THE QUEEN'S AWARDS
FOR ENTERPRISE
2001

BBC

R&D White Paper

WHP 071

September 2003

Mixed Reality Productions of the Future

V. Lalioti[1] and A. Woolard[2]
[1]BBC R&D and [2]BBC Creative R&D, U.K.

Research & Development
BRITISH BROADCASTING CORPORATION

BBC Research & Development
White Paper WHP 071

Mixed Reality Productions of the Future

V. Lalioti[1] and A. Woolard[2]

[1]BBC R&D and [2]BBC Creative R&D, U.K.

Abstract

Augmented and Mixed Reality has been used in a variety of applications within the scientific and industrial communities, and edutainment (education through entertainment) and interactive installations in public spaces. However, the great potential of these technologies has very rarely been explored within a broadcasting context.

BBC is developing the creative concepts and prototype production tools that would innovate broadcast production and enhance audience experience, based on and extending state-of-the-art research in Mixed Reality.

This paper presents preliminary results from the introduction of AR technologies in a public service entertainment organization, such as the BBC, and then focuses on the production tools and interactive productions developed. The paper also summarizes technical issues that would allow use of this approach in multiple environments, such as in studios, classrooms and in the home.

This document was originally published in the Conference Publication of the International Broadcasting Convention (IBC 2003) Amsterdam 11th-15th September 2003

Key words: television, edutainment, production tools, augmented reality, mixed reality, interactive. .

MIXED REALITY PRODUCTIONS OF THE FUTURE

V. Lalioti[1] and A. Woolard[2]

[1]BBC R&D and [2]BBC Creative R&D, U.K.

ABSTRACT

Augmented and Mixed Reality has been used in a variety of applications within the scientific and industrial communities, and *edutainment* (education through entertainment) and interactive installations in public spaces. However, the great potential of these technologies has very rarely been explored within a broadcasting context.

BBC is developing the creative concepts and prototype production tools that would innovate broadcast production and enhance audience experience, based on and extending state-of-the-art research in Mixed Reality.

This paper presents preliminary results from the introduction of AR technologies in a public service entertainment organization, such as the BBC, and then focuses on the production tools and interactive productions developed. The paper also summarizes technical issues that would allow use of this approach in multiple environments, such as in studios, classrooms and in the home.

INTRODUCTION

Recent years have seen augmented reality (AR) technologies becoming more widely applied, specifically in the areas of medical visualization, equipment maintenance / repair and in military applications, Azuma (2). The majority of the entertainment industry have yet to take full advantage of the potential of AR technology. This is due to the practical requirements and tight schedule of television production that allow for minimal experimentation with new technologies; and the fact that AR is still in its infancy in terms of providing robust real-time systems that can be confidently used by production staff.

The British Broadcasting Corporation (BBC) has recently begun to evaluate the potential of AR in broadcast production, future learning and online services. In collaboration with ARToolworks, we have explored several application areas related to broadcast and multimedia production, focusing on existing and future content and on user and viewer experiences. Based on this evaluation we are developing the creative concepts and prototype production tools that could innovate broadcast production and enhance audience experience.

This paper presents a summary of the evaluation results focusing on the development of production tools and AR prototypes. The background section discusses AR, its application to entertainment and the state-of-the-art in broadcast production technology. The paper summarises the approach to evaluation and gives an overview of the results. The production tools and applications section, describes the prototype tools that were developed for use in the production, classroom and home environments. This paper concludes by summarizing the results and discussing ways forward.

BACKGROUND – STATE OF THE ART

Augmented reality (AR) has developed rapidly in the 1990s. Since 1997, when Azuma (2) (3) provided his seminal overview of augmented reality research, advances in display and tracking technology have continued. These have provided the basis for reliable platforms with which increasingly advanced applications have been built.

Currently AR can use web cameras to visually track patterns or specific features of the physical environment. The software subsequently superimpose synthetic information or virtual objects on the video image at the location of these tracked elements Welch and Foxlin (16). This technology also allows for a more flexible and physical interaction between the real and the virtual elements. For example, The Magic Book (4) allowed users to interact with non-immersive AR interfaces. The Magic Book demonstrates a potentially new and original method for the creation of entertainment that merges physical objects, such as a book, with the sophistication of current computer games.

