https://doi.org/10.2352/ISSN.2470-1173.2017.3.ERVR-089

Oculus Rift with Stereo Camera for Augmented Reality Medical Intubation Training

Kyung yul Kevin Lim, Preetham Suresh, Jürgen P. Schulze; University of California San Diego, La Jolla, CA, USA

Abstract

Augmented Reality is a widely anticipated platform for user interfaces. AR devices have been around for decades but are for the first time becoming affordable and viable as a consumer device. Through direct representation of 3D space and integration with haptic controls, AR brings many benefits to a user during training scenarios, namely increased knowledge acquisition and direct applicability. We believe these opportunities are not enough explored yet in medical training scenarios. This paper reports on our medical simulation for intubation training, which uses an Oculus Rift DK2 with the stereo camera device Ovrvision Pro. Our work shows great potential for augmented reality devices in medical training, but the hardware devices have yet to mature for widespread use.

Introduction

Augmented and virtual reality can aid medical training. This is true for both performance [12] as well as cost. A full body training patient simulator owned by the UC San Diego Simulation Training Center costs well over $50,000, much more than the cost of equipment used in this paper.

Augmented reality (AR) is becoming an increasingly attractive option for transferring medical training simulations into, as AR devices are getting cheaper with off-the-shelf solutions such as the HoloLens [8] already available. Soon they will surpass traditional medical simulations—done with physical mannequins (Figure 1)—in equipment cost, and extensibility. Furthermore, the lower system weight makes it possible for transportation off-site away from the hospital or training facility, saving doctors' time, and reaching remote rural locations that lack such training equipment and facilities. In addition, certain training scenarios that may occur in invasive procedures such as bleeding during emergency airway placement through the neck cannot be feasibly simulated physically, but are much easier to recreate in a digital setting. For these reasons, we believe that AR can benefit and advance the field of medical training.

To this end, we present an augmented reality prototype for simulating the laryngoscopy during intubation. This is the high stakes procedure that medical providers use to place a breathing tube into the airway in order to breathe for someone who isnt breathing for themselves. We've prototyped what such an AR medical training simulation might look like (Figure 2) and detail the steps and technologies used in the hope to contribute a process for others to expand further. The rest of the paper is organized as follows: we begin by describing related work and provide details for the hardware and software setup used. Next we present the simulation that was created and its features. Finally, we provide discussion and future work for the project.

Figure 1. *A doctor-in-training performing intubation on a patient simulator (Image by Christiana Care licensed under Creative Commons)*

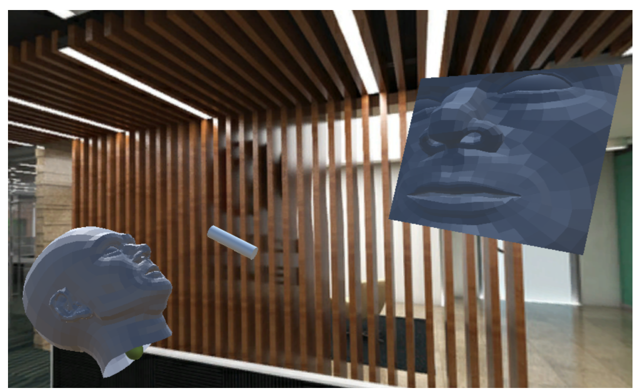

Figure 2. *A scene of our intubation medical simulation.*

Related Work

Before the advent of virtual and augmented reality systems, and even still today, the most popular electronically-assisted training method for medical procedures was video. Video-assisted trachaeal intubation, for example, has been studied by Biro and Weiss [2].

Seymour et al. [12] studied that virtual reality training improves performance in the operating room. This work compares traditional physical training and virtual reality training and finds compelling evidence that the group trained with a virtual reality simulation performed better. This is the basis for our belief that augmented reality is worthwhile pursuing as we add further haptic controls by augmenting reality as opposed to moving all activity into the virtual.

Haubner et al. [6] predicted that with how quickly the performance of the consumer desktop system is increasing, that soon virtual reality medical applications can demonstrate improved spatial impressions and provide more realistic simulation of surgical procedures than standard medical image sequences. With how much easier it is to obtain a device for virtual and augmented reality, and a desktop that is powerful enough to support those hardwares, we think that the time is now.

