British Journal of Educational Technology Vol 41 No 3 2010 420–431
doi:10.1111/j.1467-8535.2009.00958.x

A simple, low-cost stereographic video capture and viewing solution for teaching psychomotor skills using online delivery

Ian White

Ian White is a senior lecturer in Digital Design and New Media at the University of the Sunshine Coast in Queensland, Australia. His research interests lie in the use of digital media technologies in the educational context and the creative use of computers and software as constructivist learning tools. Address for correspondence: School of Communication, Faculty of Arts and Social Sciences, University of the Sunshine Coast, Maroochydore DC. Qld 4558, Australia. Tel: +61-7-5459-4437; email: iwhite@usc.edu.au

Abstract

It is recognised that the teaching of complex psychomotor skills using online delivery is difficult without the support of either face-to-face coaching and tuition or a stereoscopic viewing system that provides users with a feel for the spatial nature of the skills being taught. To date, the limitations of bandwidth, and the high cost and sophistication of existing three-dimensional video production and viewing technologies have limited the use of stereoscopic video imaging to highly funded fields, such as sports and medical research or military applications. The advent of desktop video editing software, along with personal video players (such as the Apple *iPod* and *iPhone*) with small screens utilising efficient video codecs, means that high-quality video podcasts can now be effectively created and delivered via the Internet. Combining these new video technologies with a conventional analogue stereo viewing and capture system makes the production of stereoscopic video potentially much more accessible to educators as a practical teaching tool. This paper seeks to alert educational designers to an exploratory study into a potentially useful methodology for the capture, production, dissemination and viewing of stereoscopic video images using existing, low-cost technologies. Aside from the production of a simple viewer, the process is straightforward and requires only basic and readily available equipment. Applications in education as well as vocational and sports training are self-evident.

Introduction

Until recently, it has been generally accepted that the teaching of complex psychomotor skills (precise movement in a three-dimensional environment) cannot be done effectively using existing web-based technologies—see for example Driscoll (2002), Horton (2000) and Shale (1988). This is largely because such skills require extensive coaching, accurate demonstrations and immediate feedback, which is best provided in a face-to-face situation. Driscoll (2002) notes that some difficulties may be overcome through the use of high-quality animation or the use of conventional video, although this demands substantial programming, sophisticated editing and access to high-speed network resources. Horton (2000) argues that 'online training cannot teach psychomotor skills perfectly or completely, however, it can be used to introduce skills, thus making later face-to-face training more efficient.'

The need to include psychomotor skills in a diverse range of learning activities is well understood. For example, University of South Australia researchers Ferris and Aziz (2005) note that the effective development of sophisticated psychomotor skills is so critical to the development of competent engineers that they propose Bloom's original taxonomy of educational objectives be expanded to better reflect the importance of the psychomotor domain, in keeping with the increased emphasis given more recently by such researchers as Harrow (1972) and Simpson (1972). Although there are strategies for overcoming some of the difficulties in teaching motor skills in an online environment, the need to improve the effectiveness of web-based training for demonstrating spatial skills is clear, especially as educational institutions increasingly embrace online learning as a core teaching strategy. The ability to easily create low-cost, high-quality simulations using stereoscopic video as an alternative to animation or conventional video may, however, provide educators with an effective tool in addressing this challenge.