Current research that investigates areas of interest related to the entertainment industry includes the RV Border multiplayer game (5) and the AR Quake demo (6). Similarly, the work of Benford et al (7) demonstrated the potential for emerging mobile and public space entertainment. Other examples of visual tracking in entertainment include research by Freeman et al (9) and Marks (10) where the users see themselves on the television screen using gestures to play games with the virtual elements.

For outdoor productions, such as televising sports events, camera movement is tracked through either mechanical sensors or image analysis. This allows the graphic images to be merged with the video image Symah's (14), (15) augmenting the video with for example 2D match statistics, critical information related to the play such as the location of the ice puck and advertising banners Cavallaro (11).

One of the more advanced technologies used in studio production are 'virtual studios'. These systems merge people and real objects within a fully synthetic 3D set. Virtual studios typically require a purpose-build space covered with chroma-keying material (blue, green or retro-reflective) and use robust and highly accurate camera tracking systems Thomas (12), Gibbs et. al. (13). The cumbersome set-up and calibration process, in conjunction with the cost of physical studio space and camera tracking systems make its ad-hoc use in a conventional studio or outdoors difficult.

In the above systems, interaction between real and virtual components is limited to pre-scripted animations manually triggered by the director. As a result interaction between the real and virtual elements is minimal. Also, interaction between elements of virtual content has not been attempted and is considered difficult to achieve, as the majority of systems use separate devices to track each pattern.

EVALUTION FRAMEWORK AND RESULTS

As we seek to evaluate the potential for AR in many different areas of the BBC, it is quite clear that the common and critical factor is the reaction and adoption by a wide variety of users. The user can vary from the presenter and director, producing television broadcasts to the child at home playing a future interactive storytelling challenge on their PC. Their experience and needs are critical factors in our evaluation.

Evaluation Methods

Our user testing lab set up resembles a typical living room with two sofas and a television. We used this space and a number of prototype interactive AR applications to explore user's basic interactions with AR and determine any basic ergonomic and human factors problems.

Users sat as a pair at a table in front of a flat screen monitor. A Logitech web camera was mounted directly behind and above the monitor facing the user. The camera was connected to a standard PC laptop with an Nvidia GeForce4Go graphics card running ARToolkit v2.53 on Windows. A mirrored view of the world from the camera's perspective was presented to the user, via the display. The tabletop surface was cleared of keyboard and mouse and various black and white patterns, mounted on cards, were made available for manipulation. All graphical models included animations. An example of the content used is shown in Figure 1.

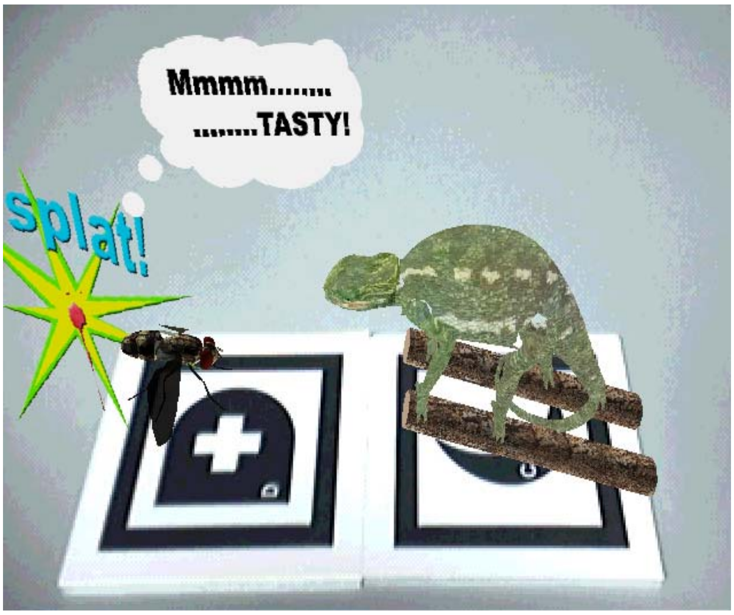

Figure 1 – Example of interaction using a virtual predator and its prey

A mixed-methods approach was taken towards data collection, using both observation and survey techniques. During the tasks, objective measures such as time taken to complete a task, success rate, number of pattern occlusions, were used to capture the participants' interaction with the AR interface. Each participant completed a questionnaire about his or her experience after each individual trial. Seven point Likert scales were used to rate how easy participants found each AR model to use, how much fun it was and how much they liked playing with it.