Fuchs et al. [4] built and described a system for using augmented reality in the operating room directly with a head mounted stereo camera, in order to overcome limitations of laparoscopy or laryngoscopy by providing a 3D image with depth cues instead of the 2D image that they provide. Our work follows in the footsteps of their work, but with the aim that this will be used in training scenarios as it is still difficult to provide all the rendering equipment in a compact HMD—as Fuchs points out in 1998 as well.

Mayrose et al. [9] describe a virtual reality intubation training sytem. As opposed to ours, theirs is entirely built for virtual reality and does not utilize physical props. Their haptic feedback is done with a SensAble Phantom haptic feedback device. While this provides more flexibility than our solution, the haptic feedback is much more realistic in our solution because a real laryngoscope is used.

The closest system to ours that we could find is Hamza-Lup's training system for medical training [5]. But their approach is based on a distributed system with a see through AR head set. Our Oculus-based AR system allows for better occlusion of the environment with computer imagery, and we focus on use of the laryngoscope rather than intubation through the mouth.

Hardware

Oculus Rift DK2

We choose to use a head mounted display (HMD) for the head tracked display that we can use. The Oculus Rift DK2 is such a HMD virtual reality device that was released in 2015, one year ahead of the commercial release of the Oculus Rift. Its display uses an OLED screen and has a 960×1080 pixels resolution for each eye, which combine to 1920×1080 pixels. Its field of view is 90 degrees with an update rate of 75 Hz. It connects to a computer through an HDMI and a USB 3.0 cable, which also connects with the camera that does the position tracking of the head. The HMD itself has a head tracking sensor that enables our whole application [3, 10].

Ovrvision Pro

In order to simulate the operating room, the training simulation should show the doctor's environment and tools. There are two ways to achieve this: to recreate the operating room in virtual reality or to augment the pre-existing physical reality with the information necessary for the training; we went with the latter. The Ovrvision Pro is the stereo camera goggle (Figure 3) that enables this. It can be mounted on the front of the Oculus Rift DK2. This is our core equipment that enables augmented reality, essentially allowing the user to "see" through the head mounted display with information overlay [14]. The two lenses have a field of view of 115 degrees which is slightly wider than the Oculus Rift. It connects to the desktop computer through a USB 3.0 port.

The Ovrvision Pro supports several resolution options as

Figure 3. *The Ovrvision Pro stereo camera attached to the front of an Oculus Rift DK2.*

listed in Table 1. Ideally we would prefer options that support the same refresh rate as the Oculus Rift DK2—75 Hz—as well as the closest resolution—$960 \times 950 \times 2$ pixels—but due to driver issues we could only get the $1280 \times 960 \times 2$ resolution on 45 Hz to work (more on this in the Results section). In informal evaluation this turned out to not pose a significant issue. For reference, the resolution difference is shown in Figure 4.

Supported Resolutions and Framerates in Ovrvision

Resolution (pixels)	Refresh Rate (Hz)
$2560 \times 1920 \times 2$	15
$1920 \times 1080 \times 2$	30
$1280 \times 960 \times 2$	45
$1280 \times 800 \times 2$	60
$960 \times 950 \times 2$	60
$640 \times 480 \times 2$	90
$320 \times 240 \times 2$	120

Sixense Hydra

During an operation, the surgeon uses many tools to operate on a single person, and it is important that the training simulation allows for haptic controls that emulate this. The Sixense Razer Hydra (Figure 5) is a six-axis controller that allows tracking both hands' rotation and movement in space. This controller system allows us to precisely track any generic two hand interaction. We attach the left hand controller to our head model to be able to augment the reference frame of the head model (Figure 6), and the right hand controller is held to emulate the laryngoscope and the endotracheal tube [7]. Our head model is currently a simple styrofoam wig model, but we will eventually put on it a rubber mask from a training mannequin, see Figure 7.

