Project Proposal:

A study of hand and finger tracking in Virtual Reality for use in surgical training simulations

Contents

Section 1 Student Details

Full name:	Pearson, David
Student Number:	1725412
Award/Course:	MSc Computer Science
University email:	d.pearson2@wlv.ac.uk
Date of Submission:	6th January 2021

Section 2 Statement of Project Details

Project Title
A study of hand and finger tracking for use in VR surgical training simulations

Academic Question
Which methods of digit (finger) recognition offer the highest level of fidelity when applied in a training simulation?

Purpose Statement
The primary motivation of the proposed research is to increase the efficacy of VR training when applied to the complex field of practical surgical training. This research will allow training solution providers to have an increased awareness of the currently available technologies and how they may be applied to hand and finger tracking within a virtual reality simulation.

Aims
- Assess methods of hand and finger tracking
- Show, if possible, which method offers the greatest level of fidelity

Objectives
- Consult with existing surgical training providers
- Decide upon an agreed set of metrics with which to measure fidelity
- Design a robust and comprehensive test framework
- Conduct testing and data gathering
- Review and critically evaluate the data gathered
- Report findings and suggest future areas of research

Section 3 Project Proposal

Introduction

Virtual reality since its arrival into the lexicon of the average individual could be seen in two main areas, entertainment, and training simulations. Indeed, some of the earliest recorded applications of Virtual Reality are within a training scenario, such as the Link flight simulator in 1929, Fedorov (2015).

The global advancements across all technological frontiers during the last 100 years has impacted many areas of people's lives, none more so perhaps than the advancement made within medicine. We are able to replace complex organs such as the heart with artificial replicas, either in part or entirely, Chors (2017).

Within the last decade Virtual Reality has seen somewhat of a renaissance period, with entertainment-based systems such as the Facebook owned Oculus range, Sony's PlayStation VR, HTC Rift and Valve Index, together making up huge proportion of the market share.

This research will thoroughly and comprehensively evaluate a wide range of both hardware and software solutions with a specific focus on the tracking of an individual's hand and finger movements.

Literary Review

When exploring and researching the topic of hand tracking solutions, the commercial organisation UltraLeap (2020) boasts that their Leap Motion hardware and combined software solution provides "the most advanced hand tracking". Indeed, this could be inferred from the initial research carried out. In the 2020 paper by Rasakatla et al, on using a virtual reality in a surgical training format, the researchers used the Leap Motion unit. This was also similar to the paper by Polsinelli et al in 2019, where in their approach they used two Leap Motion units with one placed in a horizontal position and the second placed in a vertical position. A more thorough exploration of the possible applications of the Leap Motion system was carried out by Wozniak (2016) in that he concluded there is great scope for inclusion into the simulation sector by way of hand movements and gestures being captured accurately.

The use of analogous experiences or simulations in training is not a new concept, indeed its application can be seen across multiple fields such as vehicle control, cars, planes and even tanks. There are several commercially available surgical simulators. LAPARO Aspire (2020) is a haptic based handheld device that allows a trainee to manipulate a physical device where their hand movements are captured and then simulated on a screen in a virtual simulation. LAPSIM offered by Surgical Science (2020) is a similar product to the LAPARO though with a key difference in that the output is displayed via a head mounted Virtual Reality headset.

Head mounted Virtual Reality Headsets tend to come have several distinct categories and classifications that can be identified. Headsets like the Oculus Rift S are a tethered offering where trailing wires will run from the headset to the computer running the simulation, in these instances the simulation is being processed on the computer and then sent to the headset for display. Other headsets such as the Oculus Quest 2 are wire free and require no cables or external computational input. However, it is worth noting that the untethered versions are not able to use visual assets of a greater detail and fidelity. The second main distinction between head mounted virtual reality headsets, is the position of the important hand tracking sensors, whilst all headsets, universally, contain a suite of gyroscopes, accelerometers and other sensors the specific sensors used to locate and gather input from the user's hands are either mounted to the external surface of the head mounted display or the alternatively on top of external tripods placed facing the user.

Output beneficiaries

There are multiple, identifiable beneficiaries that could potentially use the results from this research with varying degrees of direct and indirect impact.

- Starting with training solution providers, there is a large commercial industry built on specifically creating the tools to deliver effective and comprehensive training solutions across a range of sectors, the medical sector is no exception to this. This research will potentially allow these organisations to make more informed business decisions with regards to the direction they may wish to focus their research and development of new products or services.
- The next logical beneficiaries in the chain, would be the training providers themselves. Whilst in almost all cases this will typically be training Hospitals and Medical schools. It is worth speculating that with a suitable enough training simulation it would be possible to offer a centralised specialised training centre, to deliver more focused training.
- Surgeons, being the primary interactor with the proposed result of the research will be one of the most direct beneficiaries, as a simulation with a higher level of fidelity and realism should translate into an overall greater experience. Whilst offering the most optimum learning conditions for the surgical candidate
- One of the more abstract yet identifiable beneficiary groups would be the public. Being more specific the patients who would be operated on by the surgeons who had potentially had access to the enhanced VR training solution envisioned as a result of this proposed research.