Evaluation Results

The general findings of the study were as follows;

Users took prompting to get started; particularly to touch, move and manipulate AR card patterns. However, once they did, they quickly learnt the basic interaction models. Users were also more dexterous with cards than previously assumed and appeared to take the technology for granted. It was felt that the technology did not grab attention, content did with humour, action and colour all considered important by the user. AR applications that lacked interactivity and manipulation were not popular despite colour and animation and were considered of limited appeal for repeated use.

The technology was considered frustrating when the image disappeared but there was a high tolerance for brief disappearances. Image stability in AR was important and problems with image rendering impacted on learning how to handle the cards, i.e. occlusions, pattern off camera. There were few, if any, problems caused by latency or pattern mis-registration.

PRODUCTION TOOLS AND APPLICATIONS

Based on the evaluation results we further developed prototype tools and applications for three key environments, namely the production, classroom and home spaces. We defined the *production space* as a conventional television studio, film set or outdoors location. Our generalized definition related to the use of studio cameras, chroma-keyer technology, synchronization or delay units, video mixers and other equipment currently used for television production. In the broader production context, the presenters, directors and graphics teams producing television broadcasts are also considered users of AR.

Our definition of a *classroom space* relates to a PC platform with access to a web camera and AR tracking patterns. Display is via a projected or large screen for group teaching or through a standard monitor for small group or individual learning. Users in the *classroom space* are the teacher or the student. The teacher uses the technology to help convey key learning concepts to a whole class. The student may use AR as a stimulating tool to help solve problems or homework issues and it can be done individually or collaboratively with other students.

Our generalized definition of a *home space* related to a household with the current proliferation of devices or platforms such as interactive TV, games consoles, mobile devices and standard home PCs. It is the primary entertainment social space available for the broadcaster.

Production Space

For the production space we used a similar approach and enabled a presenter to analyse news of a country in conflict in a *conventional studio space*. A 3D landscape of a fictional country incorporating positions of military forces was linked to an AR tracked pattern placed on a table surface, as shown in Figure 2. The presenter then positioned additional forces represented by 3D tanks or missiles, using other AR trained patterns, in key areas of the landscape allowing analysis of ‘what if’ scenarios. Positioning patterns close to each other allowed the presenter to trigger animations of missiles flying towards tank locations. As shown in Figure 3, a missile appears on top of the presenter’s hand flying towards a tank located left of the hand in the image.

