Development of VR (Virtual Reality) Based Pathology Practice System

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1. Introduction

VR (Virtual Reality) is a computer-generated technology that allows users to experience, through VR devices such as head-mounted displays, artificial spaces that do not exist in actual reality. Unlike VR, AR (Augmented Reality) is based on the real world and that is augmented or supplemented by superimposing information on it, using mainly devices such as smartphones and tablets. It is used in the well-known Pokémon Go game and in showing the conceptualized appearance of a yet-to-be completed building constructed on part of the surrounding landscape. MR (Mixed Reality), on the other hand, is similar to AR in that it is based on the real world. In other words, it is a technology that creates a world that combines VR and AR. These VR, AR, and MR technologies are sometimes collectively referred to as XR (Cross Reality, eXtended Reality), because of many unclear attributes where the boundaries among them are not clear (Barteit, 2021).

VR is already being actively used in various medical fields. In particular, it is very useful in surgical simulations (Verhey, 2020) and in infection control education (Luo, 2021) because it teaches the trainee in learning advanced medical techniques while forestalling the risk of invasive procedures on actual patients and of infection by the medical personnel. It also has the advantage of training a large number of participants under the uniform standards. Thus, the use of VR is developing in the medical field, and its implementation is expected to broadcast widely. Efforts have already been initiated to utilize VR in the various fields of pathology. Presently, Ehime University has been selected as a partner in a project by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) to promote university reform under "Paradigm Shift in Learning Pioneered by DX: Building a Virtual Classroom Digital Learning (VCDL) Environment to Achieve New Normal Education" (The applicant is Hiroshima University). As part of this project, Ehime University worked on the development of a pathology education system using VR in academic year 2021 under the theme "Construction of a VR pathology training room by merging macroscopic and microscopic images".

In medical education, pathology requires particular delicacy of images, and the high resolution of microimages requires a fairly large file size for each individual subject. In the university syllabus, pathology lectures are progressing from general pathology to systemic pathology for each organ. In this process, the normal macro- and microstructures of the human body are seriously taken into consideration. Since a lack of understanding of normal structures will not lead to a deeper understanding of pathology, the lecture should always incorporate a review of anatomy and histology. The VR system allows visual and vivid side-by-side comparison of normal and pathological structures, making it possible to give more effective lectures. In the process, various difficulties were encountered, such as the limitations of the VR system and the mode of cooperating with and the stance of software development companies. We look forward to introducing some of our experiences to date with others in the hope that our observations will be considered by lecturers who may be involved or interested in instruction using the VR system.

2. Project Background

2.1 Remote education under the COVID-19 pandemic

The Coronavirus outbreak from Wuhan city in China spread rapidly, causing worldwide loss of life and inflicting tremendous economic losses. In addition to the overcrowding of medical facilities, students were forced to stay home and many classes had to be conducted remotely. At the same time, the low diffusion rate of digital devices other than smartphones was distressing. At Ehime University, faculty and the student body were forced to deal with the sudden decision of conducting pathology lectures and practice remotely.

As previously described (Kitazawa, 2021), considerable difficulty was encountered in procuring equipment, video delivery methods, and in evaluating the level of comprehension, proficiency and feedback. In the process, the present study led to interest in VR in the belief that students could take part actually in practical training within a virtual space than in viewing videos alone in their rooms. The initial idea was that if the students could create a simulated training room through an avatar that represented them, as in social games in the Internet society, they would not feel detached and could practice with "others" regardless of their location. Nonetheless, with limited time and funds, the difficulty of constructing a VR space where students could congregate and of developing a system that included the management of the space, was recognized. The focus was then directed at developing an individual participation system using VR goggles. A pair of VR goggles (Oculus Quest 2, now renamed Meta Quest 2) was actually purchased to experience what the VR world was like. Although some drawbacks need to be overcome, that the system could in the near future be applied to student practice of pathology and pathological diagnosis is foreseeable. The grants for the promotion of university reforms were to be used entirely for software development; consequently, search for a relevant company was initiated.