That the use of stereoscopic imaging enhances the effectiveness of user interaction in a computer-mediated environment is well documented. Remote manipulators and tele-operated vehicles utilising real- time stereoscopic video feeds are used widely in the nuclear and electrical industries, by the police and military forces, in the aerospace and space industries, and in undersea operations (Drasic, 1991). In such applications, stereoscopic cues are essential, especially where only single-attempt missions are possible, such as in space repairs and bomb disposal. In terms of skills development and training, the use of stereoscopic video displays enhances the learning process and ongoing effectiveness of users by allowing operators 'to undertake less initial training and less constant practice in order to maintain their skills at a suitable level' (Drasic, 1991). So effective is the utilisation of stereoscopic imaging in the training environment that the use of static, stereo-paired images and three-dimensionally rotatable graphical models is commonplace in areas where spatial understanding is essential—such as in the teaching of anatomy and surgery (Hamilton *et al*, 2002; Karger, 1999; Perry, Kuehn & Langlois, 2007), civil and mining engineering (Grimes, Warschauer, Hutchinson & Kuester, 2006; McAlpine & Stothard, 2005), and in physics and chemistry. The use of stereo-photogrammetry to recreate topographical data from aerial survey photographs is a well-established practice and has been used for nearly a century. Although the visualisation of static objects and environments in three-dimensional form is now commonplace, the task of reproducing and displaying continuous human movement in a stereoscopic form continues to present a significant challenge.

At present, research into visualising and recreating movement using animation for educational purposes is ongoing, ranging from the teaching of Chinese calligraphy using an animated virtual teacher (Leung & Komura, 2006) to the animation of dance movements and crowd evacuation training applications (Li, Lau, Komura, Wang & Siu, 2007). In the field of biomechanics and sports medicine, dedicated systems such as the *Vicon Motion Measurement System* are commonly used to capture and record movement, but these are expensive and complex facilities requiring specialised laboratories and the installation of proprietary high-speed cameras, hardware and software systems. Regardless of how motion data is captured or generated, the anatomical complexity of joint movement and the sheer number of joints involved in human movement generates files that are very large in size, because they require the production and transmission of a continuous data stream in order to describe the spatial changes of all joints in each articulation of the figure (Li *et al*, 2007).

Fortunately, not all forms of movement or motor skills require the kind of in-depth analysis or accuracy of reproduction that might be associated with the training of elite athletes. An alternative, the use of directly captured stereoscopic video/film from live action has long been recognised as having the potential to overcome the problems associated with the modelling and animation approach to recreating movement, but, to date, has largely been held back by the sophistication of the technology required to generate it and the bandwidth issues which have also constrained the delivery of streamed animation and video using the Internet.

Issues with current stereographic motion viewing systems

Most readers would be familiar with the anaglyphic process of creating stereographic stills and film, for which the viewer wears red and cyan coloured glasses to view a composite single image in which the left and right views appear misregistered when seen unaided. Though an effective and long-established technique for creating a stereoscopic effect, the main disadvantage of this process is the reduction in colour quality and the resultant reduction in the sense of realism. For this reason, the effect works best with still images and is generally used only in short sequences in films—with the audience being prompted as to when to don the coloured glasses.

In the production of stereoscopic video, left and right views may be captured using two cameras mounted in parallel or by using a single camera with a lens attachment that splits the image into left and right fields and which then either converts the content directly into field sequential format or saves it for later combination. At present, the principal technique used to produce stereographic video requires the creation of interlaced (field sequential) images whereby left and right views are multiplexed using dedicated hardware and software into sequentially alternating bands—as with a Venetian blind—and then viewed on a computer screen using liquid crystal shutter (LCS) synchronised glasses so that the left eye sees only the left scan and the right only the right (these may also be delivered directly to the appropriate eye using a head-mounted display). An adaptation of this allows stereoscopic video and film to be projected for group viewing. This requires the superimposition of dual projected, oppositely polarised left and right fields onto a special reflective screen, which is then viewed using low-cost polarised glasses. Such dual imaging systems create images of breathtaking realism when seen on very large screens, such as those used in *Imax* cinemas. Unfortunately, an emerging issue with the LCS method of viewing individualised three-dimensional video content is the rapid decline in the manufacture and use of cathode ray tube displays and their subsequent replacement with liquid crystal display (LCD) monitors which, because of their slower pixel response rate and scan-like image updating method, are less capable of presenting field sequential information in a manner suited to present LCS systems (Woods & Yuen, 2006).