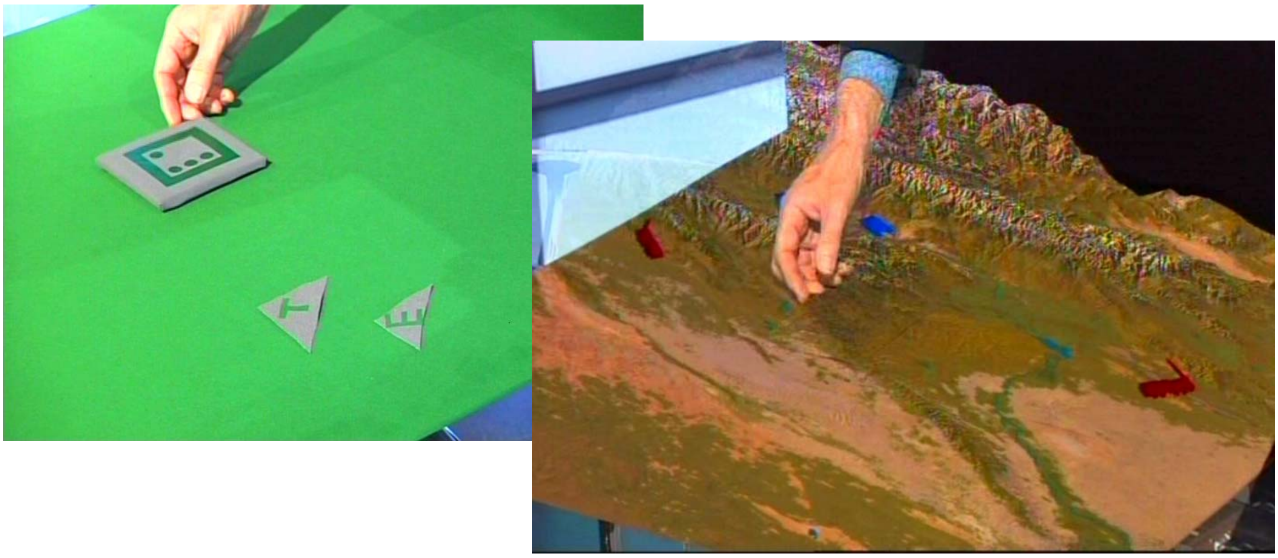

Figure 2 Chroma-keying pattern and Virtual Landscape

The AR applications discussed in later sections, used the open source ARToolkit (1) allowing rapid prototyping of content and interactive scenarios. This software tracks black and white patterns using a web camera, renders 3D virtual objects on the location of the markers and superimposes the virtual elements on top of the video image, as was already shown in Figure 1.

However, within the *production space* specific software was developed to allow the incorporation of studio cameras, which run at higher image resolution. For example, dealing with interlaced images, zooming of camera lens, linking to a proprietary high-end rendering engine, ability to merge virtual objects both in front and behind real elements and chroma-keying patterns that can be also recognized by the visual tracking algorithms. The production tools were developed on a standard PC, with a DVS video board and Nvidia GeForce4 Graphics card. The 3D assets were modelled in Alias|Wavefront Maya™ and exported as VRML 2.0 static and animated models.

The system captured and analyzed interlaced video of a higher than a web camera resolution. To reach the required broadcast production speed of tracking of 50 frames/sec we separated the tracking of patterns from the rendering of the virtual objects. This could also allow future use of more powerful commercial rendering engines required for broadcast quality images.

Another important issue was that of removing the pattern from the final composited image. We changed the core tracking algorithms to allow tracking of green, blue or patterns made of retro-reflective cloth, similar to the ones shown in Figure 2. Furthermore, in the production environment it was desirable to allow, for example, the presenter to point on top of virtual objects, while other virtual objects appear on top of his hand, as the missile in Figure 3. We achieved that by generating an alpha mask for the missile and use chroma-key techniques and video mixing equipment, to combine the different layers.

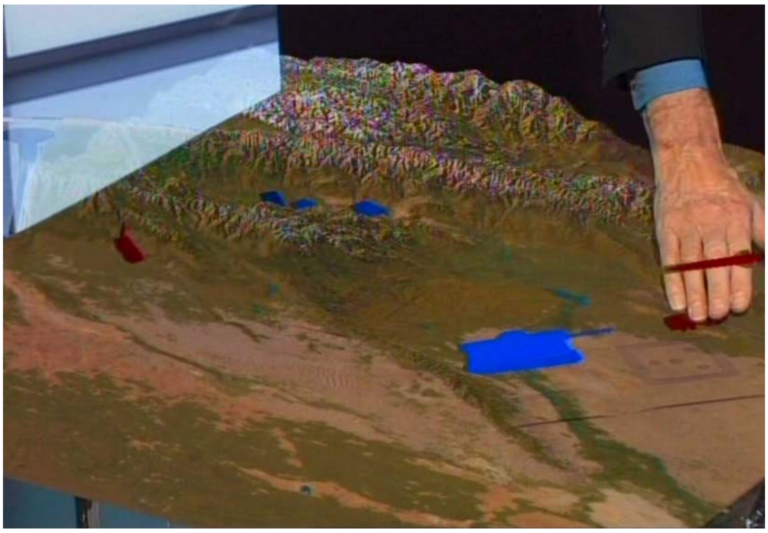

Figure 3 Missile flying towards tank

In case a zoom sensor is available the system incorporated the data from the sensor to distinguish between bringing two patterns closer together or having their distance appear to be shortened due to zooming of the camera lens. Therefore, we eliminated the possibility of wrongly triggering animations.