Desktop PC

We use a Windows 10 64-bit PC running on an Intel Core i7-3820 3.60GHz CPU with 32 GB of RAM and NVIDIA GeForce GTX 980 Ti to drive the whole simulation. Our prototype does not require this high performance equipment, but since we plan to expand on our simulation to a higher fidelity model in the future,

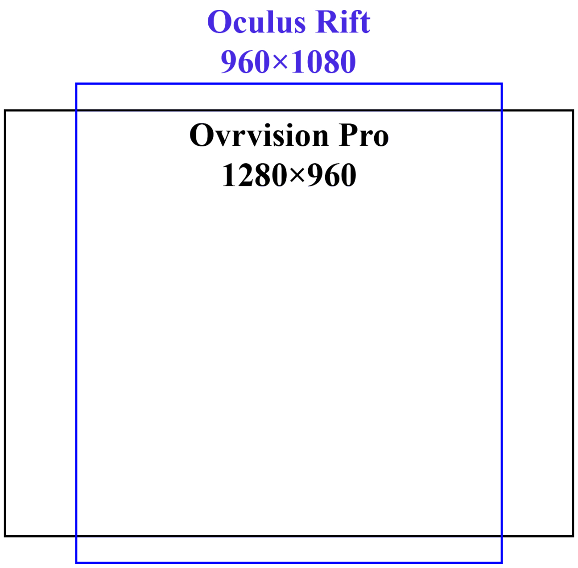

Figure 4. *The Ovrvision Pro camera resolution (wider) and the Oculus Rift display resolution (taller).*

Figure 5. *The Sixense Razer Hydra controller provides us a natural user interface for moving objects in 3D space with two hands.*

we've created our work on a desktop that is future-proof.

Software

Unity 3D

The main engine controlling all the parts is done by the Unity 3D game engine. All of our hardware mentioned above—the Oculus Rift, Ovrvision, and Hydra—provide Unity plugins. The specific version of Unity used is 5.3.2. All interactions within the simulation are scripted via C# or made within the Unity GUI [13].

Maya

All modeling of 3D meshes was done using the 3D package Autodesk Maya. 3D modeling was done to represent a human head model (Figure 8) for the user to interact with, and a marker was placed at the bottom of the throat to indicate where the larynx in a higher fidelity model would go. This model's jaw was then rigged for us to be able to pull on it with the tool as a doctor might. This 3D model was then exported to the Unity-compatible FBX format [1].

Figure 6. *The left hand controller is attached to the physical head model to provide haptic tracking of the head movement as the trainee moves the head.*

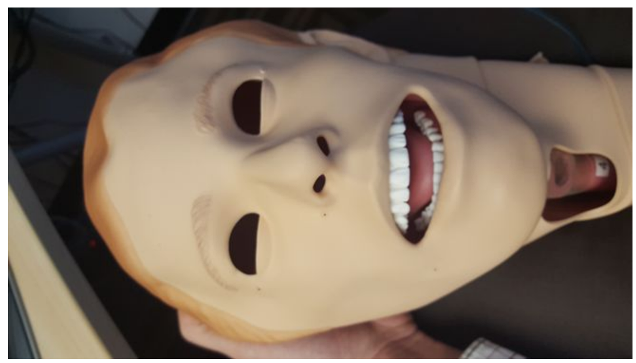

Figure 7. *This rubber mask with a physical trachaea will be put over the styrofoam head model to make the head model more realistic for the training simulation.*

Simulation

In a typical endotracheal intubation training scenario the trainee is given a mannequin with anatomical representations that model the target trachea. The trainee is tasked with several points to be aware of, namely to use the windpipe not the esophagus. There are several scenarios the students need to go through. For example, because the intubation is such an invasive procedure, the surgeon might cause the patient to vomit, limiting visibility. In this case, the surgeon must reach for a vacuum in a short amount of time and quickly clean up before proceeding with the procedure.