2.2 Meeting with system-and-software developer

Only a limited number of companies with extensive experience in developing medical-related VR systems is available, and even after consulting with the university administrative staff, introduction to a company that could handle VR development for an individual enterprise was challenging. When applying for grants, quotations were needed from VR system-development companies, but our being VR novices, where to start was uncertain. Google search came up with several prospective VR development companies with experience in the development and production of user-friendly educational software, through joint development with several universities, that even beginners could readily use. The VR Design Institute (https://vracademy.jp) had the aptitude for joint development. The company manages classes in the basics of VR programming, and some of their graduates' product is available on their website; it stood out as a viable developer with teaching capabilities. The company was contacted by e-mail, and after receiving their consent that were the grant application not approved, all plans "to date" would be scrapped. A ZOOM meeting was convened with the person in charge of development and the director of the VR Design Institute to explain our concept of developing a VR setup. After their consonance, agreement was reached to jointly develop our pathology practice system. The design of the required 3D images and other details were readied before the grant was approved. In our communications with the VR Design Institute, the basics of the background knowledge of pathology practice, tissue and macroscopic specimens and other aspects were explained to them. Videos of operating the virtual slide screen (the whole slide image) used in practice sessions and relevant information was given to the person in charge. In the whole process of developing the project, no face-to-face meetings were held with the development staff; all information was exchanged through Internet conferencing and e-mail. The grant application was accepted and development of the VR system was implemented. The most important aspect in the development process was making specific requests regarding the design of virtual space the client -the pathologist- envisioned. Regardless of differences in the degree of difficulty, virtual design allows the creation of the desired space with almost no limitations, giving the programmer a high degree for improvisation. Therefore, having a solid image prepared and based on a storyboard is essential.

Having the programmers create three or more models for detailed operation, then selecting one of them, or modifying the one closest to the original concept was effective. The following five basic design aspects were emphasized. (1) During practical training it should be possible to follow the actual training manual with current virtual slides in the VR space and on the virtual monitor. (2) Images of normal structures, organs and such can be displayed side by side. (3) By viewing macroscopic organ findings and pointing to an altered area, the corresponding microscopic image of the altered area can be viewed. (4) All operations should be consistent, and by mastering one operation, the user should be able to carry out other operations. (5) The system should be operable by "hand gestures" only without any intervening hand-operated contrivance. The five prerequisites were set as the basis of the VR course, but that their implementation would be challenging in terms of both time and funds in accommodating all aspects of each pathology specimen was anticipated. Therefore, completing some of the diseases of the circulatory organs was set as the goal. For other diseases of other organs, agreement was reached with the VR Design Institute to modify some of the completed programs and to adopt the same process for creating a prototype that could be completed whenever time and funds were available. For details such as the shapes of touch buttons, several typical patterns were selected while testing the operation of the device.

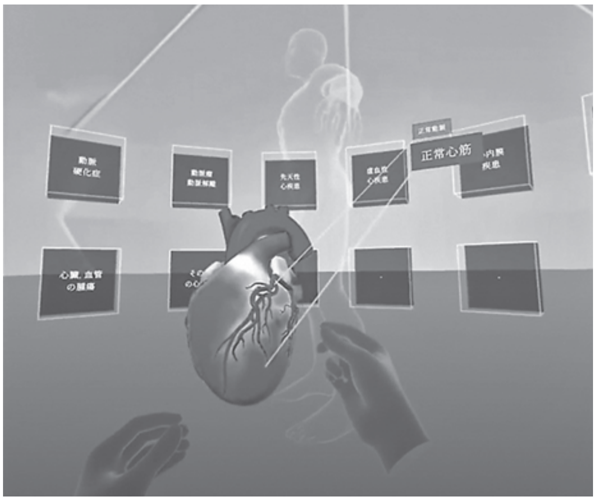

Figure 2. Normal heart with histology tags for virtual microscopic images.

3. The Prototype

Based on the above discussions, three models were produced as prototypes of specific VR systems. One prototype was ultimately produced by integrating the merits of each.

Figure 1. Opening menu of VR pathology practice system.

See video link https://youtu.be/KeIHuNsiq4I for the actual user's view. On the first screen (Figure 1), the 3D images of the human body slowly rotate for the user to make a selection from the body to the organ. The menu is arranged in an arc showing the circulatory, respiratory, nephrological-urinary, etc., system that can be selected by touching a virtual button. When one of the systems, for example the cardiovascular, is selected, a sub-menu appears for the user to select the normal cardiovascular structure and related diseases (Figure 2).

By selecting the heart, a normal heart appears that can be handled and magnified. Although a real 3D scanner can create data from an actual heart, a VR model of a typical heart is constructed and color-coded with mainly red and blue tones to create a 3D image of the heart. 3D images are then created by reference to human anatomy atlases and other reference material and a beginner's guide, and colored red for arteries and blue for veins, regardless of the actual natural color tones. For ischemic heart disease, data of the normal heart is modified and 3D data is created, as shown in Figure 3, assuming the case of a ruptured myocardium on the 5th day after the onset of an acute myocardial infarction in a patient with a history of myocardial infarction.

Figure 3. 3D view of ischemic heart disease with mural rupture.

The status of the coronary arteries is also made discernible, so that the ruptured unstable plaque that is the source of the acute myocardial infarction can be seen in the coronary artery at the infarction site (in this case, the anterior descending branch). The software used to create, color, and reform the 3D data of the macroscopic organs is free software called Blender (https://www.blender.org). Since constructing specific data from scratch is very labor-intensive, there is a limit to what can be accomplished at one institution in preparing macroscopic images corresponding to various diseases. By touching a lesion in the macroscopic image, as shown in Figure 4, a virtual microscopic image appears on a virtual monitor.