While digitally generated stereoscopic content is now relatively easy to produce from three-dimensional modelling and animation software, there seems to have been a lapse in the market for dedicated stereographic video production systems, with most advanced-level users now custom building systems to suit their research or business needs. Commercial interest in producing 'consumer level' stereoscopic video equipment has diminished significantly during the past decade and many of the devices described by Woods (2000) are no longer in production, including the popular low-cost *NuView 3D* attachment and the higher-end *Ikegami LK-33*. Chong (2007) comes close to the intention of the study reported here in analysing the accuracy and effectiveness of the *NuView 3D* camera attachment in capturing the movement of the extremities of players in rugby training, recognising, however, that the *NuView 3D* is now dated and that his study required five stages of further image processing following initial capture.

At the present moment, educators seeking a simple and effective strategy for producing stereoscopic content will find many of the commercially available solutions to be at best impractical, expensive or simply unavailable. As can be seen, there are, at present, a number of impediments to the widespread implementation and use of stereographic imaging in the teaching and learning environment.

The video production and viewing system

The system proposed and tested in this exploratory study has the potential to extend the capacity of online delivery systems to deliver stereoscopic video images through an adaptation of existing processes that allow for the capture and presentation of three-dimensional images using existing analogue fittings, freely available software and a relatively low-cost and widely used consumer appliance—the *Apple Video iPod*. In addition, the model intentionally leverages advances in three-dimensional rapid prototyping technology, allowing users to construct the latest version of the viewer with only the need for some simple assembly of pre-designed components. Figure 1 illustrates how the capture and viewing system operates.

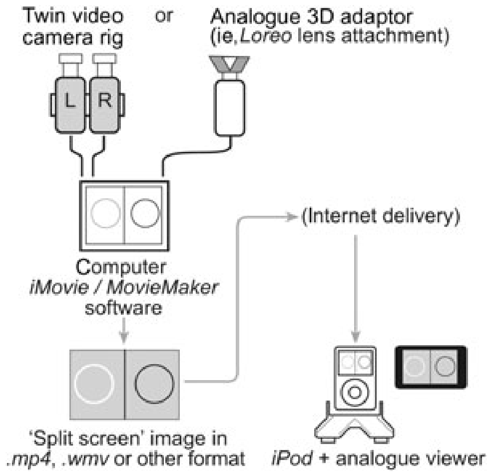

Figure 1: The stereoscopic video capture and viewing system

Background

In late 2005, Apple introduced the video *iPod* and has since sought to broaden its consumer market to include the education sector through its promotion of *podcasting* as a means of delivering audio and video content. The core feature of the video *iPod* is its storage capacity (40–60 gigabytes) and the ability to playback large amounts of video within a 320×240 pixel resolution screen, using the highly effective H.264 video codec. The key to the methodology used in this project is that video produced for use on the now-named *iPod Classic* (and its subsequent variants) does not need to be interlaced. Rather, left and right images can be recorded side by side using a simple mirror or prism-based stereoscopic lens attachment and, on playback using the *iPod*, each half is small enough to be adapted to a hand-held image viewing device such as was popular in the mid-1970s for viewing stereoscopic 35 mm slides (an example of which—the *Ashai-Pentax* 35 mm stereo slide viewer—served as the basis for the design of the test viewer). Alternatively, a simple dual camera system may be used to capture footage, which is then edited into a single frame using freely available software such as *iMovie* or *Windows Movie Maker*. This is not a new technology—stereographic photography using side-by-side images has been popular since the mid-1800s—but the ability to create and playback two sharp windows of video within a space small enough to be viewed using an existing style of stereoscopic viewer means that extant analogue technologies can be brought together with digital displays in a new and unique combination. The fact that the image is substantially magnified by the viewing lenses used in the hand-held viewer means that the image presented on the *iPod* screen seems much larger to the observer than is at first imagined, and thus reduces the issues of eye strain and convergence encountered with older devices.