Ethical Considerations

Considering the ethical implications of the research planned, one of the main areas that would require significant consideration is that of simulated detachment and reset culture. In existing surgical training practices, candidate is taught to not bring any emotional attachment into the operating theatre if possible, to separate the task to be completed from the individual who is potentially opened up on the table in front of them. Within a surgical simulation, certainly one that is envisioned as using the results generated from this research, if a candidate made an error then they would, hypothetically, be able to press reset and simply try again. If this practice is repeated frequently enough over an extended period of time, then it is suggested that the psychological implications of this approach be independently researched to assess if there is any significant impact on the trainee.

Section 4 Methodology

Development Plan

Within this section you will find the road map for how the research proposed will be carried out, whilst at this planning stage a great deal of thought has gone into considering possible issues during the research process, it is worth noting that an element of flexibility has been included around time frames, to account for any unforeseen occurrences.

The first step is to consult with surgical training providers, in an informal interview and gather from them the specifics around hand movements that and level of precision that is used within the scope of their day-to-day activity. From this gathered data, analysis will take place to identify and home in on the specific metrics with which each of the VR systems will be measured against each other. The baseline will be provided by multi angle live recording cameras that will allow side by side comparisons to be made between the simulation and the actual movements. The time period allocated for this will be twelve to sixteen weeks.

Following the identification of the metrics to be measured, a test framework will be created. The test frame work will use both the software provided by each manufacturer of Virtual Reality system as well as a custom developed hand tracking solution using Unity development software. The largest allocation of time here will be given to the in-house development of a hand tracking algorithm, as estimated twenty-six to thirty-six weeks.

Once a robust and flexible test framework has been created then the process of data gathering will begin. Each candidate will, after signing the relevant GDPR declarations and having the purpose of the research explained to them comprehensively, complete the test process. For each candidate there will be multi angle video recordings of the hand as well as the test room. In addition to this there will be separate audio recordings created to allow for transcription of the testing process. It is envisioned that the data gathering process may be repeated several times, initially, to allow for any adjustments to be made from candidate feedback. Once finalised the candidates will complete the test framework a total of four times, once per week, to give a broader dataset for analysis. A period of six to eight weeks would be allocated for this section.

Finally, there will be a period of twelve to sixteen weeks allocated to review and critically evaluate the data gathered. The process of transcription will be completed by a third-party company, under confidentiality agreements. This will speed up the time needed for this section of the research. Following the data review then the findings will be collated and presented in a journal article or conference paper.

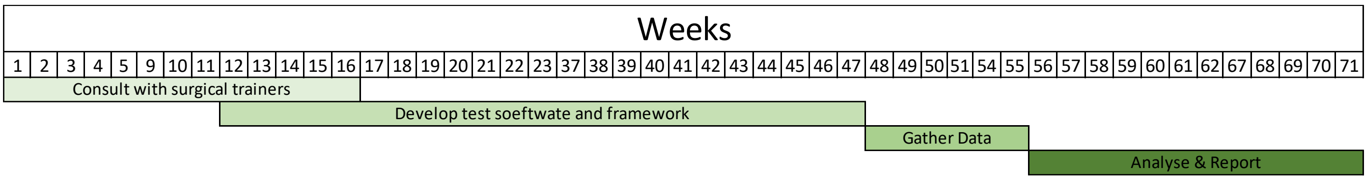
Milestones

Proceeding with this research using milestones to effectively manage the time and overall process will hopefully result in reducing any potential issues around planning. Depending on if additional researchers are allocated to this project then the proposed milestones will require revision to adequately account for the increase in human resources.

The broad milestones that have been identified are:

- Consult with medical trainers
- Define test variables and develop test software
- Gather data
- Analyse and report

The above milestones are broad in nature and could be broken down into smaller chunks during execution of the research project.



n.b. some weeks have been removed for display purposes.

Resource Requirements

When planning the proposed research, a great deal of importance has been given to the topic of resource requirements.

Addressing the hardware requirements first. At least one possibly two high specification computer units would be required, as minimum each should have an intel i7 10th gen processor or equivalent, 32 gigabytes of DDR4 memory with a clock speed of at least 3200mhz. Up to four high definition (1080p minimum) digital recording cameras will be needed to capture the hand movements and test area, each camera should be able to record directly to the computing units or via memory card as a secondary option. Depending on the size of the research area two to three Dictaphone devices will be needed to capture audio.

Multiple Virtual Reality systems and accessories will be required, it is envisioned as a minimum this would include.

- HTC Vive Cosmos
- Oculus Rift S / Quest
- Valve Index
- UltraLeap

From a software standpoint, there will be a requirement to have access to Unity development software this is widely regarded as the main VR software solution available. In addition to this there will also be a requirement to use other programming languages such as Java which is used by the UltraLeap solution. Other software required will include a video editing suite as well as an audio management solution. Finally, there will be a requirement for a basic office style suite, word processor, spreadsheets etc.

One of the most important resources to be allocated and managed is that of time. From the proposed research methodology, a timeframe of twelve to eighteen months seems to be realistic, this is given the complexity and scope of what is to be achieved.