We added two more special effects; namely that of reporting from location and transitions from real to virtual camera and back. In the context of a broadcast reporting from location, the material incorporated live video streams displayed via virtual walls within the 3D landscape, as shown in Figure4. Transition from real to virtual camera allowed us to fly over the virtual landscape in ways that the real camera could not. Also, a generic application layer was developed to provide convenient ways to script interaction between patterns.

Although we did not carry out a scientific study on the effect of introducing this technology to production teams and the reactions of viewers, from discussions and observation during the production and at numerous demonstrations, there is a strong indication that interaction, between the presenter or studio audience and the virtual elements, could enhance believability. If carefully scripted, this might lead to suspension of disbelief for the viewer at home; a target very often unattainable in virtual productions or even post-productions that merge virtual and real elements.

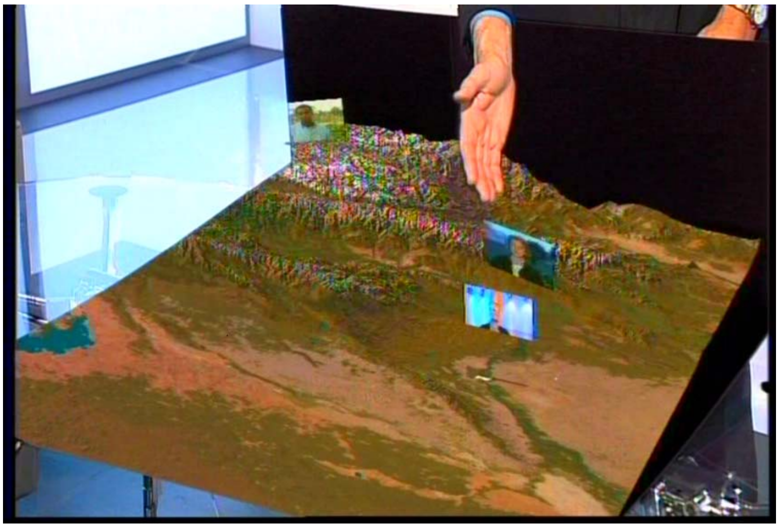

Figure 4 – Live video of remote correspondent within the landscape

The current limitations identified were rendering quality in terms of resolution of the virtual model, and authoring of interactive dynamic content. The robustness and speed of tracking were also seen as critical to adoption in the *production space*.

Classroom Space

In the classroom space we wanted to evaluate the use of AR and its potential impact as a learning tool for the students and as a teaching aid for the teacher. A further goal was to assess the potential benefits of AR over and above current presentation platforms of teaching curriculum material and therefore this comparison was made against content already provided through the existing Learning website Fletcher (8) and (17).