We combined our Unity and Maya work to create an interactive prototype that simulates such a scenario. The exported head model retains its rigged skinning information, which exposes the jaw joint to be controllable within Unity and the head mesh's jaw. The simulation is displayed on the Oculus Rift's screen, as well as an LCD monitor. When an Ovrvision Pro is connected, the displayed background is the view through the camera (Figure 9). Otherwise, a indoor cube map is used (Figure 10). For controls, when the Sixense Razer Hydra is present the left and right controllers move and rotate the head and tool respectively. When no Hydra is present, the keyboard is used to move the head and the

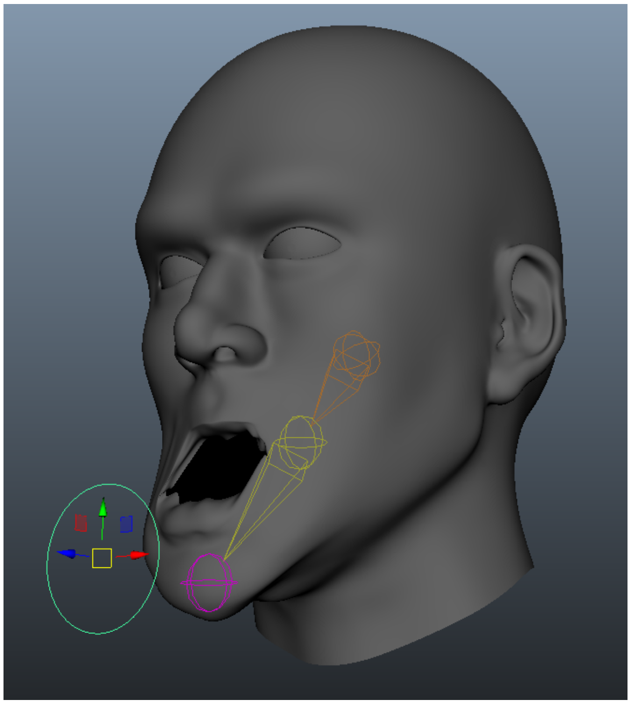

Figure 8. *The 3D modeled head with the rigged structure with a controllable jaw.*

mouse is used to move the tool. These options allow for a simplified debug environment where not all hardware is available, but they are not how this software is meant to be used eventually.

In the head model there are Unity colliders that when touched will cause the head to vomit particles. Attached to the tool is a second camera that simulates what the trainee might see down the throat through a real laryngoscope, and also avoid the colliders. Successful navigation of the throat can then be judged and this provides a simplified intubation training scenario in which the trainee has to locate the trachea and introduce an endotracheal tube, while avoiding the surrounding structures.

Figure 9. *Scene with augemented reality background when Ovrvision Pro connected.*

Figure 10. *Scene with cubemap background when Ovrvision Pro is not connected.*

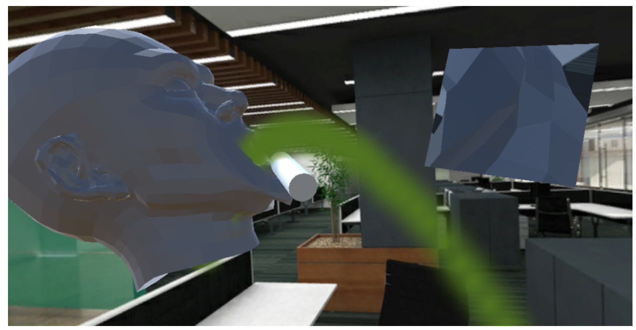

Figure 11. *The virtual patient vomiting due to the invasive procedure. The trainee's goal would be to avoid this scenario, or be able to quickly resolve the scenario with the vacuum tool.*

Ease of Development

Both Unity and Maya make the production of such a simulation much easier than developing from scratch. Being a game engine, Unity already has the tools for developing 3D interaction on a desktop PC with the ability to display meshes, materials and environment cubemaps. Unity has a robust community of developers supporting it, and it has a myriad of plugins that work with the chosen hardware components.

Autodesk Maya is an animation and game industry standard 3D package and can be a challenge to use for a beginner. But with some practice it is a very powerful 3D modeling tool, which also allows the rigging of the models, which can then be imported into Unity.

Hardware Issues

There are many off-the-shelf hardware options that can introduce potential compatibility issues, and this was seen especially with the Ovrvision Pro. The least vetted out of the three pieces of hardware used, the Ovrvision would cause an application to crash whenever any resolution except $1280 \times 960 \times 2$ on 45 Hz was chosen. This is our refresh rate choice, which though as mentioned earlier, from our informal evaluation, the resolution of $1280 \times 960 \times 2$ on 45 Hz didn't cause any issues after some initial acclimation.

