Using a High-Resolution Wall-Sized Virtual Microscope to Teach Undergraduate Medical Students

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Abstract

The Leeds Virtual Microscope is an interactive visualization system, capable of rendering gigapixel virtual slides onto high-resolution, wall-sized displays. We describe the evaluation of this technology for teaching pathology to undergraduate medical students, providing insights into the use of high-resolution, wall-sized displays in an educational context. Students were quickly able to become confident in using the technology, collaboratively exploring virtual slides in order to understand the mechanisms of disease. Being able to point with a finger to features on virtual slides promoted multi-way interaction between the students and tutor, led to the spontaneous expansion of the tutorial's scope, and was indicative of a high level of engagement. Students were very positive about being able to interact with the virtual slides and described their increased enthusiasm for pathology as a subject.

Author Keywords

Wall-sized displays; virtual slides; digital pathology; visualization; undergraduate education

ACM Classification Keywords

H.5.2. [Information interfaces and presentation]: User Interfaces – Graphical user interfaces;

Introduction

High-resolution, wall-sized ('gigapixel') displays [1, 2] are both physically large in size (several meters wide) and contain tens of millions of pixels. These displays are profoundly different to the wall-sized projected displays that are commonplace in lecture theatres (large, but ordinary in resolution) or specialist monitors such as Barco's Coronis Fusion 10MP (10 million pixels, but measuring only 30 inches diagonally; Barco N.V., Kortrijk, Belgium). Applications for high-resolution, wall-sized displays include vehicle design, scientific visualization, public information displays and education [9] but, to date, their use in education has been largely limited to the earth sciences (e.g. [4]). We also know little about how users interact with and around such displays when they are used in an educational context.

Histopathology is the science of diagnosing cancer and other diseases by using a microscope to examine glass slides containing sections of human tissue. Today it is possible to scan histopathology slides, storing them as digital images ('virtual slides') for viewing on computer displays, but the resulting images are extremely large (typically 100,000 × 80,000 pixels) because of the magnification that is required to resolve cellular details and make a correct diagnosis. Virtual slides may be viewed on desktop displays, with web-based or local client applications, e.g. Aperio ImageScope (Aperio Technologies, San Diego, CA, USA), but a fundamental disadvantage of desktop displays is they show only a small percentage of what is visible with a conventional microscope at the same equivalent magnification [10].

An important part of medical students' undergraduate education is learning about the mechanisms of disease. Traditionally, this learning process is by viewing microscopic specimens on histopathology slides, using a multiheaded microscope (see figure 1) and guided by a tutor. However, due partly to the many hours it takes students to become accustomed to microscope usage, their use in medical schools has decreased markedly in recent years [10].

To counter this, a number of medical schools now use virtual slides, which have been received positively by both medical students and educators [3, 5-8]. A byproduct is that less experienced demonstrators feel more confident answering questions about virtual slides, because students can point out the morphological feature they are querying on the computer screen [7]. That is impossible with a multiheaded microscope.

This article describes initial results from an evaluation of using an interactive high-resolution, wall-sized display to teach histopathology to second year undergraduate medical students. Key advantages of a wall-sized display come from its resolution (it shows a 5× greater area of a slide than a conventional microscope at the equivalent magnification) and physical size (well-suited to group collaboration). It follows that the wall-sized display holds manifold advantages over desktop displays.

Leeds Virtual Microscope

We have developed the Leeds Virtual Microscope, an interactive visualization system that is capable of rendering gigapixel virtual slides onto high-resolution, wall-sized displays in real time (see figure 2). Navigation on the Virtual Microscope is controlled by a wireless Logitech Rumblepad 2 game pad, with one joystick used for panning and the other for zooming.

figure 1. A fourteen-headed microscope

figure 2. Leeds Virtual Microscope

figure 3. Macroscopic image of lungs showing pulmonary emboli in the blood vessels

(Even with a wall-sized display, panning and zooming is necessary to see microscopic features, e.g. the type of cells in the tissue). An 8-million pixel 'thumbnail' in the top right-hand corner of the display can be turned on, indicating the area of the virtual slide that users are currently viewing. We run the Virtual Microscope on our wall-sized display which comprises an array of 28 x 20-inch monitors that provides an overall image size of 3.0 x 1.2 m and resolution of 54 million pixels. A previous study showed that using the Virtual Microscope on this display allowed histopathologists to make clinical diagnoses as quickly as they could with a conventional microscope [11], instead of taking considerably longer, as is the case with current desktop virtual slide systems. The remainder of this article describes an evaluation of the same Virtual Microscope in the context of teaching undergraduate medical students.

