

Improve Content Validity of Virtual Drilling Simulator

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Team 14

Table of Contents

1	Introduction	Pages 2-3
1.1	Problem Statement	2
1.2	Clinical Motivation	2
1.3	Prior Work	3
2	Technical Approach	Pages 3-4
2.1	Data Collection	3-4
2.2	Modelling Data	4
2.3	Implementation	4
2.4	Testing	4
3	Management Plan	Pages 4-6
3.1	Deliverables	4-5
3.2	Dependencies	5
3.3	Timeline	5-6
4	Reading List	Pages 6-7
5	References	Pages 7

1. Introduction:

1.1. Problem Statement:

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

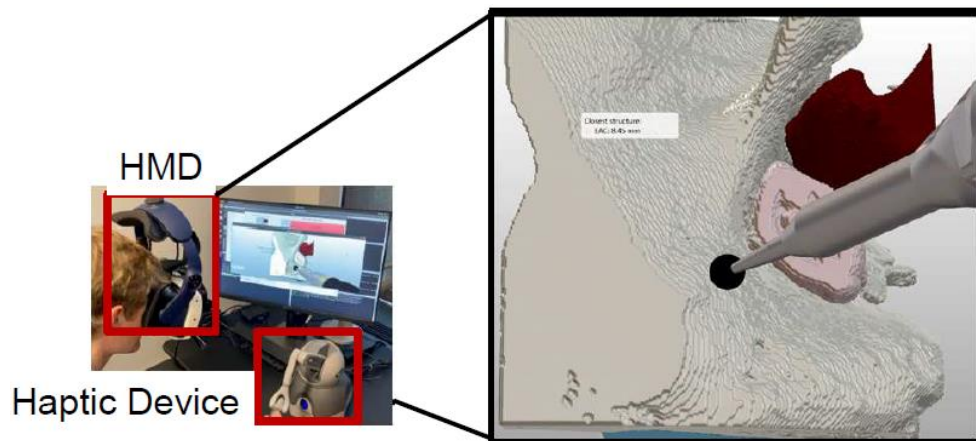


Figure 1: Virtual Drilling Simulator (Reference: (Munawar et al., 2023))

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.

1.2. 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))

1.3. 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.

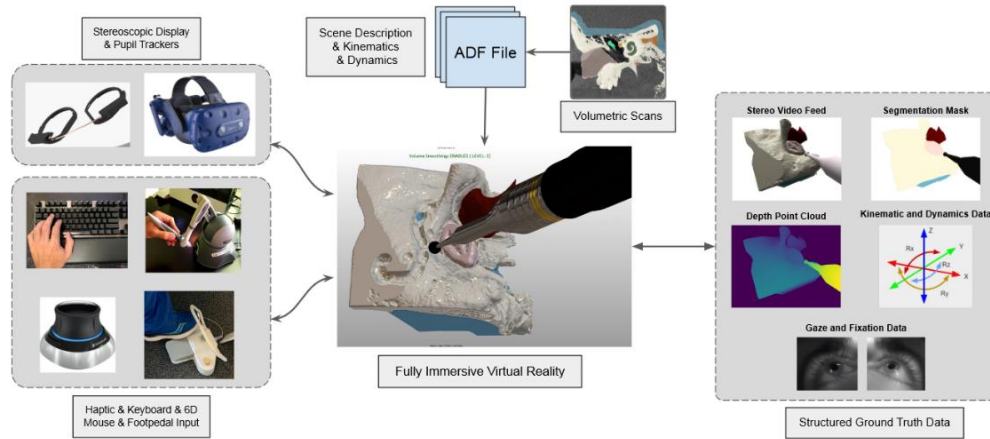


Figure 2: Fully Immersive Virtual Reality for Skull-base Surgery (Reference: (Munawar et al., 2023))

Audio Feedback presently in FIVRS:

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

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

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

2. Technical Approach:

2.1. Data Collection:

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

- a. Constant RPM of the drill
- b. 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.

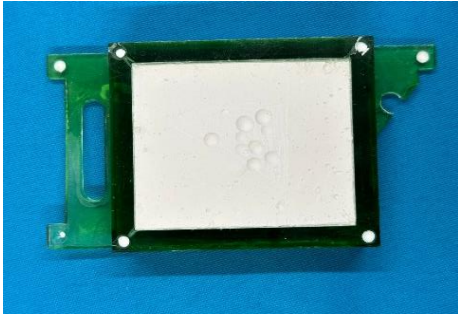


Figure 3: Phantom 1



Figure 4: Phantom 2

2.2. 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.