The Sixense Razer Hydra, though functional, hasn't had an updated Unity plugin release since Unity 4.5.5 or January 20, 2015. Depending on the backwards compatibility of future Unity releases beyond the version used (5.3.2) there is justifiable concern how long these controllers will be supported. We recommend to use the new Oculus Touch controllers in future projects - they are well supported in Unity but weren't available yet at the time this research was done. Alternatively, an HTC Vive could be used. It even has a built-in camera, but a single camera does not give the user the more realistic 3D stereo view the Ovrvision system gives, and this system was designed for the Oculus Rift DK2.

Further, the synchronization of all these hardware components required much manual calibration. As neither the Ovrvision Pro nor the Oculus Rift directly tracks the Hydra controllers, a manual offset and particular physical distance had to be setup. The challenge of calibration between devices will be alleviated with the use of a device such as the Oculus Touch controllers or the HTC Vive which support their own sets of controllers natively in the same coordinate system as the HMD.

Discussion

We started with the goal of developing an augmented reality intubation training simulation as a proof of concept. The system was built with all off-the-shelf components and quite successfully demonstrates the plausibility of such a scenario. The next step would be to flesh out the simulation into a higher production quality with anatomically correct pharynx, and additional medically based challenges for the trainee to overcome. Our plan is to then clinically evaluate this higher fidelity simulation in collaboration with the UC San Diego Simulation Training Center.

The question of what direction the simulation would need to improve to achieve higher fidelity is an interesting question to evaluate. Is it the visual realism? Is it the number of interaction scenarios? If so, how much of these is necessary before the trainee feel as if they're in an actual operating room and an ideal simulation can be created? These are all research vectors worth pursuing in future clinical studies.

Currently our simulation only tracks one type of tool, supported by one of the two controllers. However, having multiple tangible and haptic controls is extremely important for surgeons in training as they need to become well acquainted with the various tools that will be in use in real emergency scenarios. Even within our scenario of the patient vomiting, the surgeon would need access to a second vacuum tool. Currently there is no framework in place for tracking multiple tools and this is an extremely important area we can expand on. Possible implementations would be ID tracked controllers for each type of tool the doctor might pick up (e.g., the Hydra can support up to 4 simultaneous controllers) or a motion tracking rig that is even more extensible. The soon to be available HTC Vive Tracker units (see Figure 12) appear to be well suited to solve this problem in an elegant fashion.

Once a general enough framework is set up for both tools and various body parts, a simulation that can be extended to the whole body or different types of surgeries can be realized, making the augmented reality simulation much more extensible than the physical patient simulator. What if we need to train for scenarios in which the trainee has to perform a C-section? In that case we could instead have the interactable haptic control model the abdomen and uterus, while the rest of the body is an augmented reality image.

In the future, we would want to compare multiple devices much like Polcar et al. do [11]. A particular device of interest is the Microsoft HoloLens, which itself is a see-through head-mounted augmented reality device, making it a very suitable device for our needs. For 2017, more AR goggles have been announced, such as the Meta 2, which will have a vastly greater field of view than the HoloLens, which makes it even more useful for medical training scenarios due to its greater realism.

Figure 12. *The new Vive Tracker unit. It can be attached to any object that is to be tracked, for instance our head model.*

Conclusion

Our experiment shows that a prototype for a medical training tool with augmented reality can be built at relatively low cost and yet be effective. The major issues we ran into stemmed from our very limited simulation scenario, and the use of two different tracking systems for HMD and devices. The latter can be fixed by using controllers which share the tracking system the HMD uses. Another limitation of our prototype is the requirement for physical simulation equipment, such as the head model and the laryngoscope.

