/A	Obtain another microphone to record sound	21st Feb
Phantoms	To drill onto for data collection	Acquired	N/A	Request more phantoms to be printed	21st Feb
Access to MockOR	To work on the project	Acquired	N/A	Work on the project under supervision	23rd Feb
Computer with ROS, Linux and Python	Modelling and implementation of function	Acquired	N/A	Use Virtual Machine on laptop	28th Feb

Timeline



Milestones:

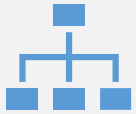
- Function relating sound and force prepared.
- Function implemented into the simulator.
- Technical Part of the project completed.
  Expected deliverables reached.

Note: The maximum deliverable cannot be achieved within the duration of this semester.

Management Plan

Bi-weekly meetings with Hisashi Ishida.

On-demand meetings with Prof. Peter Kazanzides.



All data collected will be uploaded onto a Microsoft Teams group that has already been created.

References

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5. Chen, X., Sun, P., & Liao, D. (2018). A patient-specific haptic drilling simulator based on virtual reality for dental implant surgery. International Journal of Computer Assisted Radiology and Surgery, 13(11), 1861–1870. https://doi.org/10.1007/s11548-018-1845-0
6. Munawar, A., Li, Z., Nagururu, N., Trakimas, D., Kazanzides, P., Taylor, R.H., & Creighton, F.X. (Sent for approval to IPCAI). Fully Immersive Virtual Reality for Skull-base Surgery: Surgical Training and Beyond.