Methods
Participants
We invited one tutorial group on the second year module 'Mechanisms of Disease' of the University of Leeds medical degree course to take part in six additional tutorials using the Virtual Microscope, taking place following their normal weekly tutorials. Twelve students agreed to participate. No incentives besides the additional teaching were offered to the students. All the course tutors are trainee histopathologists.

Data collection
Before the evaluation began, we held a focus group with the course leader and three course tutors, where participants discussed how best to incorporate the Virtual Microscope into the teaching. The key points were as follows. Participants felt that it was important that the session was interactive, with students

controlling navigation of the images. It was decided that each additional tutorial would show slides related to disease mechanisms that had been covered in that week's lecture and tutorial (e.g. neoplasia, metastasis), and as well as the virtual slides, macroscopic images (of the specimen which the tissue had come from, see figure 3) would also be shown, to help put the microscopic detail into context.

The students who were interested in taking part were given a brief demonstration of the Virtual Microscope and a chance to try navigating around a slide before the evaluation began. No other training was given.

The six additional tutorials using the Virtual Microscope were video-recorded. At the beginning and end of the evaluation, the students were given a brief questionnaire asking about their enthusiasm for pathology as a subject and as a future career. This questionnaire was also completed by ten students in another tutorial group, providing a control group. At the end of the evaluation, the students who participated in the additional tutorials also completed a brief questionnaire on the perceived usefulness and usability of the technology and how they thought the technology could be improved.

Ethical approval for this research was granted by the University of Leeds Medicine and Dentistry Educational Research Ethics Committee and written consent was obtained from all participants.

Analysis
This paper reports initial analysis of the video data, focusing on the strategies used by the tutor to incorporate the Virtual Microscope into the teaching

Students exhibited a high level of engagement
Interface was quick to learn and error-tolerant
Game pad can be passed between students, so they shared navigation
Students and tutor can point to features, to ask questions and provide answers
Spontaneous expansion of tutorial scope
Students explored slides cooperatively

box 1. Key benefits of the Virtual Microscope on a display-wall

figure 4. Tutor describes as student centers and zooms

sessions and the different ways in which students interacted with the Virtual Microscope. A preliminary review of the video data identified phenomena and features of the interaction of interest.

Findings
All of the students attended at least four of the six sessions and half of the students attended every session, despite conflicting pressures on their time. Each session lasted between 30 and 45 minutes. The key benefits provided by the Virtual Microscope running on a display-wall are summarized in box 1, and details are as follows.

Configuration of display, tutor and students
The tutor stood to the left-hand side of the display, turning between the display and the students who were facing the display, enabling eye contact between the tutor and the students. The students initially stood facing the whole display and as each session progressed the students gradually moved closer to the display, enabling them to see the detail of the slides and to point to features. This was indicative of students' engagement.

Open-ended versus directed navigation of the slide
The tutor encouraged the students to do all the navigation of the virtual slides. The tutor would typically begin discussion of each slide by getting the students to explore the slide and decide what type of tissue they were looking at and the nature of the abnormality. The tutor would also direct the students to navigate around the slide in order to find particular features. In doing this the tutor made a link to the diagnostic thinking that a histopathologist would apply (e.g. 'So we've got an area of ductal carcinoma *in situ*.

Whenever you see that in real life you start worrying, have we got any actual invasive carcinoma? So see if you can see any invasive carcinoma.').

This independent exploration was then followed by the tutor directing the student with the game pad to pan and zoom to particular areas of the slide (e.g. 'Have a look to the top right') so as to allow the tutor to explain the abnormality with reference to features visible on the slide.