Future Work

A more flexible training system might work entirely in VR and by using a haptic feedback device such as the Geomagic Touch, with a suitable adapter resembling the handle of the respective instrument trained on. This way many other procedures could be simulated, but as prior work in this field shows, current haptic feedback devices are limited in working volume and force, and it is hard to program them for very specific haptic effects, such as the cutting of tissue. In conclusion, augmented reality is an attractive frontier for the future of medical training, due to cost, extensibility, and certain scenarios being easier to simulate. We hope that our proof of concept and the process description for its development provided the reader with enough ideas and that this prototype will eventually lead to success in clinical trials.

References

[1] Autodesk. Autodesk maya. `www.autodesk.com/Maya`, 2016.

[2] P. Biro and M. Weiss. Difficult airway management: Clinical evaluation of video-assisted tracheal intubation. *University of Zurich*, 2001.

[3] Parth Rajesh Desai, Pooja Nikhil Desai, Komal Deepak Ajmera, and

Khushbu Mehta. A review paper on oculus rift - a virtual reality headset. *arXiv preprint arXiv:1408.1173*, 2014.

[4] Henry Fuchs, Mark A Livingston, Ramesh Raskar, Kurtis Keller, Jessica R Crawford, Paul Rademacher, Samuel H Drake, Anthony A Meyer, et al. *Augmented Reality Visualization for Laparoscopic Surgery*. Springer, 1998.

[5] Felix G. Hamza-Lup, Anand Santhanam, Cali Fidopiastis, and Jannick P. Rolland. Distributed training system with high-resolution deformable virtual models. In *Proceedings of the 43rd Annual Southeast Regional Conference - Volume 1*, ACM-SE 43, pages 268–273, New York, NY, USA, 2005. ACM.

[6] Michael Haubner, Christian Krapichler, Andreas Lösch, Karl-Hans Englmeier, and Wilhelm Van Eimeren. Virtual reality in medicine - computer graphics and interaction techniques. *Information Technology in Biomedicine, IEEE Transactions on*, 1(1):61–72, 1997.

[7] Sixense Entertainment Inc. Razer hydra. `http://sixense.com/razerhydra`, 2016.

[8] Alex Kipman. Announcing microsoft hololens development edition open for pre-order, shipping march 30. *Microsoft Devices Blog. Microsoft*, 2016.

[9] J. Mayrose, T. Kesavadas, K. Chugh, D. Joshi, and DG Ellis. Utilization of virtual reality for endotracheal intubation training. *Resuscitation, Oct 2003, 59(1):133-8*, 2003.

[10] VR Oculus. Oculus rift dk2, 2014.

[11] Jiri Polcar and Petr Horejsi. Knowledge acquisition and cyber sickness: A comparison of vr devices in virtual tours. *Science*, 2013.

[12] Neal E Seymour, Anthony G Gallagher, Sanziana A Roman, Michael K OBrien, Vipin K Bansal, Dana K Andersen, and Richard M Satava. Virtual reality training improves operating room performance: Results of a randomized, double-blinded study. *Annals of surgery*, 236(4):458–464, 2002.

[13] Unity Technologies. Unity. `http://unity3d.com`, 2016.

[14] Wizapply. Ovrvision pro. `http://ovrvision.com`, 2016.

Author Biography

Kyung yul Kevin Lim received his B.S. in Electrical Engineering and Computer Science from the University of California, Berkeley in 2011. He worked at DreamWorks Animation as a Lighting Technical Assistant from 2011 to 2014, after which he began attending University of California, San Diego for his MS in Computer Science. He graduated in June 2016. His work has focused on the development of visual narrative and entertainment technology and the human technology interaction within that context.

Dr. Suresh is a board certified anesthesiologist at the University of California, San Diego. He works clinically in obstetric anesthesia and regional anesthesia. He is also the medical director of the Simulation Training Center for the School of Medicine at UCSD. His research interests are in developing new simulators and studying the correlation between simulated and clinical medical procedures.

Dr. Jürgen Schulze is an Associate Research Scientist at UC San Diego's Qualcomm Institute, and an Associate Adjunct Professor in the computer science department, where he teaches computer graphics and 3D user interfaces. He holds an M.S. degree from the University of Massachusetts and a Ph.D. from the University of Stuttgart, Germany. After his graduation he spent two years as a post-doctoral researcher in the Computer Science Department at Brown University.