2.3. 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.

2.4. 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.

3. Management Plan:

3.1. Deliverables:

Minimum:

1. Data sets created using the existing phantom containing sound and force values while drilling.
2. A function modelled on the collected sound and force to relate the pitch of the drill to the force applied by the drill.

Expected:

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

Maximum:

1. A paper is written up.

3.2. 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	21 st Feb
Basic Microphone	Sound data collection	Acquired	N/A	Obtain another microphone to record sound	21 st Feb
Phantoms	To drill onto for data collection	Acquired	N/A	Request more phantoms to be printed	21 st Feb
Access to MockOR	To work on the project	Acquired	N/A	Work on the project under supervision	23 rd Feb
Computer with ROS, Linux and Python	Modelling and implementation of function	Acquired	N/A	Use Virtual Machine on laptop	28 th Feb
Access to Galen Robot	To collect data	Acquired	N/A	N/A	1 st March

Figure 5: Dependencies

3.3. Timeline:

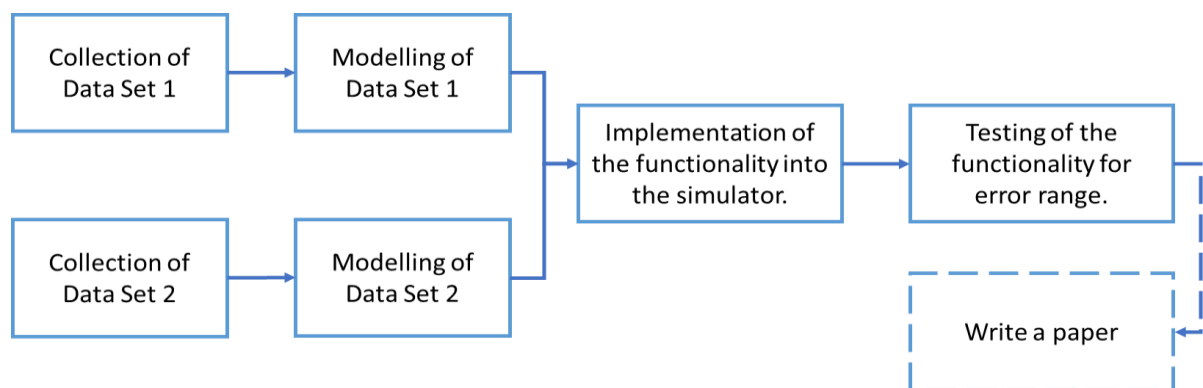




Figure 6: Process Flow of the Project


	February				March				April				May			
	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
Data Collection																
Collection of Data Set 1																
Collection of Data Set 2																
Modelling Data																
Modelling of Data Set 1																
Modelling of Data Set 2																
Implementation																
Testing																
Final Evaluation																
Final Report and presentation																
Documentation																
Collected data																
Function modelled																
Implementation Report																
Testing Report																

Figure 7: Timeline

Key Dates:

 Function relating sound and force prepared. (15th April)

 Function implemented into the simulator. (22nd April)

 Technical Part of the project completed. Expected deliverables reached. (30th April)

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

4. Reading List:

[1] BOESNACH, I., HAHN, M., MOLDENHAUER, J., BETH, T. H., & SPETZGER, U. (2004). Analysis of drill sound in spine surgery. *Perspective in Image-Guided Surgery*, 77–84. https://doi.org/10.1142/9789812702678_0011

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[3] Hoffmann, P.F., Gosselin, F., & Taha, F. (2009). Analysis of the drilling sound component from expert performance in a maxillo-facial surgery.

[4] Munawar, A., Li, Z., Kunjam, P., Nagururu, N., Ding, A. S., Kazanzides, P., Looi, T., Creighton, F. X., Taylor, R. H., & Unberath, M. (2021). Virtual reality for synergistic surgical training and data generation. *Computer Methods in Biomechanics and Biomedical*

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<https://doi.org/10.1080/21681163.2021.1999331>

[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.

[7] Hoffmann, P.F., Gosselin, F., & Taha, F. (2009). Analysis of the drilling sound component from expert performance in a maxillo-facial surgery.

[8] Y. Dai, Y. Xue and J. Zhang, "Condition monitoring based on sound feature extraction during bone drilling process," Proceedings of the 33rd Chinese Control Conference, Nanjing, China, 2014, pp. 7317-7322, doi: 10.1109/ChiCC.2014.6896213.

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[1] Hoffmann, P.F., Gosselin, F., & Taha, F. (2009). Analysis of the drilling sound component from expert performance in a maxillo-facial surgery.

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