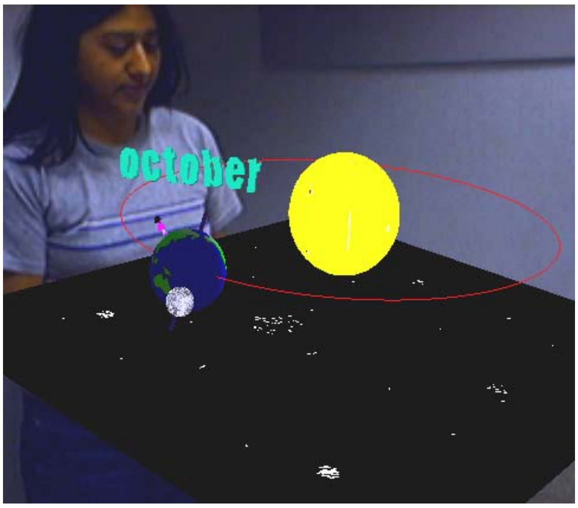

Figure 5 Example of Earth-Sun-Moon content

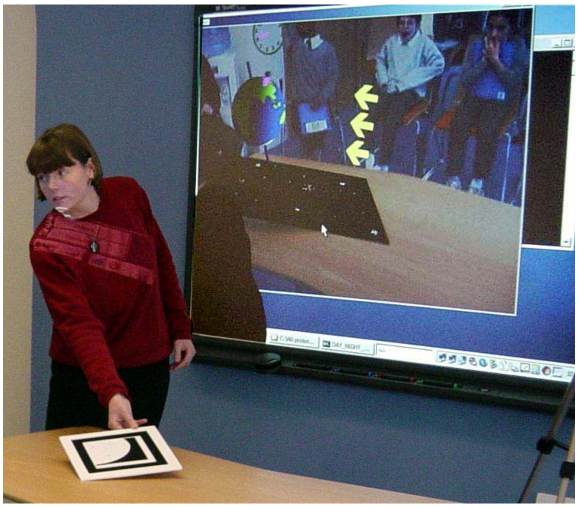

Figure 6 Teacher using AR content with a class

Based on the research of Shelton and Hedley (18) and incorporating existing 3D assets, the most appropriate content for the study was defined as Earth-Sun-Moon (ESM) material. This is part of Year 5 Key-Stage 2 learning curriculum for primary school students aged 10-11 years old. The current curriculum requires teachers to demonstrate the relationship between the earth, sun and moon by using objects such as beach balls, tennis balls and peas (19).

Two interactive AR applications were developed; the first displayed the rotation of the earth about its axis in relation to the sun's rays to help explain how day and night occur, as in Figure 5. The second AR application displayed the earth's orbit around the sun and the moon's orbit around the earth, which help explain what causes a year, as shown in Figure 6.

We carried an evaluation in two separate sessions each comprising 15 students, 30 in total. All were given a pre-task test, comprising of five multiple choice questions related to ESM, then split into two smaller groups of 7 or 8 students. The subject material was then presented either through the desktop interface (showing web content) or by a teacher using AR. The *classroom space* was configured using a web camera and an interactive projector display whiteboard. The set-up is shown in Figure 6.

After thirty minutes, all children then completed a post-task test of the same questions. As far as possible the content in both conditions, web & AR, were identical (in graphical content and style) to control for variables other than the presentation medium influencing learning outcomes. The same evaluation techniques were repeated to assess the effectiveness of AR as a teaching tool from the class teacher and from the students.

The preliminary results showed that AR produced greater improvements in test scores compared to the group who experienced web based instruction. However, low participant numbers may have led to the difference not being statistically significant. The data suggested AR confers benefits but the sample size will need to be increased in order to confirm this. The teacher found AR a simple and straightforward tool with which to teach ESM. She had little trouble using the AR and incorporating it into her lesson. The AR models remained stable and gave the impression of a robust system. The teacher found it was simple and straightforward to use but the frequent disappearance of the image was frustrating.

Home Space

In the *home space* we based our applications around scenarios of future interactive AR applications to support a Children's drama animation television series designed for 8 to 12 year olds. Our key aim was to evaluate the impact of narrative on children's enjoyment and interaction with AR.

The application content was based on a challenge of a team of four characters trying to save a rare chameleon. It contained five mini-games produced using a variety of prototype technologies including; ARToolkit applications, a web application called Pulse Veepers™ and a human "storyteller". Within the challenge, a variety of tasks were undertaken by the user, including character selection, exploration of the virtual world, and a race against the clock to build a base. Each AR application combined the common models of interaction defined earlier. An example screen is shown in Figure 7.

Figure 7 Example of content from a mini-game

The children were evaluated in pairs of same gender and age. Efforts were taken to observe individual behaviour and reaction to minimize effects of peer pressure. Overall, the study suggested that the introduction of narrative through characters, worlds and interactive challenges proved popular with the test users.

Children were able to recognize the different virtual characters and objects displayed and understand what was required with minimal explanation from the storyteller. Humour and animation were seen as stimulating when used as a reward for successful completion of a challenge. All users liked the challenges of each mini-game and were able to successfully complete them, though certain users took significantly longer. Further investigation is required to understand the reasons for this. They all provided rich and vivid suggestions as to what they would like to see developed next. This suggests their enthusiasm for AR applications remains high despite repeated use.