Constructing the viewer

The key dimensions determining the design of the hand-held viewer used in this study were the width and thickness of the *iPod* (in this project the *iPod* '*Classic*' was used, as the '*Touch*' had not yet been released in Australia) and the human interpupillary distance (IPD)—because fine focussing to compensate for the closeness of the image is resolved by the viewing lenses and the construction of the viewer. The average IPD value of 65 mm was chosen as the starting point for the design because, for ergonomic reasons, it is essential that the human dimension should be the key determinant. Variations in individual IPDs are compensated for by allowing the viewing lenses to slide a few millimetres horizontally left and right from the centre, thereby allowing for personalised adjustment. Because the lens attachment used in the capture stage of this study closely matches this value, only the external diameter of the lens ring attachment had to be customised to fit the Sony DV camera used for making the test videos.

Construction of the viewer required that it should make maximum advantage of the *iPod* screen and should make provision for both the holding tray in which the *iPod* is mounted and a sturdy, snug-fitting bracket with which to hold it in place. The design of the bracket assembly used to hold the tray intentionally avoided the inclusion of any fixing mechanism (which would be essential in the construction of a mass-produced device) to allow for the viewing plane of the screen to be moved relative to the body of the viewer, thereby compensating for any minor miscalculations in the design of the focussing elements of the device. Although the physical dimensions of the video *iPod* display are 320 × 240 pixels (50 mm × 38 mm), there is a loss of approximately 4 mm in the vertical centre of the display caused by the intersection of the mirrors in both the capture device and viewer—thus, the maximum image size available for each view is 23 mm in width by 38 mm in height. The image displayed on the *iPod* has a 0.15 mm dot pitch, thereby producing an overall image resolution of approximately 64 pixels per cm—the equivalent of a small, but reasonably high-quality colour magazine photograph.

To create the test model, Initial Graphics Exchange Specification (IGES) files were exported from Dassault Systemes' *Solidworks*, and the model was built using computer numerical control (CNC) machining by Arptech in Melbourne, Australia (CNC milling is essentially a subtractive process in which the final model is machined from a solid piece of plastic using milling cutters which move with great accuracy within a three-dimensional space). Mirrors were hand cut from commercially available sheet mirror and fitted as shown. Figure 2 shows computer renderings of the assembled viewer, while Figure 3 shows the way in which the mirroring system reflects the split image from the Apple *iPod* to the eyepieces. Figure 4 shows the assembled CNC model with the lid removed and the mirrors in situ. For those interested, fully dimensioned working drawings of the viewer, along with the IGES files for editing or producing it using rapid prototyping technology, can be downloaded from the author's website at http://homepage.mac.com/ian.white1/FileSharing1.html.

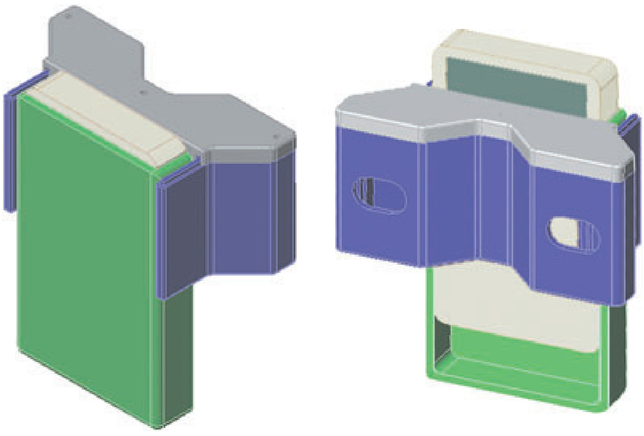

Figure 2: A computer-rendered model showing how the elements are assembled
Note: viewing lenses are not shown in the illustration