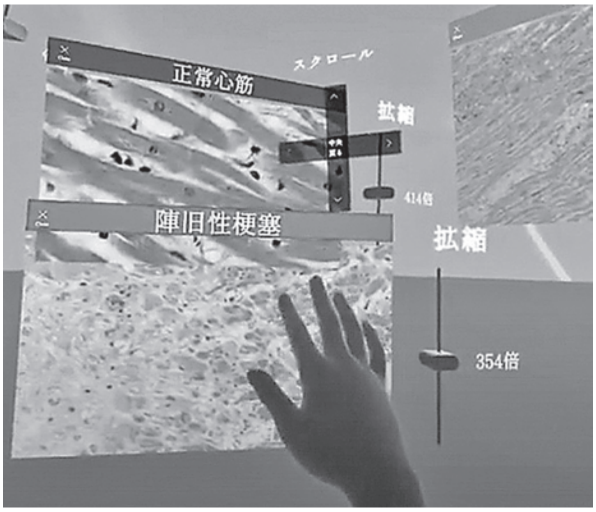

Figure 4. Virtual microscopy images on virtual monitors.

Then using a virtual slide on an alternative virtual monitor, the microscopic image is enlarged, reduced and moved, by scale bars and cursors. This whole image is then modified to allow enlarging and reducing the screen with both hands and moving it with one hand, resulting in one all-inclusive screen configuration. The multiple virtual monitors floating in space and the microscopic images being zoomed in and out and moved by hand gestures conjures a scene from a science fiction movie, foreshadowing pathological diagnosis without the use of optical microscopes and actual monitors. This VR system will reduce space and cost of the training, since the macroscopic and microscopic views of the normal and altered organ can be viewed simultaneously on one common user interface. Furthermore, once one system, e.g. the cardiovascular is mastered, it would be easy to conceptualize and run another system through the same interface thus promoting efficient learning. Even in a

Figure 5. View of person using the VR system.

limited space such as a home, the content of the practical training would not be visible to persons in the vicinity. The trainee would conduct macroscopic and microscopic operations without concern for those around who may feel intrigued seeing a person wearing goggles and pushing, pulling and grasping thin air (Figure 5).

4. Problems pending construction of the VR educational system

In the process of constructing the system, the Internet was perused for websites of archived 3D images we could access. While relatively numerous themes developed for gross anatomical practice were available (many of them for a fee), very few 3D materials dealt with pathology. Sharing actual human gross organs or glass slides for microscopy practice among many institutions is challenging, but VR 3D data being digital can be shared among and archived by multiple institutions. Pathologist societies are also making progress in the use of virtual slides for pathology core images, education programs, and various case review meetings. Taking this one step further and accumulating data on typical macroscopic images of pathological organs after determining certain standard formats is warranted.

Although a method of converting photos of actual organs into digital data with the use of 3D scanners is available, scanning bloodstained organs on a slab at autopsy is unseemly. Reforming and coloring the images based on the 3D digital data of normal organs, as done in this project, would be practical. When the system is near completion minor modifications can be introduced provided they are within the specifications and within budget. The client needs to understand, however, that an additional grant would be required for each modification after the completion and delivery of the system. In the original grant application, the use of friendly avatars was explained as the orientation of prospective high school students visiting open-campus days, who could acquaint themselves with the VR system. In the present VR system, however, the plan to include avatars resembling faculty members, was not included by an oversight, and the memorandum explaining the pathological findings gleaned during the course had not been completed. We became aware that these details were missing from our grant application after the completion of the software, and that major changes in the specifications would entail additional funds.

Currently, the software development environment and the treatment of programmers is at a very delicate stage, and bargaining for intellectual creativity after delivery of the system seems impractical. Because expensive VR goggles apparatus were needed to introduce VR, it was not possible to ask all students' opinion. When the department-assigned undergraduate students experienced the VR education, they all commented that they participated more actively in the learning process because they had to select the images and move them around by themselves, compared to passively watching videos at home. The construction of a system that facilitates lecture practice beyond the actual distance in an interactive VR space with the lecturer is a future issue. As an advanced version of this system, we are constructing a system that can simulate pathology practice in a more practical way by utilizing VR180, and are promoting education that explains pathology-related techniques and allows students to experience autopsies, which we expect will contribute to post-coronary education.

5. Conclusion

Although our experience with VR was limited, we shared with VR Design Institute some information on the construction of a practical pathology training system using VR. The VR environment can be shared by many, and further development in this field is foreseeable, including pathology education, training of medical specialists, and histopathological diagnosis.

6. References

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