There was general agreement about desire for greater complexity and elements of skill in the mini-games. A number of participants referred to wanting the challenges to “get harder and harder like other computer games” they currently play at home.

CONCLUSIONS

We have presented preliminary evaluation results from the introduction of AR technologies in a public service entertainments organisation, such as the BBC, and for the production, classroom and home environments.

The use of ARToolkit allowed us to develop rapid prototyping of content and interactive AR applications providing great flexibility to engage and stimulate new ideas from creative staff, and test application for the classroom and the home.

The development of a bespoke system to allow a production team direct use of AR in a broadcast studio produced encouraging results for future adoption in the *production space*, and we are currently improving both the productions tools and the ergonomics of the approach, focusing on the realities of time scales and cost of development remain critical factors in the adoption of AR applications for the *production space*.

REFERENCES

1. *ARToolkit* computer vision software, http://www.hitl.washington.edu/artoolkit
2. Azuma, R.T., 2001. Recent Advances in Augmented Reality. IEEE Computers and Graphics, November/December 2001:34-47.
3. Azuma, R. T., 1997. A survey of augmented reality. Presence 6 (4): 355-385, 1997.
4. Billinghurst, M., Kato, H., Poupyrev, I., 2001. The Magic Book–Moving Seamlessly between Reality and Virtuality. IEEE Computers Graphics and Applications, vol. 21, no. 3, 2-4, May/June 2001.
5. Ohshima, T. et al., 1999. RV-Border Guards: A Multi-Player Mixed Reality Entertainment. Trans. Virtual Reality Soc. Japan, vol.4, no.4, pp.699-705, 1999.
6. Thomas, B. et al., 2000. ARQuake: An Outdoor/Indoor Augmented Reality First Person Application. Proc.4th Int’l Symp. Wearable Computers (ISWC 2000), pp.139-146, 2000.
7. Benford, S., et al., 2002. Staging and Evaluating Public Performances as an approach to CVE Research. In Greenhalgh & Brolll, editor, Collaborative Virtual Environments 2002, pages 1--8. ACM, September 2002.
8. Fletcher, J., White, J., 2002. Simutainment: A factual TV documentary as a 3D interactive experience. Proc. of International Broadcasting Convention 2002, Amsterdam, September 2002.
9. Freeman, W., et al., "Computer Vision for Interactive Computer Graphics", *IEEE Computer Graphics and Applications*, Vol. 18, Issue 3, pp. 42-53, May-June 1998.

10. Marks, R., 2001. Enhanced Reality: A new frontier in computing entertainment, Sketch paper, Proceedings of Siggraph 2001, July 2001.
11. Cavallaro, R., 1997. The FoxTrax Hockey Puck Tracking System. IEEE Computer Graphics and Applications, vol. 17, no. 2, pp. 6-12, Mar./Apr. 1997.
12. Thomas, G., Prompting Guide for Chroma-Keying. US Patent No5,886,747.
13. Gibbs, S., et al., 1998. Virtual Studios: State of the Art. IEEE MultiMedia journal, January-March, 1998.
14. Symah's EPSIS system. Method and apparatus for replacing target zones in a video sequence. US patent No. 6,181,345.
15. Symah's EPSIS system. Method and device for modifying a zone in successive images. US patent No. 5,515,485.
16. Welch, G., Foxlin, E., 2002. Motion Tracking: No Silver Bullet, but a Respectable Arsenal. IEEE Computer Graphics and Applications, Vol. 22, No 6, pp. 39-45, Nov / Dec 2002.
17. BBC Learning website. ReviseWise: National Curriculum Year 5 Key Stage 2 tests in Science, http://www.bbc.co.uk/schools/revisewise/science/physical
18. Shelton, B. E. and Hedley, N. R. 2002. Using augmented reality for teaching earth-sun relationships to undergraduate geography students. The First IEEE International Augmented Reality Toolkit Workshop, Darmstadt, Germany, September 2002.
19. Qualification and Curriculum Authority. UK Department of Education and Skills Standards website, http://www.standards.dfes.gov.uk/schemes2/science/sci5e