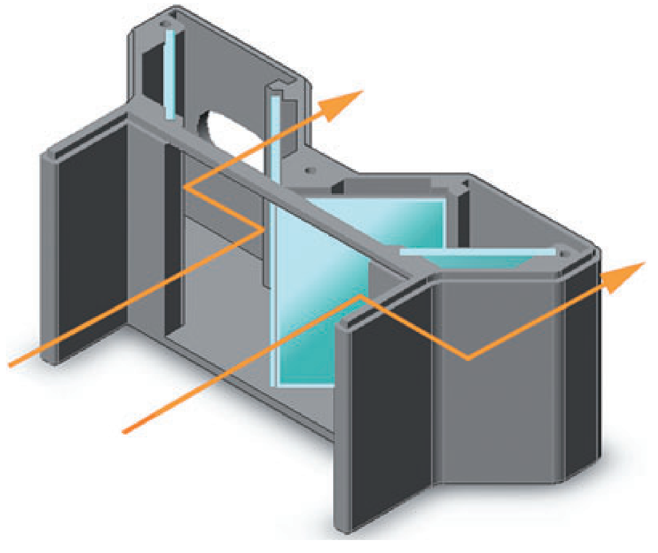

Figure 3: A rendering of the viewer body showing the mirroring system

Stereographic video capture options

Video may be captured using two video cameras mounted side by side on a simple parallel mount (as shown top left in Figure 1), with synchronisation being achieved through the use of a timer filmed at the beginning and at regular intervals during the capture process. The increasing compactness and lowering cost of present-generation digital video cameras make this method of capturing content simple and easy to replicate, although the two streams must be edited into one image using video editing

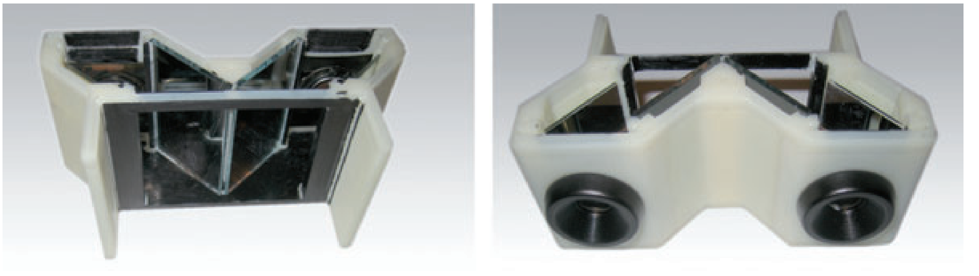

Figure 4: The assembled computer numerical control-manufactured test viewer with the lid removed, front and rear views

software for subsequent use. Alternatively, a low-cost stereographic lens attachment—such as the commercially available *Loreo 3D Lens in a Cap* (http://www.loreo.com/pages/products/loreo_3dcap.html)—may be adapted to a single-camera system, thereby minimising the need for subsequent editing and possible mis-synchronisation caused by tiny variations in the speed of the two camera motors (as shown top centre in Figure 1). Importantly, the latter video capture and viewing method allows for stereographic video images to be captured and viewed without the need for any intermediate electronic processing, other than transfer to a computer and conversion to a file format suitable for replay on the *iPod*. Because the principle objective of stage one of this project was to test whether or not the concept of using an *iPod* to recreate stereographic video was actually feasible, the use of a single-camera set-up using an older style *Pentax* 3D stereo adapter attachment was deemed to be the most practical and immediate option, as this recorded both left and right views in a single frame in-camera. Once captured onto the computer, the conversion of the single-frame split image stereographic video for replay on the *iPod* was done using Apple's *Quicktime Pro*, which is downloadable for both Macintosh and PC computers. Digital video editing software, such as *iMovie* or Microsoft's *Windows Movie Maker*, may be used for cut-and-paste editing to improve the visual flow, but are not necessary.