By getting the students to navigate the slides, the tutor was able to concentrate on speaking, while the students were actively engaged, which is likely to increase learning. The game pad interface only took a few seconds to learn, and the Virtual Microscope prevented slides from being panned out of view or zoomed excessively large/small, making it error-tolerant if a student accidentally kept pushing a joystick. An advantage of using the wireless game pad to control navigation is that it can easily be passed between students, so they all took turns.
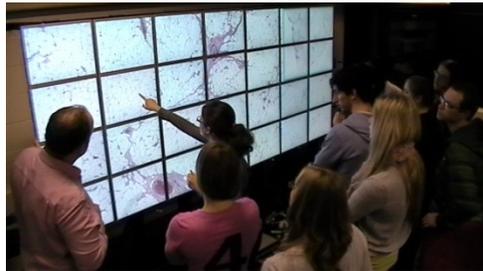
Illustrating the mechanisms of disease
In each session, the tutor showed between 6 and 11 virtual slides (see figures 2, 4 & 5) and between 1 and 11 macro images (see figure 3). In one session, he also included an x-ray and a photograph of a patient. (All images were anonymized.) The students appeared to appreciate having the microscopic images placed in context in this way.

As the students were second year undergraduates it was necessary for the tutor to spend time explaining what was visible on the slides, made easier because the tutor could point with his finger to particular features.

figure 5. Student asks about features on the slide

'*Made [histopathology] much more engaging and easier to understand.*'

'*…it showed how the knowledge in the […] course is actually applied in real life. I had no interest in [histopathology] previously…*'

'*Makes histopathology much more interesting.*'

'*Before I had no interest in [histopathology] as I couldn't see what the lecturer was telling us was there!*'

box 2. Student comments on enthusiasm for histopathology

Interestingly, as the tutor did this, often the student with the game pad would centre and zoom in on the feature that the tutor was pointing to (see figure 4). If the student zoomed in further, this seemed to prompt further, unplanned detail from the tutor.

The students interjected with lots of questions, suggesting a high level of engagement in the learning process. They would spontaneously point to particular features on the slides that they wanted the tutor to explain (see figure 5). Pointing was also useful when the tutor asked questions that required the students identify features on the slides (e.g. 'Where's the tumour?') or students were explaining their answers to other questions that the tutor asked.

Cooperative navigation
Rather than navigation being dominated by the student who held the game pad at a given time, students often cooperated to navigate. While one student would pan and zoom using the game pad, the other students would point to particular areas of the slide to direct them. When zoomed in, students to the right side of the screen would look at the thumbnail to suggest areas to look at.

This cooperation was also visible when the tutor asked about a particular area of the slide; the student with the game pad would bring that area into the centre of the wall and zoom in, so that the other students could get a better look to answer the tutor's question.

Confidence with the technology
Students were quickly able to learn to pan, zoom and move between slides. While in the first two sessions students first sat down and waited to be invited up to

the Virtual Microscope by the tutor, in later sessions, some of the students would begin interacting with the slides as soon as they arrived, with other students then coming to join them.

Student feedback
The feedback at the end of the course was very positive. Students described their increased enthusiasm for histopathology as a subject (see box 2). A theme in the responses was the benefit of being able to interact with the virtual slides (see box 3).

Conclusions
We have described the evaluation of a high-resolution, wall-sized display for teaching histopathology to undergraduate students, providing insights into the use of such technology in an educational context. Analysis of the video data is still underway and what we have reported here represents initial observations. However, the evaluation demonstrates the clear potential for wall-sized displays and software such as the Leeds Virtual Microscope to support collaborative learning (see box 1). On the basis of these results, we hope to install four wall-sized displays so that all undergraduate medical students at the University of Leeds can be taught in this way.

Future work
Further analysis of the video data will look more closely at the moment-by-moment interaction to explore how the Virtual Microscope acts a resource for producing actions such as pointing to diagnostic features on the virtual slides and how knowledge is constructed through the interaction. We are also undertaking an evaluation with trainee histopathologists, comparing teaching sessions on the multiheaded microscope with

> *'Everyone can see and get involved.'*

> *'Being able to move around the slide and zoom in at such high power really helped.'*

> *'Great being able to get close to screen and point to structures.'*

box 3. Student comments on benefits of interaction

teaching sessions on the Virtual Microscope. This will allow us to explore differences in communication and interaction when using these two technologies. Through this further work, we will develop design recommendations for those seeking to integrate high-resolution, wall-sized displays into educational contexts.

Acknowledgements

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