There is room here to also consider the human element to the proposed research. Depending on candidate availability it may not be possible to have access to surgical candidates, in these instances, then depending on the robust nature of the test framework a lay person could conceivably be used as an acceptable analogous. Though, this would only be for the elements where the accuracy of actual motion is being compared to the virtual movement.

Section 5 References & Bibliography

References

LAPARO ASPIRE ver. Modules. Available at: https://sklep.laparo.pl/en/145-laparo-aspire-ver-modules.html (Accessed: Dec 22, 2020).

'Training simulators for laparoscopy | LapSim®', Surgical Science, . Available at: https://surgicalscience.com/systems/lapsim/technology/ (Accessed: Dec 22, 2020).

Cohrs, N.H., Petrou, A., Loepfe, M., Yliruka, M., Schumacher, C.M., Kohll, A.X., Starck, C.T., Schmid Daners, M., Meboldt, M., Falk, V. and Stark, W.J. (2017) 'A Soft Total Artificial Heart-First Concept Evaluation on a Hybrid Mock Circulation', Artificial organs, 41(10), pp. 948-958. doi: 10.1111/aor.12956.

Fedorov, N. (2015) The History of Virtual Reality. Available at: https://www.avadirect.com/blog/the-history-of-virtual-reality/ (Accessed: Dec 20, 2020).

Rasakatla, S., Mizuuchi, I. and Indurkhya, B. (Aug 17, 2020) Robotic Surgical training simulation for dexterity training of hands and fingers (LESUR). ACM, pp. 1.

Wozniak, P., Vauderwange, O., Mandal, A., Javahiraly, N. and Curticapean, D. (Sep 27, 2016) Possible applications of the LEAP motion controller for more interactive simulated experiments in augmented or virtual reality. SPIE, pp. 99460P.

Bibliography

Boletsis, C. and Cedergren, J.E. (2019) 'VR Locomotion in the New Era of Virtual Reality: An Empirical Comparison of Prevalent Techniques', Advances in human-computer interaction, 2019, pp. 1-15. doi: 10.1155/2019/7420781.

Bric, J., Connolly, M., Kastenmeier, A., Goldblatt, M. and Gould, J. (2014) 'Proficiency training on a virtual reality robotic surgical skills curriculum', Surgical endoscopy, 28(12), pp. 3343-3348. doi: 10.1007/s00464-014-3624-5.

Dixon, S. (2006) 'A history of virtual reality in performance', International journal of performance arts and digital media, 2(1), pp. 23-54. doi: 10.1386/padm.2.1.23/1.

Grant, A., Bsc, W. and , H. (2020) A Multiple Optical Tracking Based Approach for Enhancing Hand- Based Interaction in Virtual Reality Simulations.

Hagelsteen, K., Johansson, R., Ekelund, M., Bergenfelz, A. and Anderberg, M. (2019) 'Performance and perception of haptic feedback in a laparoscopic 3D virtual reality simulator', Minimally invasive therapy and allied technologies, 28(5), pp. 1-8. doi: 10.1080/13645706.2018.1539012.

Hanzaki, M.R. and Boulanger, P. (Nov 2020) Proxy Haptics for Surgical Training. IEEE, pp. 134.

Johnson, E. (2016) 'Surgical Simulators and Simulated Surgeons: Reconstituting Medical Practice and Practitioners in Simulations', Social studies of science, 37(4), pp. 585-608. doi: 10.1177/0306312706072179.

Kessel, D., Gould, D. and Lewandowski, B. (2006) 'Virtual Reality Simulation Training can Improve Inexperienced Surgeons' Endovascular Skills. Eur J Vasc Endovasc Surg 2006;31:588–593', European journal of vascular and endovascular surgery, 33(2), pp. 259. doi: 10.1016/j.ejvs.2006.10.032.

Lemos, J.D., Hernandez, A.M. and Soto-Romero, G. (2017) 'An Instrumented Glove to Assess Manual Dexterity in Simulation-Based Neurosurgical Education', Sensors (Basel, Switzerland), 17(5), pp. 988. doi: 10.3390/s17050988.

Lewis, T.M., Aggarwal, R., Rajaretnam, N., Grantcharov, T.P. and Darzi, A. (2011) 'Training in surgical oncology – The role of VR simulation', Surgical oncology, 20(3), pp. 134-139. doi: 10.1016/j.suronc.2011.04.005.

Meijden, O.A.J. and Schijven, M.P. (2009) The value of haptic feedback in conventional and robot-assisted minimal invasive surgery and virtual reality training: a current review.

Placidi, G., Cinque, L., Polsinelli, M. and Spezialetti, M. (2018) 'Measurements by A LEAP-Based Virtual Glove for the Hand Rehabilitation', Sensors (Basel, Switzerland), 18(3), pp. 834. doi: 10.3390/s18030834.

Song, K., Kim, S.H., Jin, S., Kim, S., Lee, S., Kim, J., Park, J. and Cha, Y. (2019) 'Pneumatic actuator and flexible piezoelectric sensor for soft virtual reality glove system', Scientific reports, 9(1), pp. 8988-8. doi: 10.1038/s41598-019-45422-6.