Test capture

Because the primary aim of this stage of the project was to demonstrate the feasibility of capturing and viewing stereoscopic video images using low-cost video cameras and fittings, readily available software and the analogue viewer, the original test footage was not captured under strictly controlled conditions. For this reason, while the stereographic effect is clearly apparent for most users when using the viewer, the extent of the effect varied according to a range of factors that are readily apparent on closer study and which are well known to experienced stereoscopic image makers (these will be discussed briefly in the next section). Given that the author's original interest lay in replicating human movement in a spatial context, most footage involved shots of people moving and performing simple tasks within a range of spatial situations and under a diversity of lighting and focussing situations. While these initial images clearly demonstrated the feasibility of the process and produced a definite and obvious stereographic video effect, they also made clear some of the issues that need to be taken into account in capturing such video for use within the relatively low-resolution environment of the prototype viewing device.

Observations

To test the effectiveness of the viewing system in displaying live captured movement, two groups of volunteer test subjects (the author's students) were shown examples of the test sequences on the viewing device in an informal capacity. Of the 32 students who viewed the video, there were four students who were unable to see a stereographic effect at all, and several others required some time (15–45 seconds on average) before the stereoscopic effect was perceived. Of the 28 students who were able to resolve the moving images, all said they were initially unable to combine the split images into one blended image, initially seeing two clearly distinct images, although most noted that it took only a few seconds to adapt. The complete inability of some individuals to fuse the images is recognised in the literature (see, for example, Tam & Stelmach, 1998), and is referred to as stereo blindness or stereo anomalous vision, and is found to be present in a very small percentage of the population.

Figure 5 shows two stills from indoor shots made using available light and at distances of between 1.5 m and 50 cm. Both these sequences, when shown to test subjects, were highly effective in conveying the stereoscopic effect and were the most quickly resolved by those who did see in stereo—the knife and cutting sequence being especially so. Although the author had initial concerns about the use of artificial (and relatively low-level) lighting, the contrast such lighting created between areas of light and shadow significantly enhanced the stereoscopic effect by emphasising surface form and texture, thus providing additional spatial cues as to the relative placement of visual elements. Oddly, the disparity between the two scenes captured in each view enhanced, rather than distracted from the effect—as might otherwise be thought—note, for example, the position of the carrot and the knife handle in the right hand frame of the kitchen images.

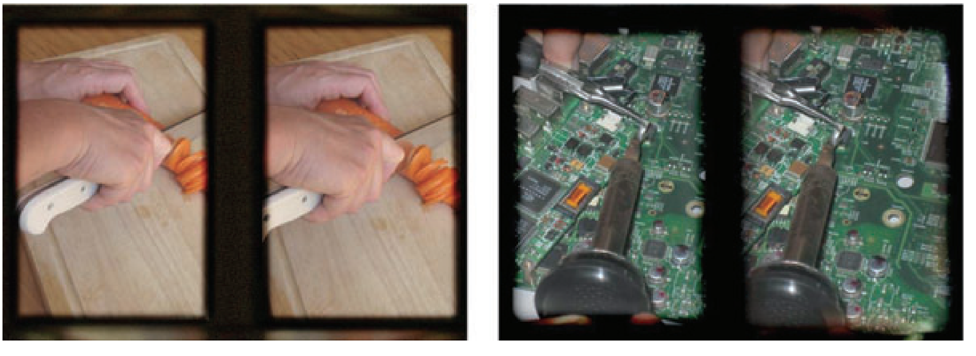

Figure 5: Paired screenshots taken from original test footage. Variations in framing are caused by minor slippage of the lens attachment

Outdoor shots captured at distances of between 1 m and 10 m under natural lighting conditions and with a fixed depth of field gave a reasonable sense of stereoscopic depth and movement, but as distance increased, the effect became noticeably more reliant on the provision of depth cues, which provided supporting perspective cues from which the spatial movement of figures could be judged (for example, converging lines such as stair railings, pathways or desks and tables were all of particular value). External shots captured at distances of between 10 m and 30 m under natural lighting conditions proved to be only moderately effective in conveying a sense of depth when observed through the viewer, although this could be improved slightly (in a dual camera capture set-up) by increasing the separation of the two cameras slightly, as is done in conventional stereo imaging.

Because stereoptic and retinal disparity cues diminish according to distance (being replaced increasingly with monocular cues), images captured at greater distances are generally less effective in conveying a definite sense of space using this system. Importantly, as distance increases, the subtle cues normally evident to the naked eye are readily overwhelmed by relatively minor variations in exposure and processing. For example, although the LCD screen of the Apple *iPod* allows for some adjustment to the brightness level of the image, it is essential to ensure that extreme lighting conditions are compensated for in-camera rather than in replay. Thus, avoidance of any backlighting situations and the provision of definite spatial reference cues, such as motion parallax, perspective and kinetic depth cues, become increasingly important as the distance to the movement being studied increases. Based on initial observations, it appears that the system works optimally at distances between 0.5 m and 5 m—sufficient to allow for both close-up, detailed demonstrations and up to full figure framing—beyond which the size and resolution of the image rapidly become subject to a loss of quality and detail, due mainly to the physical constraints of both the *iPod* and the viewer.

Findings and future implications

To date, the author has been unable to find any reference to a similar combination of tools on the World Wide Web or in any readily available literature—although it is believed that it will only be a matter of time before the connection is made elsewhere. At the time of writing, Sony has a much larger widescreen (480×272 pixels) player available with their *Playstation Portable* (PSP) gaming device—but provide little support for content editing and somewhat limit alternative video input options. Interestingly, some stereoscopic animated content has been created for use on the Sony *PSP*, which is viewed using a simple cardboard viewer designed to attach to the device and which is bundled with the game *Metal Gear Acid 4*. Users view a short computer-animated three-dimensional scenario through the viewer during the transitions between several levels in the game. In competition to the Sony *PSP*, Apple recently introduced a new touch screen player and mobile phone with a 480×320 pixel playback screen, for which a new viewer, based on the more familiar and much simpler Holmes model stereoscope (circa 1896), is presently being designed by the author. It is believed that the larger viewing area provided by the new generation of portable device screens will overcome several of the difficulties encountered in the initial version, and that the new viewer will be simpler and easier to construct, in that no mirrors are required and a much greater range of focussing possibilities will be available. These larger screen formats have potentially far greater use in stereoscopic video playback, and it is only a matter of time before such widescreen format players become commonplace. The possibility of delivering content directly to a device such as the *iPhone* adds a further level of potential to the system.

It is clear from the initial outcomes of this study that hand-held video players such as the Apple *iPod* can be used to present stereoscopic video without the need for dedicated processing software or expensive capture devices and viewing hardware. The original viewing device designed for this study could be built commercially on a large scale and should retail for less than £20, although some consideration would need to be given to making it adaptable to viewers other than the Apple player. However, given the rapidly increasing availability of rapid prototyping systems and three-dimensional printing, it is envisioned that making the IGES files available via the Internet would allow interested researchers and educators to easily construct their own viewers at minimum cost, and thereby ensure that new versions of the viewer are made available as soon as they are developed. This is one way in which personalised manufacturing would assist users in staying abreast of frequent technical and stylistic changes in the most expensive part of the system—the digital players themselves.

Finally—even given the relatively low resolution and small size of currently available screens—it can be said that this method is effective in capturing and replaying movement that requires stereoscopic observation within a moderate range. As well, increasing screen sizes will be of significant value in improving image quality, even if we account for the slightly larger file sizes this may entail. The ability of current-generation personal video players to present clear, split screen images that can be captured using existing analogue and digital technology and viewed using a simple analogue device presents an opportunity for researchers and educators to create, present and utilise spatial information in a readily accessible and easy-to-use way. Given that many of the software tools used in this study are free on new computers and that video compression methods are rapidly reducing the bandwidth requirements needed for the transmission of video, it seems that the possibility of using the Internet to teach certain complex psychomotor skills—particularly those that require fairly close-up observation—will become increasingly practicable in the very near future. The extent to which the system increases teaching effectiveness, along with the practicalities of using this simple technology in an applied teaching and learning context, is presently being assessed in the second stage of this research. In addition, the design of a simpler Holmes style viewer to accommodate the new-generation widescreen viewers (a draft drawing is available on the website) is presently being undertaken and will be tested as part of the study.

Acknowledgements
This project was funded by a seeding grant provided by the University of the Sunshine Coast.

Special thanks are due to my colleague Jennifer Loy of the University of Tasmania, without whose knowledge of the three-dimensional modelling process, this device could not have been built.

References

Chong, A. (2007). An inexpensive stereo-image capture tool for motion study. *The Photogrammetric Record*, *22*, 119, 226–237.

Drascic, D. (1991). Skill Acquisition and Task Performance in Teleoperation Using Monoscopic and Stereoscopic Video Remote Viewing. *Proceedings of the Human Factors Society 35th Annual Meeting*, San Francisco pp. 1367–71.

Driscoll, M. (2002). *Web-based training: creating e-learning experiences* (2nd ed.). San Francisco, CA: Jossey-Bass/Pfeiffer.

Ferris, L. J. & Aziz, S. M. (2005). *A psychomotor skills extension to Bloom's taxonomy of education objectives for engineering education*. Paper presented at the Exploring Innovation in Education and Research Conference, Tainan, Taiwan, March 2005.

Grimes, D., Warschauer, M., Hutchinson, T. & Kuester, F. (2006). Civil engineering education in a visualization environment: experiences with vizclass. *Journal of Engineering Education*, *95*/3, 249–255.

Hamilton, E. C., Scott, D. J., Fleming, R. V., Rege, R., Leycock, P. C., Bergen, S. T. *et al* (2002). Comparison of video trainer and virtual reality training systems on acquisition of laproscopic skills. *Surgical endoscopy* Vol. *16* (pp. 406–411). New York: Springer-Verlag.

Harrow, A. (1972). *A taxonomy of psychomotor domain: a guide for developing behavioral objectives*. New York: David McKay.

Horton, W. K. (2000). *Designing web-based training: how to teach anyone anything anywhere anytime*. New York: John Wiley & Sons.

Karger, S. (1999). *Neuroanatomy. 3D stereoscopic atlas of the human brain*. New York: Springer-Verlag.

Leung, H. & Komura, T. (2006). Web-based handwriting education with animated virtual teacher. *International Journal of Distance Education Technologies*, *4*/1, 71–80.

Li, F. W., Lau, R. W., Komura, T., Wang, M. & Siu, B. (2007). Adaptive animation of human motion for e-learning applications. *International Journal of Distance Education Technologies*, *5/2*, 74–85.

McAlpine, I. & Stothard, P. (2005). Course design and student responses to an online PBL course in 3D modelling for mining engineers. *Australasian Journal of Educational Technology*, *21/3*, 335–354.

Perry, J., Kuehn, D. & Langlois, R. (2007). Teaching anatomy and physiology using computer-based, stereoscopic images. *Journal of College Science Teaching*, *36/4*, 18–24.

Shale, D. (1988). Toward a reconceptualization of distance education. *The American Journal of Distance Education*, *2/3*, 25–35.

Simpson, E. (1972). *The classification of educational objectives in the psychomotor domain*. Washington, DC: Gryphon House.

Tam, W. A. & Stelmach, L. W. (1998). Display duration and stereoscopic depth discrimination. *Canadian Journal of Experimental Psychology*, *52*, 1, 56–62.

Woods, A. J. (2000). *Stereoscopic presentations—taking the difficulty out of 3D*. 6th International Workshop on 3D Imaging Media Technology, Seoul, South Korea.

Woods, A. J. & Yuen, K. L. (2006). *Compatibility of LCD monitors with frame-sequential stereoscopic 3D visualisation*. IMID/IDMC '06 Digest (The 6th International Meeting on Information Display, and The 5th International Display Manufacturing Conference) (pp. 98–102), Daegu, South Korea.